Acq*Knowledge*® 4 Software Guide

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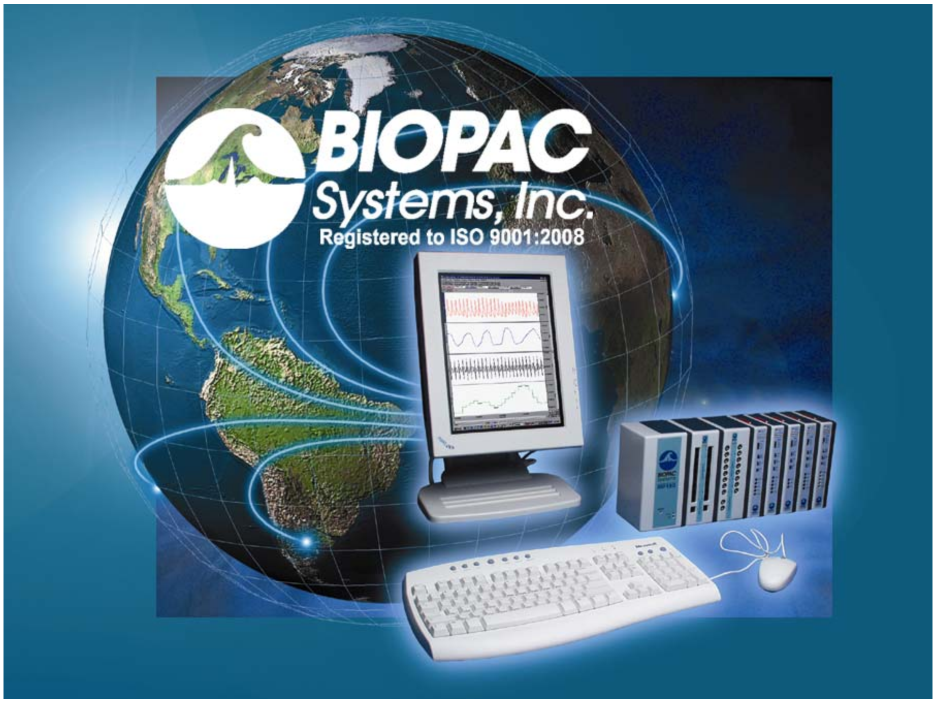
For Life Science Research Applications

Data Acquisition and Analysis with BIOPAC MP Systems



Reference Manual for

Acq*Knowledge*® 4.2 Software & MP150/MP36R or BioHarness Hardware/Firmware

on Windows® 7 or Vista, or Mac OS® X 10.4-10.6

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Preface to Acq*Knowledge* Software Guide

Welcome

Welcome to the Acq*Knowledge* Software Guide. The MP System (MP150 or MP36R) is a complete data acquisition system that includes both hardware and software for the acquisition and analysis of life science data. The MP System (MP150 or MP36R) is used for data acquisition, analysis, storage, and retrieval.

Acq*Knowledge* software not only makes data collection easier, but also performs analyses quickly and easily that are impossible on a chart recorder. Easily edit data, cut and paste sections of data, perform mathematical and statistical transformations, and copy data to other applications (such as a drawing program or spreadsheet) for reports and publication.

The MP System (MP150 or MP36R data acquisition unit) with Acq*Knowledge* 4 is compatible with Windows® 7 or Vista OS or Mac OS X® 10.4-10.6.

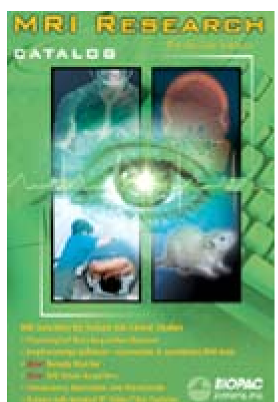
Acq*Knowledge* uses the familiar point-and-click interface common to all Windows® and Macintosh® applications. Complex tasks such as digital filtering or fast Fourier transformations are now as easy as choosing a menu item or clicking your mouse.

This manual covers use of Acq*Knowledge* software with an MP System (MP150 or MP36R) and details BIOPAC equipment available for a variety of applications. If a desired application is not addressed, just visit the BIOPAC web site at www.biopac.com to download one of our many Application Notes, or call to request a hard copy or talk to an Applications Specialist.

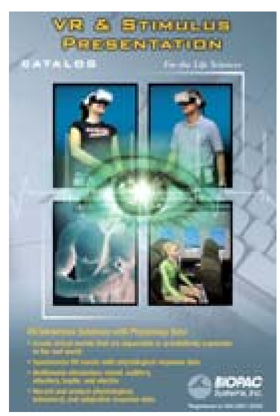
See also:

- BIOPAC Installation Guide—packed with the software CD.
- BIOPAC Hardware Guide.pdf—available under the Help menu and installed to the User Support folder. Provides details on MP System (MP150 or MP36R) modules, transducers, electrodes, etc., and setup and calibration.
- BIOPAC Catalogs

MP Research Catalog



MRI catalog



VR & Stimulus Catalog

Supported Platforms

Acq*Knowledge* 4.2 is supported on the following:

Operating Systems	*Comment*	**MP Devices**
Windows 7 or Vista32	—	MP150 UDP only
Windows 7 or Vista64	32 bit mode only	MP36R only
Windows XP	Functional, limited testing	
Mac OS X 10.4	PowerPC + x86	
Mac OS X 10.6	PowerPC + x86	

What's new for Acq*Knowledge* 4.2

BONUS! Acq*Knowledge* 4.2 includes a courtesy copy of our new Analysis package.
See the Analysis chapter for details.

Note New features for Acq*Knowledge* 4.0-4.2 apply to the English language version of the software only.
Acq*Knowledge* 3.9 software is translated for the following languages:
Chinese Simplified, Chinese Traditional, French, Italian, Japanese, and Spanish.
Contact BIOPAC to learn more Acq*Knowledge* 3.9 translations.

The following features have been added since Acq*Knowledge* 4.1 was released.

BioNomadix wireless module support

Rich Journals
- Expressions in Journal
- Tables and Excel® functions
- Docked and independent Journal windows

MP36R universal built-in amp module support
- Pulse Sequence Output Control
- Sound Sequence Output Control
- Analog Channel scaling units adapt to gain
- Simplified Hardware Filtering options

Startup Wizard for launching application

Check for MP hardware function

Email graph image as attachment

Event enhancements
- Global Event label printing
- Customizable Event markers
- Customizable append segment labels
- Sequential Event labels
- Sorted Event summary
- Mark selection from Events

Measurement enhancements
- Single point measurements
- X/Y measurement label display
- Revised invalid measurement display

Media playback —automatic segment advancement

User Interface Tools
- Most Recently Used options
- Preset menu separators
- Keyboard data selection enhancement
- Zoom out for Spectrum Analyzer
- Enable tools during acquisition (Preference)
- Cursor tools sub-menu
- Mouse scroll-wheel zoom support

Graph file display enhancements
- Select channel background
- Select line plot thickness
- Data Playback enhancements
- Start/End axis adjustment
- Horizontal Axis Hold Relative Position
- X/Y display crosshairs enhancement
- Customize default graph window position and size
- Default analog channel unit display preference

Grid enhancements
- Channel independent grid settings
- Grid presets

Gaussian Random Number Generator

Automated Analysis routine enhancements
- Poincare Plot Hemodynamic Analysis
- Locate Muscle Activation adjustable windowing

Advanced Averaging

Sound Feedback

Licensed functionality
- *New* Remote Monitoring — 'bedside monitor' display
  - View subject data remotely over a network
- *New* B-Alert X-10® Wireless EEG System
  - EEG wireless headset integration
  - Cognitive States Analysis
- BIOPAC Basic Scripting
  - Script Editor Reset Defaults button

Plus—If upgrading an older version of Acq*Knowledge*, see these additional features.

Acq*Knowledge* 4.1 updates

Windows 7 and Mac OS X 10.6 supported

Licensed functions v4.1.1

- Network data transfer
- Vibromyography
- Scripting

Analysis Automation Routines

- Independent detrending (HRV & PSD) v4.1.1
- Slew rate limiter for MRI analysis v4.1.1
- HRV algorithm improvements
- HRV analysis QRS threshold percentage
- ICG Analysis Output Options
- Event-related EDA Analysis
- Stim-response configuration enhancements
- Digital Input to Stim Events
- Specialized analysis dialogs

Module-based analog setup

MP36R Four-channel D/A unit support

Measurements

- Sum measurement
- Measurement presets

Media Capture *Windows* (audio and/or video)

Artifact Rejection functionality

Timed Reset for Integrate calculation and transformation

User Interface Enhancements

- Analysis dialogs: consolidated parameters in a single dialog
- Online averaging progress bar
- Transformation history
- Canceling Transformations & Transformation Progress Bar
- Custom toolbars for transformations and analysis
- Toolbar position retention and changes
- Event tool enhancements
- Typed event label drawing improvements
- Choose MP150 Help Button
- Button Transparency
- Vertical axis scaling buttons
- Long channel labels and units
- Customizable Chart Track Dividers
- Graph window tooltip improvements
- Menu item tooltips

Mac OS Integration

- Automator scripting language integration
- Spotlight integration

Acq*Knowledge* 4.0 updates

Acq*Knowledge* Windows included the following new features since Acq*Knowledge* 3.9 was released. If upgrading from an older version of Acq*Knowledge*, see the "Acq*Knowledge* Software Guide" for a more complete list of features.

Analysis Packages

Detect and Classify Heartbeats

Locate ECG Complex Boundaries

Chaos Analysis
- Detrended Fluctuation Analysis
- Optimal Embedding Dimension
- Optimal Time Delay
- Plot Attractor
- Correlation Coefficient

Electrodermal Activity
- Derive Phasic EDA from Tonic
- Event-related EDA Analysis
- Locate SCRs

Electroencephalography
- Compute Approximate Entropy
- Delta Power Analysis
- Derive Alpha-RMS
- Derive EEG Frequency Bands

Impedance Cardiography Analysis
- Adaptive template matching
- C point location
- Body Surface Area
- Ideal Body Weight
- ICG Analysis
- VEPT
- PEP Pre-ejection Period
- dZ/dt Derive from Raw Z
- dZ/dt Classifier: B, C, X, Y, and O Points
- dZ/dt Remove Motion Artifacts

Magnetic Resonance Imaging
- Artifact Frequency Removal
- Artifact Projection Removal
- Median Filter Artifact Removal
- Signal Blanking

- EEG Frequency Analysis
- Remove EOG Artifacts
- Electromyography
  - Derive Average Rectified EMG
  - Derive Integrated EMG
  - Derive Root Mean Square EMG
  - EMG Frequency & Power Analysis
  - Locate Muscle Activation
- Ensemble Average
- Epoch Analysis
- Hemodynamic Analysis
  - Classifiers: ABP; LVP; MAP
  - Arterial Blood Pressure
  - ECG Interval Extraction
  - HRV Poincare Plot
  - Left Ventricular Blood Pressure
  - Monophasic Action Potential
  - Respiratory Sinus Arrhythmia
  - Slew Rate Limiter
- Neurophysiology
  - Amplitude Histograms
  - Classify Spikes
  - Average Action Potentials
  - Dwell Time Histograms
  - Generate Spike Trains
  - Locate Spike Episodes
  - Find Overlapping Spike Episodes
  - Set Episode Width and Offset
- Principal Component Denoising
- Remove Trend
- Respiration
  - Compliance and Resistance
  - Penh Analysis
  - Pulmonary Airflow
- Spectral Subtraction
- Stim-Response
  - Digital Input to Stim Events
  - Stim-Response Analysis
- Waterfall Plot
- Wavelet Denoising

Multichannel Event Marking System

Event marking system is now combined with Cycle/Peak Detector, allowing automated measurements around specific events and additional event marking based on measurements taken. For example, mark when a dose or task occurs and automatically measure and mark the maximum response.

Cycle (Peak) Detector interface

Advanced Cycle/Peak Detector combines with powerful new Event Marking System. Perform amplitude, time, or event-based measurements. New output options for measurements, averaging, events, clustering (K-means), and 3D surface (cycle data, histogram, FFT, and DWT).

Transformations

Most recently used files, transformation and analysis
Adaptive template matching transformation
Normalized Cross-correlation Template Transformation
Remove projection template
Delay transformation
Cubic spline resampling options
Spectrum analyzer/real-time FFT

Calculation Channels

Calculation metachannels—daisy-chain calculations, such as Filter and Difference, on one channel
Dynamic digital filter options

Measurements

Equation Generator/Expression enhancements—online and post-acquisition
Interpolated measurements
New measurement options to optimize event marking system

User Interface – Display and control of data

3D data visualization
Text annotations—add zest to publication screen shots or annotate the file beyond marker notes
Print functions—adjust data range for printing; print waveform data in black; print file to PDF
Adaptive scaling—vertical scale updates in real time to optimize data display
Grids—Friendly grid scaling; Flexible grid options Grid Tool
Balloon Help
Multiple levels of Undo

Jump tool
Rescale operations
Selection palette—place cursors at specific time points
Mouse scrollwheel support
Keyboard Shortcuts added (accelerator keys)
Cursor Tools Contextual Menu
Replay data

Data processing
Large file support
Batch acquisitions
Multithreaded operation

File Formats
Excel Export (for reports with tabular data)
Save Selection As moved to File menu and added = Wav, EDF, JPEG; removed = Metafile (*.WMF)
Open Mac Acq*Knowledge* 3 Graph
BSL file import
EDF file import and export
Igor Pro Experiment import/export
WAV file format import/export

The following features were available in Acq*Knowledge* 3.9 but are not available in Acq*Knowledge* 4.0-4.1: They are again available in Acq*Knowledge* 4.2.
Advanced Averaging
Network Data Transfer
Preferences option to enable tools during acquisition

Using this Manual

The Acq*Knowledge* Software Guide is divided into four parts:

Part A *Getting Started*

Please review *Getting Started* whether new to computer-based data acquisition systems or an old hand at physiological monitoring. Use this section to become acquainted with how the system works and the most frequently used features.

Part B *Acquisition Functions*

Explains data acquisition features and gives a detailed summary of different acquisition parameters. Provides an in-depth description of the commands used to determine acquisition rate, acquisition duration, and specialized functions such as triggering, averaging, and online calculation of different values.

Part C *Analysis Functions*

Details information on analysis features; covers the range of post-acquisition analysis functions and transformations available with the MP System (MP150 or MP36R). Describes how to edit data, take measurements and perform basic file management options (save, print, etc).

Part D *Appendices*

Answers frequently asked questions, offers hints for working with files, includes information on upgrading from previous versions, provides technical information about the MP System (MP150 or MP36R) and other information about the Acq*Knowledge* software.

See also:

BIOPAC Installation Guide

This guide was included with the software CD. It contains full instructions for hardware and software installation, and how to be up and running with the MP System (MP150 or MP36R) in just a few minutes.

Hardware Guide

BIOPAC MP Hardware Guide.pdf is available under the Help menu. It gives practical examples of how the MP data acquisition unit is used with different components for common types of data acquisition, and includes sample results and applications for widely used test procedures. This guide provides instructions for connecting external devices to the MP150 or MP36R, electrodes, transducers, amplifiers, etc.

User Support System

User Support System files can be found in the following hard drive location; BIOPAC Systems, Inc/Acq*Knowledge* 3.x/User Support Systems in the Program Files or Applications folder.

- Acq*Knowledge* Software Guide.pdf is the software support document
- BIOPAC MP Hardware Guide.pdf is the hardware guide (with specifications)

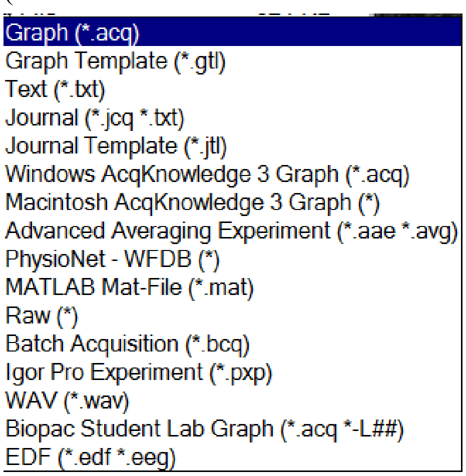
The User Support files can also be opened directly from the CD.

The files are in PDF format, and can be read by Adobe Acrobat Reader.

- Adobe Acrobat Reader can be downloaded for free at www.adobe.com under the Adobe Acrobat Reader site.

The Samples folder in the BIOPAC program folder contains sample files and graph template ***QuickStart*** files for a variety of applications. ***QuickStart*** templates establish the channel setup and acquisition parameters required for a variety of applications.

- To open sample files, choose File > Open then Browse to the BIOPAC Samples folder.
- To open a graph template ***QuickStart*** file, choose File > Open then Browse to the BIOPAC Samples folder (be sure to select/enable the desired file type).



Where do I find help?

The Introductory sections are intended to provide enough information to get up and running with the MP System (MP150 or MP36R), and become familiarized with some basic Acq*Knowledge* functions. There are far more features than described in the first few pages, so here is a guide for how to continue using this manual.

- *Help menu*

  The online Help menu includes basic information about standard Acq*Knowledge* functions and links to the tutorial, software guide and hardware guide for online searchable Help while running Acq*Knowledge*, plus links to the BIOAPC web site.

- *Application Notes*

  The BIOPAC web site at http://www.biopac.com has more than 50 available Application Notes. Download the desired Application Note or call to request a hard copy.

- *Acquiring data*

  For more specific information on different types of acquisitions, see Part B—*Acquisition Functions*. It covers basic acquisition parameters in detail, and describes some acquisition features (such as *peak detection* techniques and *online Calculation channels*) not covered in the Getting Started section.

- Acq*Knowledge*

  Information about how to edit, display and transform data can be found in Part C—*Analysis Functions*. It explains how to import and export data, how to save files, and other file management commands. This section also explains how to use all of the post-acquisition features of the Acq*Knowledge* software.

- *Connecting input devices*

  To find out how specific modules connect to the MP data acquisition unit, turn to the *BIOPAC MP Hardware Guide* PDF file. This section describes how to connect signal-conditioning modules to the MP data acquisition unit and how to connect electrodes and transducers to the modules.

- *Working with large files*

  Many users need to perform high speed (i.e., fast sampling rates) or long duration acquisitions. These types of acquisitions tend to generate large (several megabytes) data files that can be difficult to load, store, and view. The MP System (MP150 or MP36R) can handle such acquisitions—see the Appendices for information on how to optimize setup for these types of acquisitions.

- *Troubleshooting*

  Includes a list of the most frequently asked questions regarding the MP System (MP150 or MP36R). Check this section (Appendix A) for commonly encountered problems and solutions.

IMPORTANT SAFETY NOTICE

BIOPAC Systems, Inc. instrumentation is designed for educational and research-oriented life science investigations. BIOPAC Systems, Inc. does not condone the use of its instruments for clinical medical applications. Instruments, components, and accessories provided by BIOPAC Systems, Inc. are not intended for the diagnosis, mitigation, treatment, cure, or prevention of disease.

The MP data acquisition unit is an electrically isolated data acquisition system, designed for biophysical measurements.

Exercise extreme caution when applying electrodes and taking bioelectric measurements while using the MP System (MP150 or MP36R) with other external equipment that also uses electrodes or transducers that may make electrical contact with the Subject. Always assume that currents can flow between any electrodes or electrical contact points.

Extreme caution is also required when performing general stimulation (electrical or otherwise) on a subject. Stimulation currents should not be allowed to pass through the heart. Keep stimulation electrodes far from the heart and located close together on the same side of the subject's body.

It is very important (in case of equipment failure) that significant currents are not allowed to pass through the heart. If electrocautery or defibrillation equipment is used, it is recommended that all BIOPAC Systems, Inc. instrumentation be disconnected from the Subject.

Human Anatomy & Physiology Society Position Statement on Animal Use

Adopted July 28, 1995

It is the position of the Human Anatomy and Physiology Society that dissection and the manipulation of animal tissues and organs are essential elements in scientific investigation and introduce students to the excitement and challenge of their future careers.

The Human Anatomy and Physiology Society (HAPS) is a national organization of science educators dedicated to the task of providing instruction of the highest quality in human anatomy and physiology. A fundamental tenet of science is the ordered process of inquiry requiring careful and thoughtful observation by the investigator. As subdivisions of biology, both anatomy and physiology share a long history of careful and detailed examination, exploration and critical inquiry into the structure and function of the animal body. Consistent with the origins and nature of scientific inquiry, HAPS endorses the use of animals as essential to the laboratory experiences in both human anatomy and human physiology.

Historically, the principal tool of investigation in anatomy has been dissection. A properly directed dissection experience goes beyond naming structures and leads the student to conclusions and insights about the nature and relatedness of living organisms that are not otherwise possible. To succeed in their future careers, students must become thoroughly familiar with anatomical structures, their design features and their relationships to one another. Dissection is based on observational and kinesthetic learning that instills a recognition and appreciation for the three-dimensional structure of the animal body, the interconnections between organs and organ systems, and the uniqueness of biological material. While anatomical models, interactive computer programs, and multimedia materials may enhance the dissection experience, they should not be considered as equivalent alternatives or substitutes for whole animal dissection.

HAPS supports the use of biological specimens for anatomical study provided their use is in strict compliance with federal legislation and the guidelines of the National Institutes of Health and the United States Department of Agriculture and that such use fulfills clearly defined educational objectives.

Physiology experiments involving live animals provide an excellent opportunity to learn the basic elements specific to scientific investigation and experimentation. It is here that students pose questions, propose hypotheses, develop technical skills, collect data, and analyze results. It is here that they learn to remain focused on the details of procedure and technique that may influence the outcome of the experiment and the responses of the animal. When faced with unexpected and even erroneous results, students develop and improve their critical thinking and problem solving skills.

Computer simulations and video programs are useful tools that help students acquire a basic understanding of physiologic principles. However, due to the inherent variability and unpredictable nature of biological responses, such programs fail to fully depict the uniqueness of living organisms and should not be viewed as equivalent alternatives or substitutes for live animal experiments. HAPS supports the use of biological specimens in physiology experiments provided their use is in strict compliance with federal legislation and the guidelines of the National Institutes of Health and the United States Department of Agriculture and that such use fulfills clearly defined educational objectives.

Science educators have in common a respect and reverence for the natural world and therefore have a responsibility to share this with their students. They must communicate the importance of a serious approach to the study of anatomy and physiology. HAPS contends that science educators should retain responsibility for making decisions regarding the educational uses of animals. Furthermore, it opposes any legislation that would erode the educator's role in decision making or restrict dissection and animal experimentation in biology.

Used with permission of: The Human Anatomy and Physiology Society (HAPS)
222 South Meramec, Suite 203, St. Louis, MO 63105
1-800-448-HAPS

Part A—Getting Started

Chapter 1 MP Systems Overview

Part A - *Getting Started* covers the basics of data acquisition and analysis with an MP System (MP150 or MP36R). All of the material in this section is covered in more detail in subsequent sections (see *Using this Manual, page 17*).

BioHarness™ users should also see the **BioHarness User Guide** *available under the Help menu and installed to the User Support folder in the program folder.*

Overview

The MP System (MP150 or MP36R) is a computer-based data acquisition system that performs many of the same functions as a chart recorder or other data viewing device, but is superior to such devices in that it transcends the physical limits commonly encountered (such as paper width or speed). Data collection generally involves taking incoming signals (usually analog) and sending them to the computer, where they are (a) displayed on the screen and (b) stored in the computer's memory (or on the hard disk). These signals can then be stored for future examination, much as a word processor stores a document or a statistics program saves a data file. Graphical and numerical representations of the data can also be produced for use with other programs.

Function	MP150
Aggregate Sample Rate	
Internal MP150 Buffer:	400 kHz
To Cpt. Memory or Disk:	300 kHz
Internal Buffer Size:	6 Mbytes
A/D Converter Signal/Noise Ratio:	86 dB typical
D/A Resolution:	16 bits
D/A Output rate:	Independent of A/D rate
Communication to Computer:	Ethernet (10 base T, UDP and DLC Type II)

The MP System (MP150 or MP36R) utilizes the same hardware, excepting the computer interface. The software has the same "look and feel" on computers running Windows® or Mac® OS X.

- The system is referred to as "MPWSW" for Windows® or "MPWS" for Mac.

Ther MP System (MP150 or MP36R) consists of several major components, including hardware and software. The Acq*Knowledge* software included with the MP system allows full control over editing data, the way it appears on the screen, and performs four general functions:

(a) Control the data acquisition process;
(b) Perform real-time calculations (such as digital filtering and rate detection);
(c) Perform post-acquisition transformations (such as FFT's and math functions);
(d) Handle file management commands (saving, printing, and the like).

The heart of the MP System (MP150 or MP36R) is the MP data acquisition unit, which converts incoming physiological data into digital signals that can be processed and displayed on a computer interface. The MP150 data acquisition unit connects via Ethernet, the MP36R connects via USB.

The MP150 System also includes a Universal Interface Module (UIM100C) for connecting external devices to the MP150 data acquisition unit. Connect chart recorders, pre-amplified signals, and digital signals such as those from triggers or event counters/recorders. The UIM100C connects to the front of the MP150 data acquisition unit via two cables (Analog and Digital). As a rule, both cables should be connected. The connectors for each of the two cables are different, so there is only one way the UIM100C can be connected to the MP150 data acquisition unit.

A wall transformer is included with the MP System (MP150 or MP36R) to convert AC mains power into DC power suitable for system operation and safety.

MP36R support

The MP36R is a four-channel data acquisition unit designed to work with Acq*Knowledge* 4.1 and above for the research market. Acq*Knowledge* support for the MP36R unit includes:

- Standard data acquisition and data acquisition features (triggering, multiple channels, variable sampling rate, input values)
- Output control functionality for controlling stimulators, digital channel, and channel redirection to output.
- Standard analog presets for all SS series transducers
- Electrode Check support
- Multiple-MP device support. Similar to multiple MP150 support, each graph may acquire from a maximum of one unique MP device.
- Control channel support for changing digital output lines based on calculation channel analysis

MP36R Notes The computer sleep mode should be disabled—if the computer goes to sleep while Acq*Knowledge* 4 is running, communication with the MP36R may be lost and the application may freeze. To prevent this from occurring, modify the computer settings to prevent the computer from going to sleep.

- If sleep mode is enabled and causes the application to freeze, force quit the application and 'power cycle' the MP unit to re-establish communication.
- During an unresponsive period, the 'Connect Hardware' dialog may display odd characters in place of the MP serial number or the computer, upon waking up, may generate a"Driver irql not less or equal" error dialog.

Acq*Knowledge* software does not support MP36 units from the Biopac Student Lab product line (without the "R" designation).

Mac OS users: Connect the MP36R directly to the computer, do not connect MP36R via hub or keyboard.

MP System Requirements

Suggested minimum system requirements are detailed below. Recommendations are included to optimize system performance; more memory and a faster system will enhance MP System (MP150 or MP36R) performance. If planning to acquire data for more than a few hours and/or are sampling at more than 1,000 samples per second, see the Disk Space note.

Windows	For Acq*Knowledge* 4.2
OS	Requires Windows 7 or Vista or Mac OS X 10.4-10.6 see Mac on Intel and Mac OS 10.4 Tiger Notes
Port	MP150 Requires Ethernet (UDP), MP36R requires USB. **Note** To use an MP150 with UDP communication on a network with a non-Windows DHCP server, it is necessary to use firmware rev. 1.1.12 or greater in order for the MP150 unit to properly be assigned an IP address. This is also true for any DHCP system with non-Windows operating systems, such as Unix, Linux, Mac OS X, and other DHCP-aware devices.
Hard Disk	Requires 1 GB to store the software and online manuals; additional 1 GByte recommended for data storage
RAM	1 GB recommended
Processor	PC: Pentium 4 or higher Mac: Intel Core Duo or higher

MP150 DLC Limitations

UDP is the default communication for MP150 units. An administrator password is required in order to access the Ethernet network under Mac OS X. Without an administrator password, Acq*Knowledge* 4.0 can only be used in the “No Hardware” mode for data analysis.

Disk Space

With any program, adequate disk space is necessary for storage of data files. Although BIOPAC saves files in a format as compact as possible, some users may generate data files of several dozens of megabytes. To acquire data for long periods (more than a few hours) while sampling at relatively fast rates (more than 1,000 samples per second), as much disk space as possible should be available. (A removable drive may also be used). See the Appendices for hints on working with large files.

Windows XP Compatibility

Acq*Knowledge* 4.2 is officially released for Windows 7 and Vista operating systems, but testing was performed with Windows XP. If Acq*Knowledge*® 4.2 is installed on Windows XP, the user should not encounter any systemic problems related to the operating system, except for Media and Tooltips.

- Media functionality is not compatible with the XP operating system and performance will be problematic.
- Tooltips may not be displayed on XP.

Sample Data is installed to < drive>:\Documents and Settings\All Users\BIOPAC Systems, Inc\AcqKnowledge 4.1.

Mac Power PC Compatibility

Acq*Knowledge* 4.2 is officially released for Macintosh computers with Intel processor, but testing was also performed on the Power PC. When Acq*Knowledge* 4.2 is installed on a Power PC, performance will be sluggish; many of the Analysis operations will take several minutes or longer to complete.

Mac on Intel Compatibility

Acq*Knowledge* has been updated to a Universal Binary. This allows it to run natively on both PowerPC and Intel-based Macintosh computers. Acq*Knowledge* also integrates directly with operating system features when running on Mac on Intel-based computers, such as Automator and Spotlight.

Some features are not yet available for Mac on Intel-based computers due to the lack of third-party support. These features include:

- MATLAB File Exchange (requires Mac on Intel support from MATLAB and The MathWorks).
    - If MATLAB File Exchange is required, the application can be run in emulation mode by checking the “Open with Rosetta” checkbox in the Get Info inspector of the Finder.

Contact BIOPAC Systems for more details on when these features may become available.

Mac OS X 10.4 “Tiger” — these features are available in Acq*Knowledge* 4.1 and Acq*Knowledge* 3.9.1.

Spotlight Importer for Graph Files

Spotlight is an effective tool for searching for data. Acq*Knowledge* includes a Spotlight Importer that allows Spotlight to extract and search information from Acq*Knowledge* graph files including: Graph title; Duration of the recorded data in the graph; Text included in the Journal; Labels of data channels in the graph.

For example, if the names of subjects are recorded in a graph's Journal, Spotlight will be able to locate the graph file based upon names extracted from the Journal. If enough information is kept in the channel labels and graph journals, graphs can then be located and grouped using the Spotlight search features in ways not possible prior to Mac OS X 10.4 and greater.

The Spotlight importer only supports files generated by Mac Acq*Knowledge* 3.7.0 or higher.

- Older Mac Acq*Knowledge* or any Windows Acq*Knowledge* files must be resaved to disk using a compatible Mac Acq*Knowledge* file format.

Automator Integration and Scripting Support

Mac OS X 10.4 and greater includes a visual scripting environment called "Automator." Automator allows for drag and drop creation of "Workflows." Each workflow is a series of steps that is performed in another application. Each individual step is called an action. An action encapsulates a simple operation within another application, such as opening a text file in TextEdit or applying a filter within Photoshop.

Over 40 actions have been written to allow Acq*Knowledge* to be controlled from Automator workflows. Using these actions, workflows can be constructed to perform sequences of transformations, automating post-acquisition analysis, performing experimental protocols, and other repetitive operations.

Workflows can be constructed using Automator. It is also possible to create, edit, and execute workflows directly from within the Acq*Knowledge* environment using the new "Workflow" menu. The Workflow menu allows the creation of workflows specific to an individual user account or to one shared by all Acq*Knowledge* users. These workflows can then be edited in the Automator environment. Each workflow created using Workflow > New Workflow will appear at the bottom of the Workflow menu each time Acq*Knowledge* is launched. By simply selecting the name of the workflow from the Workflow menu, Acq*Knowledge* will execute the workflow.

Workflows executed from the Workflow menu should begin with either an "Open Graphs" or a "Get Active Graphs" action. Workflows intended for use outside of the Acq*Knowledge* environment (e.g. used as Folder Actions) should begin with a "Launch Application" action to start Acq*Knowledge* followed by an "Open Graphs" or a "Get Active Graphs" action.

Acq*Knowledge* 3.9.2 and later

Digital filter options have been changed as follows:

Cutoff freq: digital filter-FIR, digital filter-IIR, comb band stop, and derivative

- Sampling rate—Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.
- Line frequency—Uses the line frequency at which the data was recorded.

# of coefficients: digital filter-FIR and derivative

- Optimize for sample rate and cutoff—Estimate the number of coefficients as four times the sampling rate divided by the cutoff frequency of the filter. Optimize does not necessarily produce the best quality filter, but takes less time.

Rescale: To apply textual changes to a channel's units, apply the "Replace Active Channel Units" action.

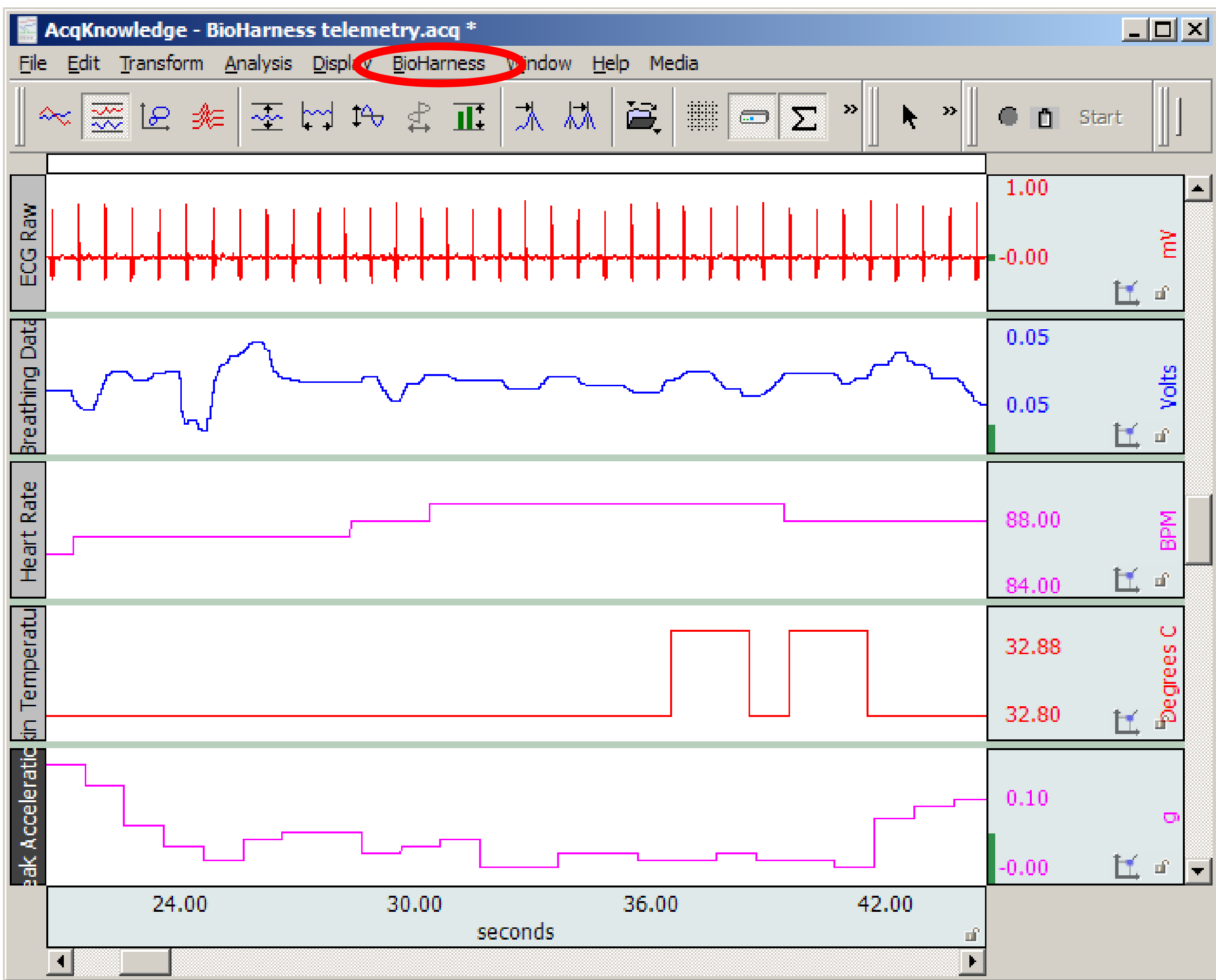
Delay

For more information about Automator and help constructing workflows, see the Apple website at: http://www.apple.com/macosx/features/automator/

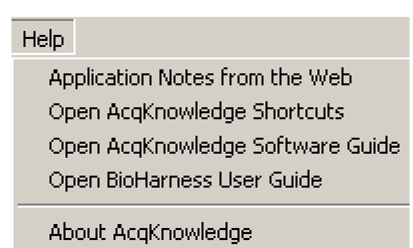
Data Acquisition and Analysis with BIOPAC BioHarness™

IMPORTANT NOTE: In Acq*Knowledge* for BioHarness

- **BioHarness** menu replaces the **MP150/MP36R** menu
- Analog channels can be turned on/off but not changed
- Other functionality remains the same



BioHarness™ users should see the **BioHarness User Guide** available under the Help menu and installed to the Uer Support folder in the program folder.



MP System Features

In conjunction with your computer, the MP System (MP150 or MP36R) is a complete system for acquiring almost any form of continuous data, whether digital or analog. The MP System (MP150 or MP36R) can perform a range of recording tasks, from high-speed acquisitions to long duration acquisitions. Generally speaking, for physiological applications, the MP System (MP150 or MP36R) is limited only by the speed of your computer and the available memory or disk space. Features of the MP System (MP150 or MP36R) include:

Easy to use	The MP System (MP150 or MP36R) offers the same convenient and easy-to-use features which computer users are accustomed to. Since the MP System (MP150 or MP36R) software runs under these Windows and Mac OS environments, you can run other applications while you are collecting data. In terms of hardware setup the MP System (MP150 or MP36R) uses simple plug-in connectors and standard interface cables. *You don't need a degree in electronics to Set Up your system!*
Flexible	The MP System (MP150 or MP36R) can be configured for a wide variety of applications, from single channel applications to multiple-device measurements (up to 16 analog and 16 digital, or multiple MP150s). You control the length of acquisition, the rate at which data is collected, how data is stored, and more...all with a few clicks of the mouse button. Whether you're measuring alpha waves or collecting zoological data, the MP System (MP150 or MP36R) can meet your needs.
Menu flexibility	You can easily customize menu displays to show only the functions you are using, thereby reducing the risk of error or confusion in your lab. This function is extremely powerful for laboratories working to GLP guidelines. It is also useful for teaching applications where instructors can hide unnecessary menu items. *See* Appendix D—Customizing Menu Functionality.
High Speed Sampling	Sample rates up to 400 KHz aggregate
Arbitrary Sample Rates	Apply different sample rates between channels or operate the STM100C stimulator at a different rate than the acquisition sample rate
View & Control Multiple MP150s	View and control multiple MP150 units over a local area network (LAN).
Calculation Channel Presets	Customize your recording for specific measurements.
Template files	Acq*Knowledge* "***Quick Start***" templates are available for over 40 applications. Just open the template file and start the acquisition—appropriate settings are established for the selected application.
Online Calculation	Although the MP System (MP150 or MP36R) provides an extensive array of measurements and transformations you can apply to collected data, sometimes you need to perform computations *while* data is being collected. The online Calculation functions allow you to calculate new channels based on incoming signals. This feature allows you to compute BPM, for instance, based on raw ECG data.
Online filtering	Many times, it is preferable to filter data as it is being collected, rather than having to wait until after the fact, so now you can apply filters to incoming data and view the results in real time. That means online monitoring of data filtered to suit your needs.
Online measurements	The MP System (MP150 or MP36R) can instantly compute over a dozen measurements and computations for any given data point(s). These options are available from pull-down menus and include mean, peak-to-peak, value, standard deviation, frequency, and BPM.

Measurement Validation	You can validate measurements with the ValidateMeasurements.acq sample file that was included with the software. The measurement definitions (page 91) include measurement formulas and "*Sample data file*" explanations.
Preview your data	Similar to chart recorders, the MP System (MP150 or MP36R) allows you to change both the vertical scale and the horizontal scale. You can change the amplitude scale or the time scale to any value you wish, or you can have the MP System (MP150 or MP36R) automatically scale them for you.
Replace (or augment) a chart recorder	Whether you want to replace a chart recorder or simply supplement an existing setup, the MP System (MP150 or MP36R) is fully compatible with most major recording devices. What's more, the MP System (MP150 or MP36R) is compatible with most popular input devices, so you can continue using the same transducers, electrodes and sensors.
Simplified editing	It used to be that once your data was collected, the only way to edit it was with scissors and adhesive tape. Now you can delete unimportant sections of your data with a keystroke. You can "paste" together sections from different waves, or simply edit out noise spikes from individual waves.
Append mode	For some applications, data only needs to be recorded during some portions of a long experiment. Acq*Knowledge* has an "Append" mode that lets you pause the acquisition for as long as you wish, and resume the acquisition as many times as needed. In this mode, you can start and stop a recording as you would with a chart recorder. Appending data saves on storage space and processing time for transformations.
Digital filtering	All data contains measurement error and noise. Now you can reduce or eliminate that error by using the digital filters and smoothing transformations included in the MP System (MP150 or MP36R). You can smooth data across any number of samples, or filter out noise from any frequency or bandwidth you wish.
Digital Output	You can control external devices when an input or calculation channel meets trigger conditions you specify. Use the Control channels to output a pulse when the signal on an analog channel falls above or below a given threshold.
X/Y plotting	You can view and acquire data in the form of an X/Y plot, with one channel on the horizontal axis and another on the vertical axis. This allows you to explore relationships between different channels and opens up a whole range of applications, from chaos plots to respiration analysis to vectorcardiograms.
Histogram function	You can easily examine the variability and the measures of central tendency of any waveform data with the histogram function. Set the plotting options to suit or let the software determine the "best fit" for graphing your data.
Math functions	In many cases, simply collecting raw data is not enough. Acq*Knowledge* has an array of built-in mathematical functions ranging from simple absolute value to computation of integrals, derivatives, and operations involving multiple waveforms (such as subtracting one wave from another). You can even chain multiple functions together to form complex equations or expressions.
Annotation	Acq*Knowledge* has a Journal you can use to append comments concerning your input data, either online or after the fact. This is especially useful for noting the characteristics of an acquisition (what was involved, what manipulations took place, and the like) for future reference. *See also*: Text annotation, page 58.

Triggering — If you need to measure response times or start data collection only after some event has occurred, the MP System (MP150 or MP36R) allows you to trigger an acquisition in a number of different ways. You can trigger on the level of a signal, or with an external synchronizing trigger.

Event marker — Many times, especially during a long acquisition or in a laboratory setting, it is useful to make a note of when specific events occurred so that these events (such as when a manipulation occurred) can be recorded and any changes in the data can be noted. The marker function allows you to insert symbols in the record and add text for each marker. These can be added either while data is being collected or after the fact. Marker functionality can be automated for sequential application or customized for Function keys.

File compatibility — You can save your data in a number of different formats. For word processor programs like Microsoft Word®, use Copy to Clipboard and then paste into the document. Use Save as Excel for Microsoft Excel®. You can output your data in either text or graphical form, and Acq*Knowledge* can even read-in raw data from a text file. Open (import) or save as (export) MATLAB™ and Igor Pro Experiments, or raw (binary) data for low level exchange.

Pattern recognition — Using an advanced pattern search/recognition algorithm, the MP System (MP150 or MP36R) can automatically find a specific pattern within waveforms. This is useful for finding abnormal waveforms (such as irregular ECG waves) within a data file.

Cycle/Peak detection — Acq*Knowledge* has a built-in algorithm to find cycle data, such as positive or negative peaks, from any size data file. You can even search for all the cycles/peaks with one command and automatically log statistics like time and area to the journal.

Printing — The MP System (MP150 or MP36R) provides a range of printing options, and allows you to fit your data on one page or many. You can print several graphs per page, even if you only have one-channel recordings. Since MP System (MP150 or MP36R)s run on Windows or Mac OS, no special printer drivers are required.

Report generation — Acq*Knowledge* has many features to simplify report generation. Use the Journal for notes and quickly copy and paste graph data or measurements to the journal or to another program. Cascade event markers to prevent print overlap and select the range of data to print and which options to display (measurements, markers, etc.). Use the Playback mode to simulate acquisition for presentations.

User Support — Whether you have a question about compatibility with your existing equipment or you need to develop a specialized measurement device, BIOPAC's Applications Department can address the problem.

Application Features

Use your MP System (MP150 or MP36R) with Acq*Knowledge* software for a wide array of applications, such as:

- Active Electrodes
- Allergies
- Amplitude Histogram
- Anaerobic Threshold
- Animal studies
- Auditory Evoked Response (AER)
- Automate Acquisition Protocols
- Automated Data Analysis
- Automatic Data Reduction
- Autonomic Nervous System Studies
- Biomechanics Measurements
- Blood Flow / Blood Pressure /Blood Volume
- Body Composition Analysis
- Breath-By-Breath Respiratory Gas Analysis
- Cardiac Output
- Cardiology Research
- Cell Transport
- Cerebral Blood Flow
- Chaos Plots
- Common Interface Connections
- Connect to MP System (MP150 or MP36R)s
- Control Pumps and Valves
- Cross- and Auto-correlation
- Current Clamping
- Defibrillation & Electrocautery
- Dividing EEG into Specific Epochs
- ECG Analysis
- ECG Recordings, 12-Lead
- ECG Recordings, 6-Lead
- EEG Spectral Analysis
- Einthoven’s Triangle
- EMG and Force
- EMG Power Spectrum Analysis
- End-tidal CO2
- Episode Counting
- Ergonomics Evaluation
- Event-related Potentials
- Evoked Response
- Exercise Physiology
- External equipment, controlling
- Extra-cellular Spike Recording
- Facial EMG
- FFT & Histograms
- FFT for Frequency Analysis
- Field Potential Measurements
- Fine Wire EMG
- Forced Expiratory Flow & Volume
- Gait Analysis
- Gastric Myoelectric Activity
- Gastric Slow Wave Propagation
- Gastrointestinal Motility Analysis
- Hardware Flexibility
- Heart Rate Variability
- Heart Sounds
- Histogram Analysis
- Imaging Equipment, Interfacing
- Indirect Blood Pressure Recordings
- Integrated (RMS) EMG
- Interface with Existing Equipment
- Interface with Third-party transducer
- Invasive Electrode Measurements
- Ion-selective Micro-electrode Interfacing
- Iontophoresis
- Irritants & Inflammation
- Isolated Inputs & Outputs
- Isolated Lung Studies
- Isometric Contraction
- Isotonic Contraction
- Jewett Sequence
- Langendorff Heart Preparations
- Laser Doppler Flowmetry
- Left Cardiac Work
- Long-term Monitoring
- Lung Volume Measurement
- LVP
- Median & Mean Frequency Analysis
- Micro-electrode signal amplification
- Migrating Myoelectric Complex
- Motor Unit Action Potential
- Movement Analysis
- MRI Applications
- Multi-Channel Sleep Recording
- Nerve Conduction Studies
- Neurology Research
- Noninvasive Cardiac Output
- Noninvasive Electrode Measurements
- Nystagmus Investigation
- Oculomotor Research
- Off-line ECG Averaging
- Online Analysis
- Online ECG Analysis
- Orthostatic Testing
- Peripheral Blood Flow
- Peristaltic (Slow Wave) Propagation
- Planted Tissue
- Pressure Volume Loops
- Psychophysiology
- Pulsatile Tissue Studies
- Pulse Rate Measurement
- Pulse Transit Time
- Range of Motion
- Real-time EEG Filtering
- Real-time EEG Filtering
- Recurrent Patterns
- Regional Blood Flow
- Relative BP Measurement
- Remote Monitoring
- Respiration Monitoring
- Respiratory Exchange Ratio
- Rheumatology
- Saccadic Eye Movements
- Sexual Arousal Studies
- Signal Averaging
- Simultaneous Monitoring
- Single Channel Analysis
- Single-fiber EMG
- Software-controlled Stimulator
- Somatosensory Evoked Response
- Spectral Analysis
- Spike Counting
- SpO2 Analysis
- Stand Alone Amplifiers
- Standard Operating Procedures
- Startle Eye Blink Tests
- Startle Response
- Stimulator, software-controlled
- Systemic Vascular Resistance
- Template Analysis
- Tissue Bath Monitoring
- Tissue Conductance Measurement
- Tissue Magnitude & Phase Modeling
- Tissue Resistance & Reactance
- Ussing Chamber Measurements
- Ventricular Late Potentials
- Vestibular Function
- Visual Attention
- Visual Evoked Response
- VO2 Consumption
- Volume/Flow Loop Relationships
- Working Heart Preparations

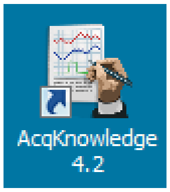
MP System (MP150 or MP36R) Application Notes

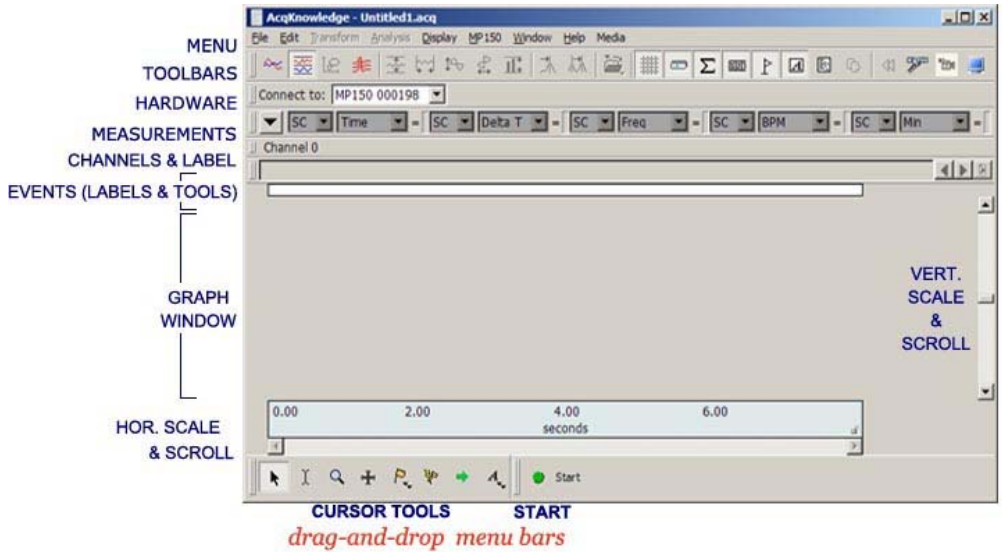
BIOPAC has prepared a wide variety of application notes as a useful source of information concerning certain operations and procedures. The notes are static pages that provide detailed technical information about either a product or application. A partial list of Application Notes follows. You can view or print application notes directly from the *Support* section of the BIOPAC website www.biopac.com.

APP NOTE	Application
#AH101	Transducer Calibration and Signal Re-Scaling
#AH102	Biopotential Amplifier Testing w/ CBLCAL
#AH103	Remote Monitoring System (TEL100C)
#AS105	Auditory Brainstem Response (ABR) Testing
#AS105b/c	ABR Testing for Jewett Sequence
#AS108	Data Reduction of Large Files
#AS109	3-, 6-, and 12-Lead ECG
#AH110	Amplifier Baseline (Offset) Adjustment
#AS111	Nerve Conduction Velocity
#AH114	TSD107A* Pneumotach Transducer
#AH114b	TSD107B* Pneumotach Transducer
#AS115	Hemodynamic Measurements—Part I
#AS116	Hemodynamic Measurements—Part II
#AS117	Pulse Transit Time and Velocity Calculation
#AS118	EMG Signal Analysis
#AS119	EMG Power Spectrum Analysis
#AS120	X/Y Loop Area Analysis
#AS121	Waveform Data Reduction
#AS122	Power Spectrum Analysis
#AH125	Pulse Oximeter Module Operation
#AH127	Precision Force Transducers
#AH128	Active Electrode Specifications and Usage
#AS129	Heart Rate Variability
#AH130	Blood Pressure Measurement
#AS131	Averaging Mode
#AH132	TSD105A Variable Force Transducer
#AH135	TSD117 Pneumotach Transducer
#AH136	BAT100 Instructions
#AH140	Angular Measurements with Goniometers
#AH141	Tri-Axial Accelerometer Calibration
#AS142	Acq*Knowledge* Rate Detector Algorithm
#AS143	Importing Acq*Knowledge* Data Into Excel
#AH144	Hand Dynamometer Calibration
#AH145	TSD101B Respiratory Effort Transducer
#AS148	Automated ECG Analysis
#AH149	O2100C Module
#AH150	O2100C Module—Sample application
#AH151	CO2100C Module
#AH152	CO2100C Module—Sample Application
#AH153	Physiological Sounds Microphone
#AH154	HLT100C High Level Transducer
#AS158	Analysis of Inspired and Expired Lung Volume
#AH159	TSD116 Series Hand Switch and Foot Switch
#AH160	Gas Analysis Module Response Time
#AS161	Automated Tissue Bath Analysis
#AH162	Stimulation Features
#AS168	Analysis of Intraventricular Pressure Wave Data (LVP Analysis)
#AS169	Speech Motor Control
#AH170	LDF100A Laser Doppler Flow Module
#AH175	Using the STMISOC Stimulus Isolator
#AS177	ECG Analysis using the Offline Averaging Mode
#AS183	VO_2 Measurement
#AH186	Psychological Assessment using the TSD115
#AH187	Electrodermal Response (EDR) using the GSR100 or TEL100
#AH190	Using the MCE100C Micro-electrode Amplifier
#AS191	Cardiac Output Measurement using the EBI100C and Acq*Knowledge*
#AH249	Online Averaging Latency Parameters (ISI, ABR)

Chapter 2 Acq*Knowledge* Overview

Overview





The MP System (MP150 or MP36R) software is called Acq*Knowledge* and performs two basic functions: acquisition and analysis. The acquisition settings determine the basic nature of the data to be collected, such as the amount of time data will be collected for and at what rate data will be collected. All of the acquisition parameters can be found under the MP150 menu. The other menu commands pertain to analysis functions such as viewing, editing, and transforming data.

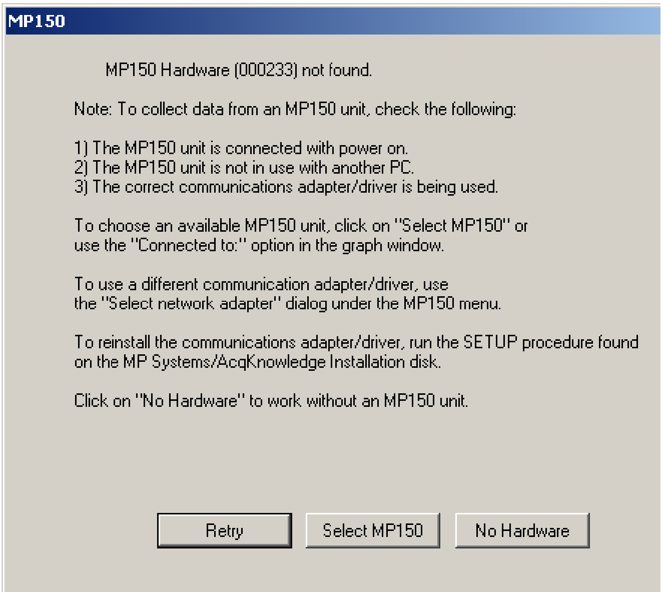
Note: Some very minor differences exist between the Windows and Mac OS X screen displays and keystroke/mouse functionality. These differences are noted throughout this section.

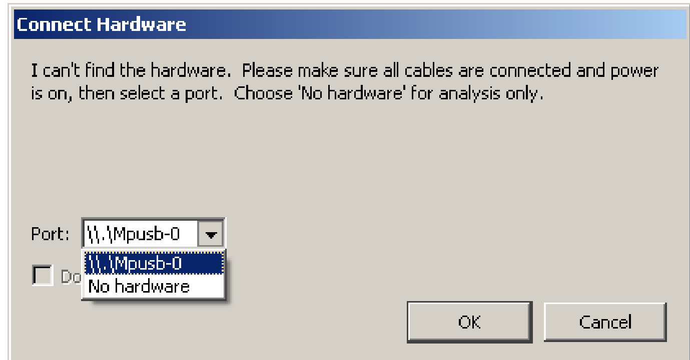
Menu	Functionality	See Page
File	New, Open, Open Recent, Open for Playback, Close, Save/Save As, Save selection As, Save Journal Text As, Send Email as Attachment, Print, Printer Setup, Quit	236
Edit	Undo, Cut, Copy, Paste, Clear/Clear All, Remove Last Appended Segment, Insert Waveform, Duplicate Waveform, Select All, Remove Waveform, Create Data Snapshot, Merge Graphs, Clipboard (Copy Measurement, Copy Wave Data, Copy Graph, Copy Acquisition Settings, Copy Data Modification History for All Channels, Copy Data Modification History for Graph), Journal (Paste Measurements, Paste Wave Data, Paste Acquisition Settings, Paste Modification History for All Channels, Paste Modification History for Selected Channel, Show Journal)	256
Transform	*operations that primarily modify the data in the graph* Recently Used, Digital Filters, Fourier Linear Combiners, Math Functions, Template Functions, Integral, Derivative, Integrate, Smoothing, Difference, Resample Waveform, Resample Graph, Expression, Delay, Rescale, Waveform Math	265
Analysis	*operations that derive data & measurements from the graph* Recently Used, Histogram, Autoregressive Modeling, Nonlinear Modeling, Power Spectral Density, Autoregressive Time-Frequency Analysis, FFT/IFFT, DWT Discrete Wavelets, Principal Component Analysis/Inverse PCA, Independent Component Analysis/Inverse, Find Cycle, Find Rate—plus a courtesy copy of the Specialized Analysis package with classifiers and automation routines	296
Display	Tile Waveforms, Autoscale Waveforms, Optimize Ranges, Overlap Waveforms, Compare Waveforms, Autoscale Horizontal, Zoom, Reset, Set Wave Position, Wave Color, Horizontal Axis, Show, Customize Toolbars, Channel Info, Preferences, Size Window, Cursor Style, Create Data View, Organize Data Snapshots, Show All Data Snapshots, Load All Data Into Memory	403
MP150	Set Up Channels, Set Up Acquisition, Set Up Triggering, Set Up Stimulator, Set Up Sound Feedback, Set Up Manual Event Insertion Keys, Set Up Segment Labels, Show Input Values, Show Manual Control, Show Gauge, Select MP150, MP150 info, Update Firmware, Auto Plot, Scroll, Warn on Overwrite, Organize Channel Presets	101

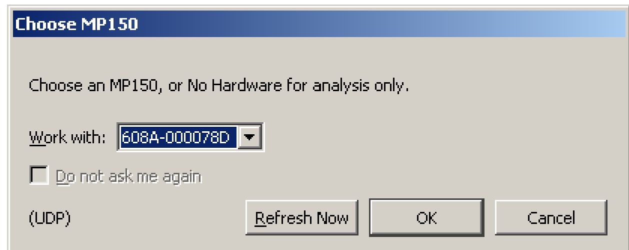
Menu	Functionality	See Page
Playback	Replaces the MP150 menu when Playback mode is active (use File > Open for Playback and Playback > Quit playback to toggle playback and acquisition modes)	44
Window	Controls the position of windows on the monitor	429
Help	Provides online support files (PDF format and web links).	429
Media	Capture or Playback media files(.avi, .wmv, or mpg) and synchronize with .acq data	431

Launching the Acq*Knowledge* software

The first step is to launch the software by double-clicking on the Acq*Knowledge* icon. You may receive a message regarding the hardware.

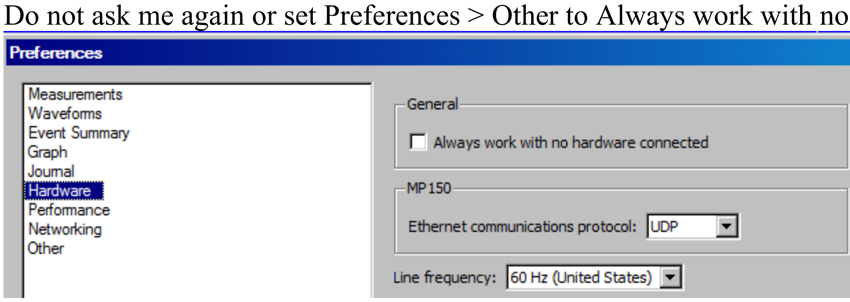




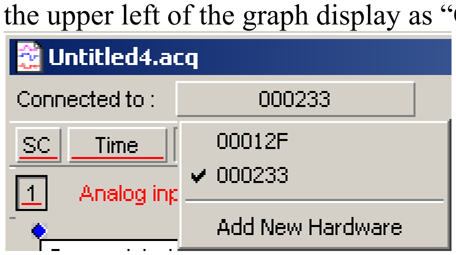


If you receive a hardware prompt when you launch Acq*Knowledge*, there are two possibilities: You have not properly connected everything and/or you have not powered up the MP System (MP150 or MP36R).

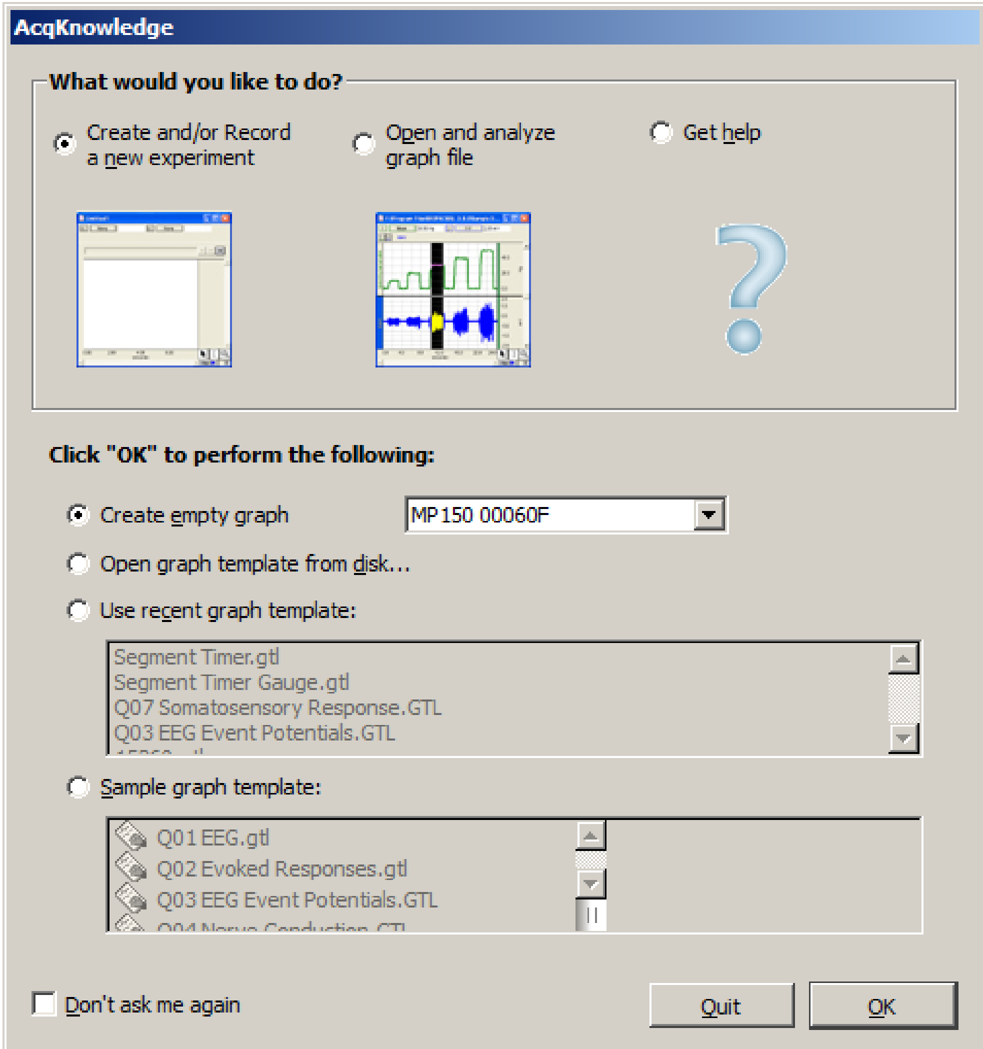
- ➢ To use Acq*Knowledge* without an MP data acquisition unit, press the "No Hardware" button. Click Do not ask me again or set Preferences > Other to Always work with no hardware connected.



When Acq*Knowledge* is first launched, the user must pick an available MP150 unit from the Select MP150 Serial number dialog. The dialog lists all MP150 units that are powered ON and sitting on the same local area network. If using more than one MP150 unit or working across a network, it will be necessary to lock/unlock an MP150 to acquire data (see Appendix E on page 476 for details). The selected MP150 unit will be listed in the upper left of the graph display as "Connected to:" if the  Show/Hide Hardware toolbar icon is enabled.



Assuming everything is properly connected and there are no conflicts, Acq*Knowledge* will launch the Startup Wizard. *(AcqKnowledge 4.2 and higher only)* Use this wizard to choose whether to create a new experiment, open a saved graph for analysis or access the Help and support files.



Startup Wizard under 'Create and/or Record a new experiment' (Default)	Functionality
Create empty graph	Opens new graph window for acquiring data with hardware. Combo box to the right selects hardware type.
Open graph template from disk	Brings up 'Open' window for browsing to location of saved graph templates.
Use recent graph template	Activates list of recently-opened graph templates for easy selection.
Sample graph template	Activates list of sample graph templates stored in Acq*Knowledge* program folder for easy selection.
Don't ask me again	If checked, the Startup Wizard will not be presented upon next application launch.
Quit/OK	Cancels or confirms selected operation.

- **Open and analyze graph file** Presents similar options for analysis of existing graphs.
- **Get help** Launch various help and support options.

NOTE: The Startup Wizard can be disabled in the Preferences, if desired. (Show > Preferences > Other)

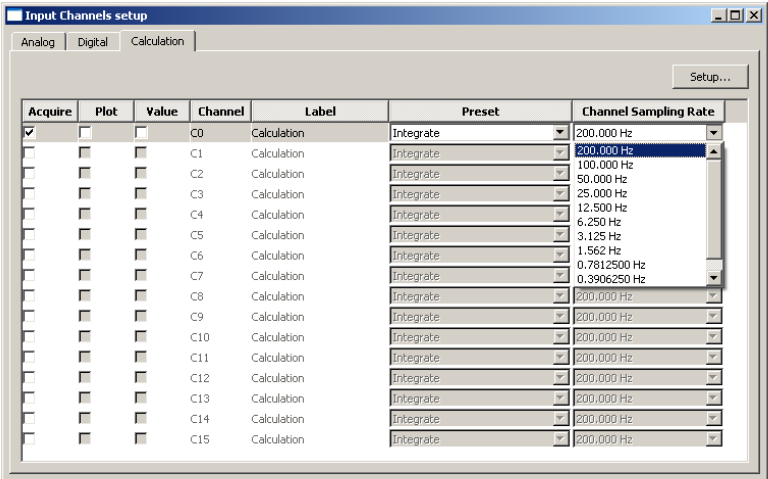
A "window" is the term used for the area on your computer's screen where data is displayed and/or manipulated. The graph window on the screen is designed to provide you with a powerful yet easy-to-use interface for working with data.

At this point, you can use this window, create a new window, or open an existing window.

It's a good idea to create a new graph window for each acquisition. To create a new graph window after the original launch, choose File > New.

Setting up channels

To tell the MP System (MP150 or MP36R) how many channels will be acquired (or collected), select Set Up Channels from the MP menu. This will generate the Input Channels Setup dialog.



If using Acq*Knowledge* 4.1 with **BioHarness™**, Analog channels can be turned on/off but not changed.

- The default is to collect one channel of data on channel A1, and to plot and list values for this channel. Usually, you will want to check all three boxes for each channel you acquire data on.

Acquire When the Acquire box is checked for a given channel that means data will be collected on that channel.

Plot Determines if data will be plotted in real-time during the acquisition. If the plot box is unchecked, data will still be recorded for that channel, but the waveforms can only be plotted after the acquisition is over.

Value Enables you to use the Show Input Values window to display the values for each channel in real time, numerically and/or graphically. These values are displayed in a separate window from the main graph window.

Channel This is a dynamic alpha-numeric heading based on the type of channel selected: Analog (or continuous), Calculation, or Digital. In the sample above, "A1" indicates Analog channel one.

Calculation channels are used for online computations and transformations of other channels. These channels are Set Up just as analog and digital channels but also have additional dialoges for you to specify what types of transformations and computations you would like to perform. For a detailed summary of Calculation channel options, see the Calculation Channel section beginning on page 115

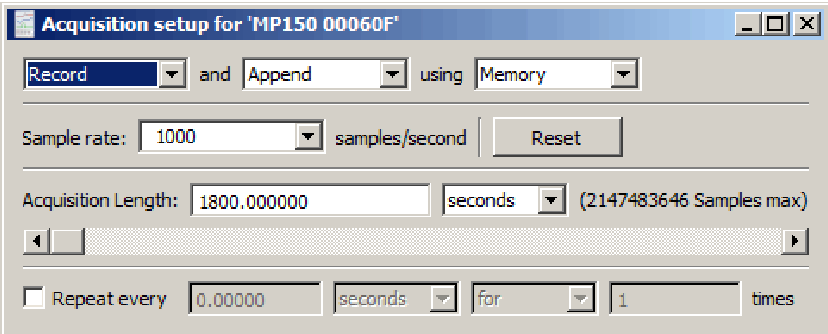
In contrast to analog data, Digital channels collect binary data that represent when a measuring instrument is "on" or "off." An example of when this could be useful is for recording whether a switch is open or closed, as in reaction time studies or control applications. You can control whether digital channels are acquired, plotted, and have values listed the same way you do for analog channels.

Label To the right of each channel number is an editable label for each channel, where you can type in a label (up to 38 characters) that identifies what each channel is measuring.

Preset Calculation channels include Presets as a quick way to get started—choose a preset and the software automatically sets the gain, offset, etc. appropriate for the selected application. Choose from the list of available presets or create a custom preset; see page 106 for details.

Channel Sampling Rate The channel sample rate is a function of the acquisition sample rate: all channel sample rate options are equal to or less than the acquisition sample rate (as established via "MP150 > Set Up Acquisition"). The options are a specific power of 2 less than the acquisition sample rate. Channel sample rate info is included in the Display > Statistics dialog. Use the pull-down menu to set the channel sample rate. See page 107 for details.

Setting up acquisitions



Once you have set up the channel parameters, the next step is to specify the acquisition settings. Choose Set Up Acquisition from the MP150 menu to generate a dialog that specifies the type of acquisition to be performed. The basic parameters involve specifying:

a) How data should be collected and stored
b) The data collection rate
c) The acquisition duration (total length)

Storage

Record and Save once to Memory is the default acquisition option. Under this option, the MP System (MP150 or MP36R) automatically records data into a single continuous file, and stores the data in computer memory (RAM) during the acquisition.

The third popup menu at the top of the dialog (which defaults to Memory) allows you to specify where the data should be stored during the acquisition. You will probably want to choose Memory or Disk storage. Computer memory (RAM) is usually faster (but less abundant) than disk space. If your system uses any virtual memory, Acq*Knowledge* will use as much as possible. You may also store data directly to the MP150 data acquisition unit, which can store 4 MB; you cannot store data directly to the MP36R.

- The advantage of storing to the MP data acquisition unit is that much faster sampling rates may be obtained.
- The disadvantages of saving data to the MP data acquisition unit are that there is limited storage space and that data is not displayed on the screen while it is being collected. When the acquisition has stopped, however, the data will be automatically displayed on the screen.

The other option under storage is Averaging, which allows you to take repeated trials of the same data. For more information on this feature, see the averaging section on page 154.

Rate

Acquisition Sample Rate is analogous to “mm/sec” on a chart recorder, and refers to how many samples the MP System (MP150 or MP36R) should take each second. As the MP System (MP150 or MP36R) takes more and more samples per second, the representation of the signal becomes more accurate. However, as the sampling rate increases, so does the demand for system resources (memory, disk space, etc.). There is a “point of diminishing return” in terms of sampling rate for almost all types of analog signals, where sampling above a given threshold adds relatively little information.

The MP150 sampling rate has a lower bound of 2 samples per hour, and an upper bound of 400 kHz aggregate. The MP150 must use a pre-defined rate, it does not accept custom rates.

Choose the best acquisition sample rate from the pop-up list.

Note: Channel sample rates are variable based on the acquisition sample rate. All channel sample rate options are equal to or a specific power of 2 less than the acquisition sample rate.

Duration

The final acquisition parameter is Acquisition Length (Total Length), which controls how long an acquisition will last. This can be scaled in seconds, minutes, hours, milliseconds or number of samples. You can set this value either by entering a number in the acquisition length box, or by moving the scroll box left or right.

Starting an acquisition

Once you have specified which channels will contain data and have defined the channel characteristics, the next step is to start the acquisition. If a file window is not already open, choose File > New > Graph window.

Status

In the lower bar of the screen, next to the Start button, you should see a circular status light. The status light indicates the communication link between your computer and the MP data acquisition unit.

- If the MP data acquisition unit is properly connected to the computer and is turned on, the circle will be solid and green.
- If the MP data acquisition unit is not properly connected or not communicating with the computer, under Windows® OS the circle will be solid and gray and under Mac OS® X the circle may not appear at all or a different symbol, such as double arrows, may be used if the application crashed during acquisition.

Start

To start an acquisition, position the cursor over the [Start] button and click the mouse button, or select **Ctrl+ Spacebar**. If there are no input devices (e.g., electrodes or transducers) connected to the MP System (MP150 or MP36R), it will collect a small value of random signal "noise" with a mean of about 0.0 Volts.

- For information on how to connect measurement devices to the MP System (MP150 or MP36R), see the *BIOPAC MP Hardware Guide.pdf*.
- To start an acquisition using a variety of "triggers," see page 166.
- Graphs that open without a Start Button
    - Compressed Graphs
    - Igor Pro Experiment
    - PhysioNet
    - DWT, IDWT
    - PCA, IPCA,
    - ICA, IICA,
    - AR Model separate graph output
    - Nonlinear Modeling separate graph output
    - HRV tachogram output
    - Chaos > Plot Attractor
    - Chaos > Detrended Fluctuation Analysis
    - MatLab Graphs
    - Merge Graphs
    - Original Data Snapshot
    - Raw Data Files
    - Text Files
    - Transform mennu operations: Off-Line Averaging; Filter Response
    - Analysis menu operations: Histogram; FFT (Magnitude and Phase); IFFT; Rate (put result in new graph option)

Once an acquisition has started, the Start button in the acquisition window will change to Stop, and two opposing arrows will blink, indicating that data is being collected. Also, the "BUSY" indicator light on the front of the MP data acquisition unit will illuminate, showing that data is being collected.

Stopping an Acquisition

To stop an acquisition at any time, click the [Stop] button in the lower right corner of the screen or select **Ctrl+ Spacebar**.

An acquisition will stop automatically when it has recorded an amount of data equal to that indicated in the Total Length box. To save this data file, choose File > Save.

Display modes

The display modes are Chart, Scope, X/Y, Stacked Plot, and Playback. You may change the way data appears on the screen at any time, even during an acquisition. To change the display mode, click the corresponding icon in the toolbar.

Chart mode

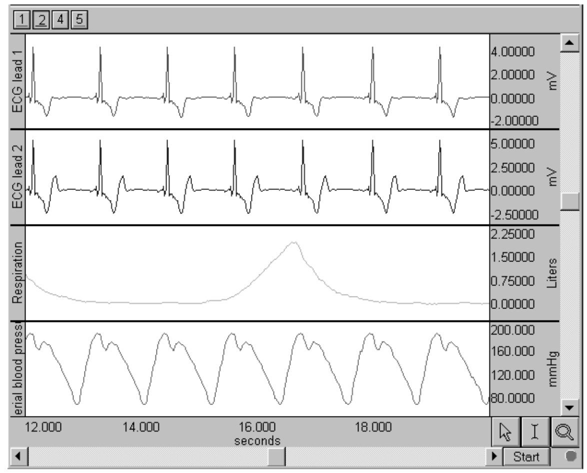
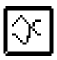


Chart mode is the default display mode.

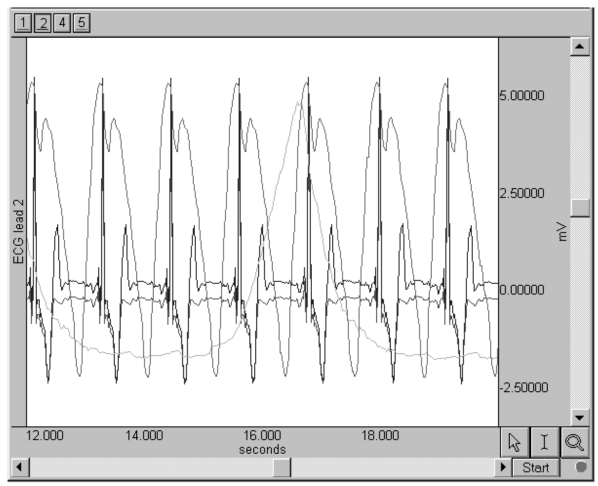
Chart mode plots data much as it might appear on a chart recorder, with time on the horizontal axis.

Each channel of data is in its own "track" across the screen, with borders between channels. The waveforms will not cross boundaries into the tracks of adjacent channels.

If a waveform is plotted off the scale of the channel track, choose autoscale waveforms and Acq*Knowledge* will select the "best fit" for waveforms to their tracks.



Scope mode



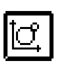
Scope mode plots data much as it might appear on an oscilloscope, with time on the horizontal axis.

Scope mode is similar to Chart mode, except that there are no borders between different channels.

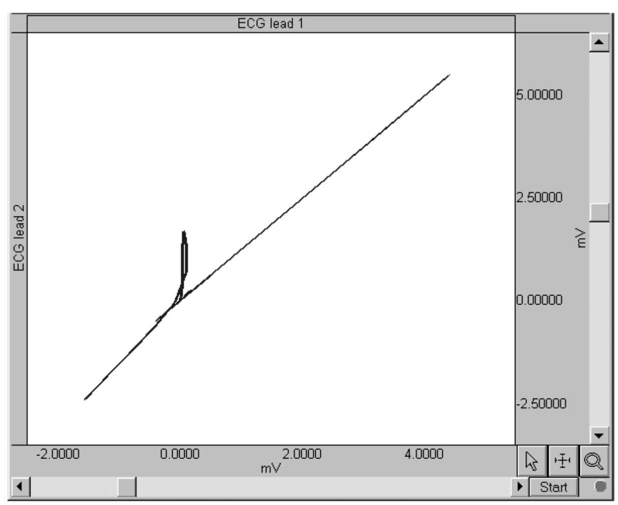
- To help emphasize the selected wave in Scope mode, select the "Gray non-selected waves" Preference (via Display > Preferences).

Waveforms can overlap. The autoscale waveforms command will automatically separate the waveforms in the graph window.

Note: When only one waveform is present, the scope and chart modes are identical.



X/Y mode

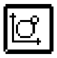


X/Y mode plots data from two channels against each other, with the values from one channel on the horizontal axis and the values from another channel on the vertical axis. Plotting a channel against itself displays a straight line.

X/Y mode can be useful for chaos investigations and respiration studies.

Note: When viewing data in X/Y mode as it is being acquired, plotting only the most recently acquired data point can be a useful option. To do this, select Display > Show > Dot Plot and then Display > Show > Last Dot only.

Switching to X/Y mode during acquisition can be slow. For best performance, switch to X/Y mode either before starting the acquisition or after stopping the acquisition.

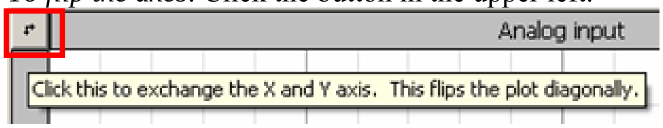
 X/Y mode continued

Plotted channels

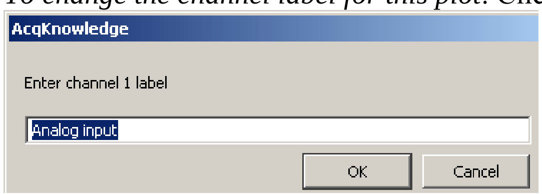
- *To change the channel being plotted*: Click the Channel label once and hold.

X-axis, click *above* the waveform; Y-axis, click *left* of the waveform.

- *To flip the axes*: Click the button in the upper left.



- *To change the channel label for this plot*: Click the Channel label.

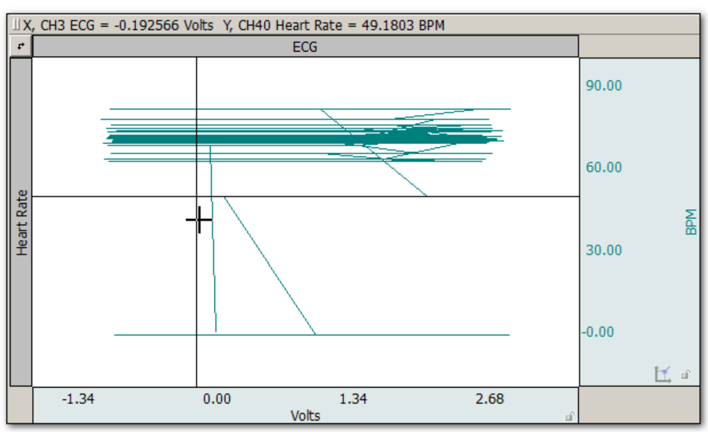


Toolbar icons

The center cluster of toolbar items is specific to X/Y mode. The left two buttons in this group are shortcuts for the Autoscale vertical and Autoscale horizontal functions. Adjacent to these buttons are two buttons that perform the center vertical and center horizontal functions.

Tools

Cursor In X/Y mode, the I-beam tool in the lower right hand corner of the graph window changes into a crosshair. When the crosshair is moved into the graph window, the coordinates of the crosshair are displayed in the upper left corner of the graph window. The X value refers to the coordinate of the crosshair in terms of the horizontal axis, and the Y value describes the location of the cursor in terms of the vertical scale. By pressing the mouse, a crosshair is drawn over the closest data point and the measurement toolbar "snaps" to that position to show the amplitudes of the actual pair of data samples plotted on the screen. In Acq*Knowledge* 4.2 and higher, the Channel number and label are also displayed next to the measurement values.

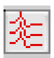


X/Y plot with ECG on X-axis and BPM on Y-axis

Autoscale In X/Y mode, the Autoscale waveform function changes to read Autoscale vertical, which plots the vertical channel so that it takes up two-thirds of the vertical channel space. This function controls the "height" of the data being plotted in the graph window.

Similarly, the Autoscale horizontal function plots the waveform so that the waveform is plotted in the center two-thirds of the window. This function controls the "width" of the data being plotted in the graph window.

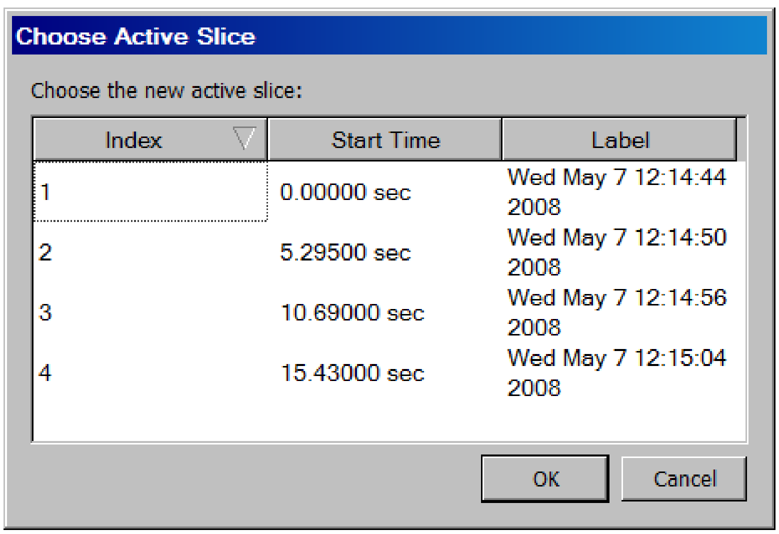
	Autoscale commands adjust the center point and the range of data displayed. To manually change the scale, click in either the horizontal or vertical scale area. In this case, the scale at the bottom edge of the graph windows (which usually reflects time) is the scale for the X variable, and the vertical scale controls the scale for the channel plotted on the Y-axis.
Center	In X/Y mode, since only two channels can be displayed at a time, tile waveforms and compare waveform are replaced with Center horizontal and Center vertical. These two Center commands change the midpoint of the horizontal and vertical scales (respectively) so that the midpoint of the scale is equal to the mean value (average) for that channel. These features are useful for centering the display so that it is easier to interpret.
Ch. # Box	In X/Y mode, the channel numbering boxes are disabled.
Meas. Menu	In X/Y mode, the measurement popup menus are disabled.

 <u>Stacked Plot mode</u>

Stacked Plot displays multiple time ranges on top of each other and is enabled for acquisitons set to Append (except when in X/Y mode). In this mode, all appended segments are stacked in the display, but only one segment “slice”is active (“selected”). To view an individual segment, click the Chart mode icon.

- Click the Stacked Plot mode icon to display the Stacked Plot controls beneath the toolbar:

To change the active slice, click the  Jump Tool or the … icon.



The selected segment is used for all enabled software functions. This means that autoscaling can easily create what looks like a mess if the selected segment is not appropriate for scaling the largest segment. In compound action potential graphs in Stacked Plot, the last segment slice will most often be the largest, so if you select the last segment before autoscaling you will likely get the expected result. The Transform menu is disabled in Stacked Plot mode.

A commonly used data visualization technique for examining the evolution of waveform morphology is the 2D waterfall plot or “stacked plot.” A stacked plot draws multiple traces for a single waveform on top of each other, or “slices.” Each individual slice is a time-shifted plot of the original waveform. The slices toward the bottom of the plot occur earlier in time then the slices toward the top.

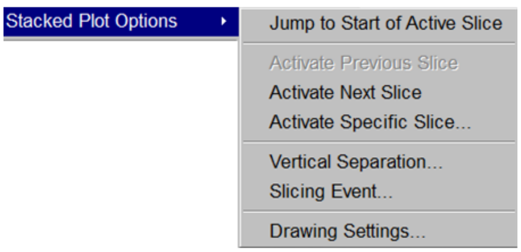
Data can be acquired in stacked plot mode, but it is processor intensive. If acquisition setup includes high sampling rates or control channels with low latency, acquire in chart or scope mode and switch to stacked plot mode after acquisition.

The slices can be aligned at any type of events in the graph. This allows for alignment at appended segments but also at locations found through other means. For example, an ECG waveform can be aligned at the start of the T-wave to examine how the T wave evolves in time.

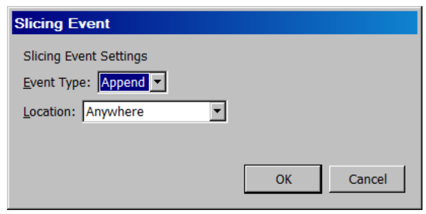
Active slice — In stacked plot mode, there is a single slice that is called the “active slice.” By default it is drawn in black; to change the color, select Stacked Plot Options > Drawing Settings. The values on the axes in the graph, grid, displayed events and text annotations, selections, and any transformations all apply to the active slice. The active slice can be changed using the navigation buttons in the graph toolbar.

Vertical Separation — The vertical separation between consecutive slices is expressed as a percentage of the entire visible area. This percentage is kept constant through zooming and scrolling operations.

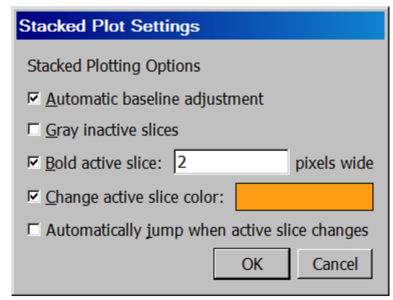
Stacked Plot Options



Display > Show > Stacked Plot Options



Slicing Event…



Drawing Settings…

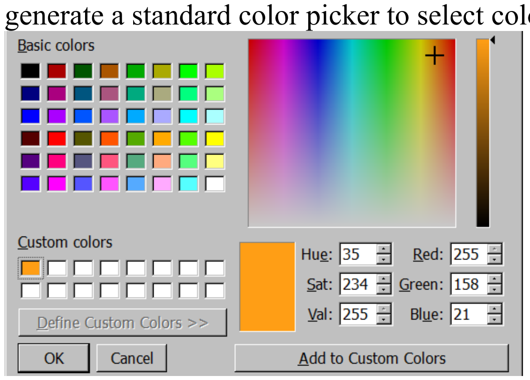
Use Stacked Plot Options to activate slices or visually distinguish the active slice from other slices being drawn in Stacked Plot mode.

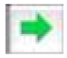
Automatic baseline — Adjusts the baseline of each inactive slice to overlap the baseline of the active slice prior to the application of any vertical separation. This helps compensate for baseline drift in a signal. If it is disabled, no baseline compensation will be applied and the stacked plot may exhibit visual vertical segment ordering problems resulting from baseline drift (but in this mode can be used as a tool to examine basline drift).

Gray inactive slices — Draws the active slice with a solid pen and draws inactive slices with a dashed gray pattern pen. The gray pattern alternates pixels between the chosen waveform color and the white background and has the effect of lightening the inactive slices, so you may need to zoom in to see the effect.

Bold active slice — Draws the active slice with a thicker pen. In step and line plot modes, plotting normally occurs with a one pixel wide pen. Inactive slices will remain one pixel wide while the active slice will have the thicker pen as indicated in the edit field. When the waveform is in dot plot mode, the pixel width will be added to the waveform's default dot size to increase the dot size for the active slice.

Change active slice… — Draws the active slice in a different color than the chosen waveform color. When enabled, the same color is used for the active slice of each waveform in the graph. The color can be changed by clicking on the colorwell to the right of the checkbox to generate a standard color picker to select color.



Automatically jump…  You can use the Jump tool (green arrow) to change the active slice.Each time the active slice is changed the left edge of the plot area will be changed to match the start of the newly activated slice. When disabled, each time the active slice is changed the display will be adjusted in such a way that the time interval between slice starting positions and the display origin is kept constant.

Functionality in Stacked Plot mode

Autoscaling

When a graph is displayed in stacked plot mode, all autoscaling and related display operations (tile, compare, overlap) will examine the visible data of the active slice only. It will not be possible to perform autoscaling operations using the data of any inactive slice.

Autoscale Horizontal

In stacked plot mode, autoscale horizontal will make the active slice occupy the entire visible area. The slicing event corresponding to the beginning of the slice will be placed at the left edge of the screen and the next slicing event (or last sample point of the waveform if the active slice is the last slice) will be placed at the right edge of the screen. The vertical offset will remain unaffected.

Data Views

Different data views may have independent Stacked Plot settings. All settings are independent including drawing preferences, slicing events, vertical separation, and active slice settings. Stacked plot settings are stored individually for each data view in the graph file and will be restored when the graph file is opened from disk.

Any graph-wide operation that may affect the active slice will update all data views that are configured to use stacked plot mode. This includes operations that affect the data (e.g. transformations) or events (e.g. waveform editing).

Graphs Containing No Slices

It is possible that graphs may not contain any slices whatsoever if no events match the slicing event criteria. If a graph in Stacked Plot mode contains no active slices, it will be drawn as if the graph was in regular chart mode with the following differences:

All data is drawn using any active slice settings given in the stacked plot drawing options.

The “Active slice” index will read “N/A”.

The previous/next/choose slice graph toolbar buttons and “Display > Show > Stacked Plot Options” menu items will be disabled.

It will be possible to view all data from t = 0 to the final data sample of the graph using the horizontal scrollbar.

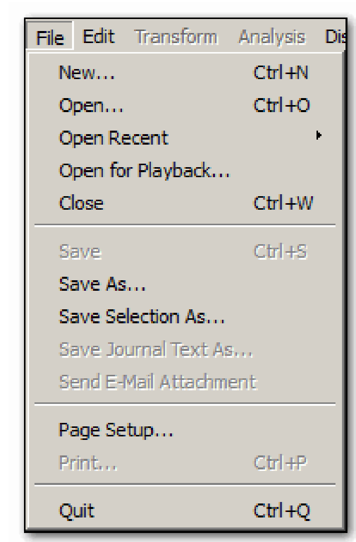
All autoscaling operations will function as if chart mode was active. Autoscale horizontal will make all of the data of the selected waveform visible on screen.

If the table of available slices was being displayed prior to the removal/editing of the last matching slicing event, the table will be emptied and the “OK” button dimmed. The cancel button will remain active for the table window to be dismissed.

The slicing event, vertical separation, and drawing menu items and toolbar controls will remain active.

Playback Mode (Replay)

Playback mode will replay a graph file stored on disk in real time to simulate acquisition. Analog, digital and calculation channels are replayed as stored in the graph file, but in Acq*Knowledge* 4.2 and higher, calculation channels can be reconfigured to reproduce online calculation channels that have no offline equivalents. Calculation channels from the original graph can be modified, extended, or removed without affecting the data stored on disk in the original graph file.



Use *Playback* to experiment with different calculation channels settings on the same data or to recreate an experiment for demonstration purposes.

1. Select File > Open for Playback.
2. Locate a graph file and then click Open.
3. A new graph window will be generated.
   - The “Connected to…: hardware menu will indicate that the graph will be “acquiring” data from the specified file and the Start button will change to a “Replay.”
4. Press Replay to begin playback.
   - Button alternates with STOP, can’t pause.
5. Select Playback > Quit Playback Mode to return to acquisition status.

Playback mode has millisecond timing accuracy and allows for reconfiguration of most acquisition parameters. Exceptions include:

- Length is limited to the amount of data in the file
- Acquisition Sample Rate is fixed (use Channel Sample Rate to downsample)
- Number of analog and digital channels is fixed
- Save last, MP, and Averaging modes are disabled
- “Append” will replay the same data.

Do not record data while playing back a data file. If one data file is open in "Playback" mode and is 'replaying' and a second data file is open in MP150 mode and is acquiring data, clicking back and forth between graph windows causes the MP150 menu to flip to the Playback menu (even though 'Connected to' shows communication with an MP150 unit).

See the Acq*Knowledge* Demo file under the Help menu as a sample of data playback.

Data Views

A "Data View" window is used to provide an alternate view of the same data. You can present data in two or more modes for comparison, such as X/Y plots and chart plots. To compare responses in real time, turn off Autoplot in one Data View (e.g., Dose 1) and continue Autoplotting in another (e.g., Dose 2).

To create a new Data View for the active (selected) graph, choose

- File > New and select type Data View or
- Display > Create Data View

This will generate a new window displaying the active graph's data, and will name the new window "Data View of 'Filename'" 

.

TIP Use the Jump-to tool (see page 58) to correlate data views.

Data Views share fundamental data characteristics such as channel labels, markers, and sampling rates, but can be customized for the following:

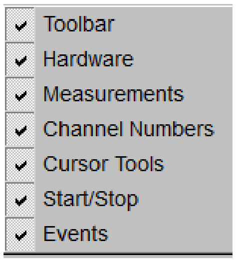
- horizontal scale, precision, and offset
- vertical scale, precision, and offset
- measurements, including number of rows, precision, visibility, and use of interpolation
- grid settings, including spacing, visibility, and locking state
- selected area
- autoplotting
- hidden channels
- autoscrolling
- channel button display state
- wave color
- marker display state
- channel order
- plot mode
- channel drawing mode (step, line, or dot, including dot plot size and type)
- hardware "connected to" display

The Data View window can be used like any other graph window. The menus and controls can be used to change how the data is presented. An acquisition can be started or stopped in any of the Data Views for a graph, and any transformations performed on the data in the Data View will be reflected in the graph and all of the other Data Views. Printing a graph from a Data View will use the display settings of that Data View for outputting the graph.

When a file is saved to disk, the display configuration of any Data Views that are open are saved into the graph file. When the graph file is reopened, all of the Data Views and their display settings will be restored.

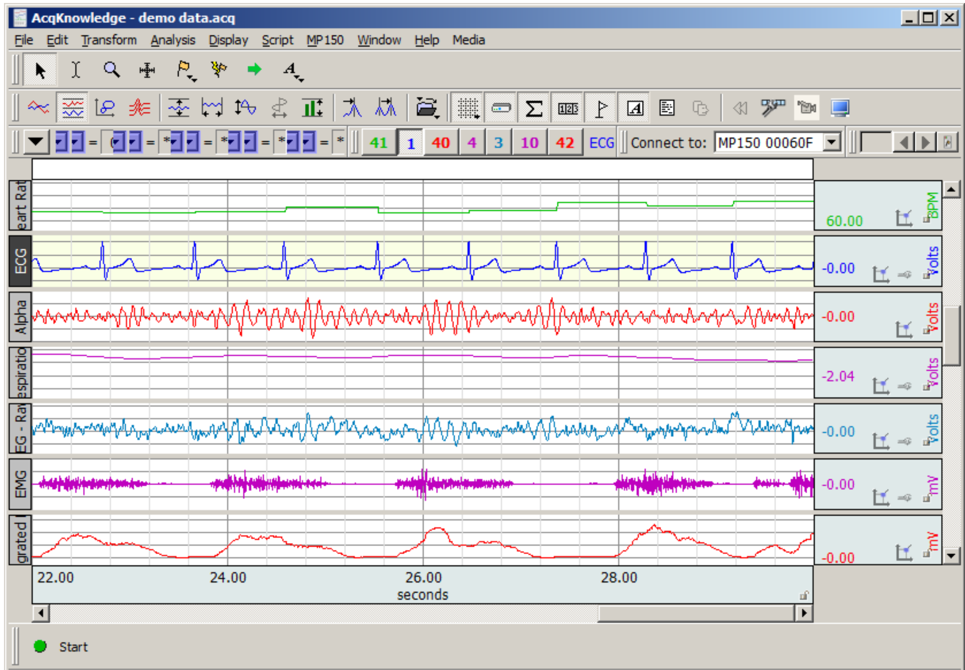
- Data Views are saved with the data file only if they are open at the time the original graph is closed and saved.
- Closing a Data View causes this view to be lost; it is not saved with original file.
- Closing a Data View that was previously saved with a data file will not be saved if the data file is saved after closing the Data View.
- Closing a Data View will not invoke a warning that the Data View will not be saved.
- Original Data Snapshot is not merged into the newly created data file.

Analysis



For purposes of illustration, you should open an existing file that contains actual data. Sample files were installed with the software. Select File > Open and choose a file from the list in the dialog.

If you open the file called demo data.acq, the screen should resemble the following sample file display.



Sample File Display

The sample graph displays six different types of data, and there is a border between the waveforms.

To the left of each waveform is a vertical strip containing a text string that can be used to help identify each waveform.

The time scale along the bottom denotes when the data was recorded relative to the beginning of the acquisition.

- Only the last eight seconds of the total data record are visible, although the file contains the complete record.
- The data displayed on the left edge of the graph represent events that occurred about 22 seconds into the record, and the data displayed at the right edge of the screen represent events that occurred about 30 seconds after the acquisition was started.

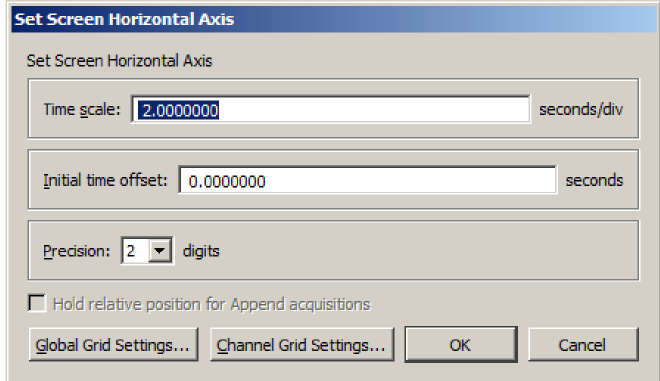
The maximum vertical scale range is from +10 to -10 Volts.

- This reflects the maximum input voltage the MP150 unit can accept and is a greater range than you will usually encounter.
- The display scale can be adjusted to virtually any value range, as demonstrated in the graph window above.

As indicated by the horizontal scale, only a few seconds of data are displayed on the screen. If you choose Statistics from the Display menu, you can determine the total length of the record.

To view data that was collected earlier in the record, you can use the horizontal scroll bar to move to different points in the record. The horizontal scroll bar allows you to move around in a data file, just as the scroll bar in a word processor allows you to move to different points in a document.

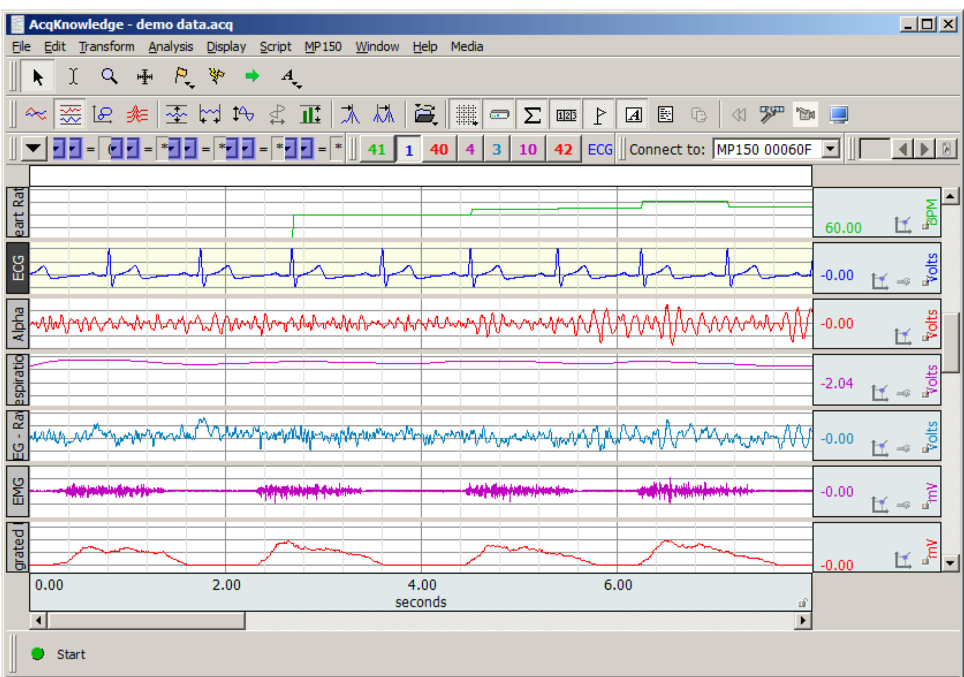
Alternatively, you can position the cursor in the horizontal scale area (where the numerical values are listed) and click the mouse button. This will generate the following dialog (see page 72 for details).



The Time scale box allows you to change the amount of data that appears on the screen at any given time. In the sample dialog, this is set to 2 seconds per division. The divisions on the screen are indicated by the four vertical lines, thus displaying eight seconds at a time (two seconds per division times four divisions). By entering a larger value in this box, more of the record will be displayed on the screen at any given time. Conversely, entering a smaller value in this box will cause a shorter segment of data to be displayed on the screen. (Above screenshot is from Acq*Knowledge* 4.2)

- ➢ To display the entire waveform (in terms of duration), a shortcut is to choose Autoscale horizontal from the Display menu. The Autoscale horizontal command fits the entire data file into the window, regardless of the total length of the acquisition.

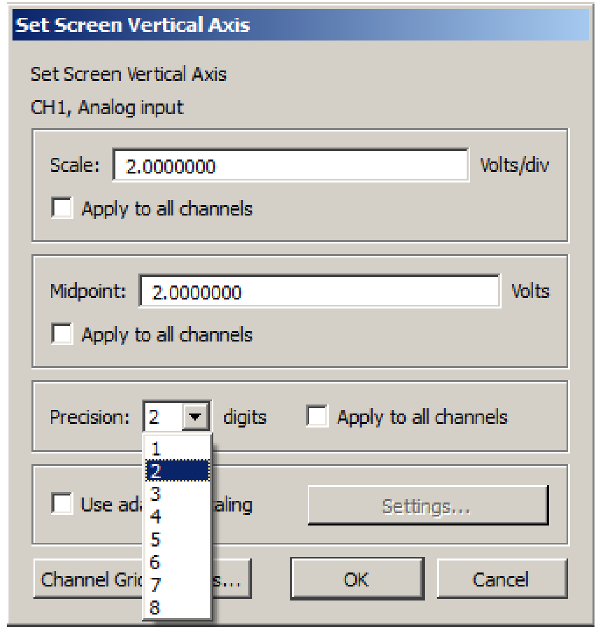
The Initial time offset box lets you “jump” to a different point in the time display. Changing the value in this box allows you to display data beginning at a certain point in the record. For instance, if you want to see the data at the beginning of this record, you would tell Acq*Knowledge* to display data with an initial offset of 0 seconds, which would result in the following:



As you can tell from the time scale, the first data displayed (at the left edge of the screen) was collected at the beginning of the acquisition. Also, the scroll box has moved to the left, indicating that the data on the screen represents data collected earlier in the record.

If you click in the horizontal scale area again, the same dialog will appear, and this time the value in the start box should have changed to reflect the new section of data being displayed on the screen.

Acq*Knowledge* also allows customization of the vertical scaling, or amplitude, of each waveform. Clicking the vertical scale area produces a dialog (see page 73 for details).



The vertical scale dialog allows you to change the range of amplitude values displayed (scale) and set the value that appears in the center of the vertical scale (midpoint).

You can vary the midpoint and apparent magnitude of each waveform by changing the values in each box. By changing the value in the scale box, a smaller value has the effect of increasing the apparent amplitude. Entering a number about half the current value will cause the amplitude of the wave to appear to double.

- Scale—In the sample dialog, the units are set to 2 Volts per division. As with the horizontal scale, there are four divisions on the vertical axis, so this setting should show 8 Volts range of data.
- Midpoint—The box below this controls the midpoint of this range. In this case, the midpoint is set to 2 Volts, which means that this channel will display the range from - 4 Volts to + 8 Volts.

As with the time scale, you can have Acq*Knowledge* automatically come up with the best fit in terms of midpoint and units per division. To do this, select the Autoscale waveform command from the Display menu, and the amplitude and offset of each wave will be adjusted to fit their sections.

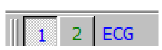
Any changes you make in terms of rescaling (either horizontal or vertical) will only affect the way data is displayed, and will not change the basic characteristics of your data file.

Selecting a waveform

Although all four waves are displayed at once, you may want to operate on only one channel at a time. To do this, you need to select the channel you wish to work with. Selecting a channel allows you to highlight all or part of that waveform, and enables you to perform transformations on a given channel.

In the upper left corner of the graph window there is a series of boxes that represent each channel of data. The numbers in the boxes correspond to the channel used to acquire the data (the specifics of setting up channels are discussed on page 36). In the sample waveforms shown previously, ECG channels are represented by channels 1 and 2, with respiration on channel 4 and blood pressure on channel 5.

To select one of these channels

- position the  cursor over the channel box 

that corresponds to the channel you wish to select and click the mouse, or
- position the  cursor on the waveform of interest and click the mouse.

Show/Hide Channel

To “hide” a waveform, press ALT for Windows or OPTION for Mac and click the channel box.

To view a hidden waveform, repeat the appropriate key-click combination.

Zoom

Another way to examine data is to use the “zoom” tool. The zoom tool allows you to select any portion of any wave and magnify it as much as possible. To use the zoom tool, click the icon in the lower right portion of the screen. As you move the mouse into the graph area, you will see it change from an arrow to a crosshair (+). Start by positioning the cursor in one corner of the box, holding down the left mouse button, and dragging the crosshair horizontally, vertically, or diagonally to form a “box” which encompasses the area you need to zoom in on. When you release the mouse button, Acq*Knowledge* will automatically adjust the horizontal and vertical scales. To “unzoom,” choose Zoom back from the Display menu.

Select an area

Once you have selected a channel, you can “edit” parts of that channel by selecting a section of the waveform. The options available to you include cutting, copying, and pasting sections of waveforms. You can also transform and analyze entire waveforms or specific sections of waveforms.

For any of these functions, you will need to select (or highlight) an area to be operated on. If you want to select a section of a waveform, position the cursor over the icon in the lower right hand corner of the screen and click the mouse button. Now move the cursor to the first point in the area that you wish to select. As you move the cursor into the graph area, you will see it change from an arrow cursor to a standard I-beam editing tool.

To highlight a section of a waveform, position the cursor at the left edge of the area you wish to select and hold down the mouse button. Now move the mouse to the right until you have selected the desired area.

To select more than one screen of data, position the cursor at the left edge of the section to be highlighted, then click and hold the mouse button. Use the scroll bars to move to a different point in the record, and when you reach the desired endpoint (right edge) of the selected area, hold down the Shift key while you position the cursor and click the mouse button. Selecting an area this way will also allow you to “fine tune” the selected area to include only a specific range of data.

Once a channel has been selected and a section of that area highlighted, you can operate on and edit that section of the waveform. The editing commands behave much the same way as the editing functions in a word processor. You can cut, copy, delete or paste sections of data as defined by the selected area. In most cases (depending on available memory) you may undo an edit by choosing Undo from the Edit menu, or by using the shortcuts **CTRL + Z** for Windows or ⌘+Z for Mac.

Selecting a portion of a waveform also allows you to apply transformations to a particular area, rather than the entire area or all waveforms. Selecting an area also allows you to take snap measurements for parameters such as delta T, mean, standard deviation, frequency, and so forth. The measurement options are discussed in the next section.

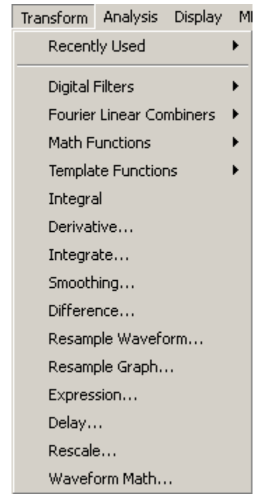
The Selection Palette (**Display > Show > Selection Palette**) can also be used to select an area.

Keyboard data selection

Keystroke combinations can similarly used to select or deselect graph data on a sample-by-sample basis. This helps add an enhanced level of precision to the selection operation. See data selection keyboard shorcuts on the following page. (Acq*Knowledge* 4.2 and higher)

Keyboard Shortcut	Description
Windows: Shift + Ctrl + Left Arrow **Mac:** Shift + Command + Left Arrow	Subtracts one sample interval from the right edge of the selection. If the selection is empty, no action is performed.
Windows: Shift + Ctrl + Right Arrow **Mac:** Shift + Command + Right Arrow	Subtracts one sample interval from the left edge of the selection. If the selection is empty, no action is performed.
Shift + Left Arrow	Adds one sample interval to the left edge of the selection.
Shift + Right Arrow	Add one sample interval to the right edge of the selection.
Left Arrow	Moves the selection one sample to the left, constructs a zero width selection.
Right Arrow	Moves the selection one sample to the right, constructs a zero width selection.

Transform data



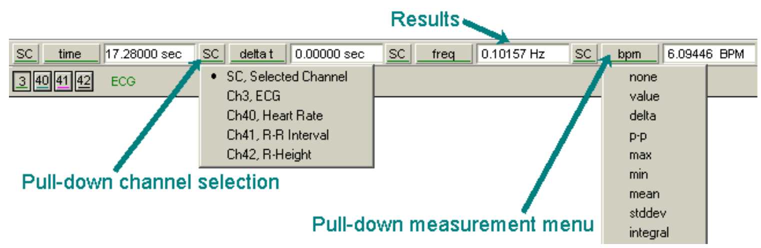
Acq*Knowledge* includes a library of functions to transform data or perform mathematical calculations on waveform data. All of these options can be found under the Transform and Analysis menus, and are discussed in detail in the Analysis section beginning on page 296.

When performing transformations

- If a section of a waveform is highlighted, the transformation will apply to that section.
- If no area is selected, Acq*Knowledge* will always select a single data point.
- If the transformation can only be performed on a selected area (digital filtering, for instance) and a single point is selected, the entire waveform will be used (and the transform entire wave option will be disabled; close out of the dialog and select an area if desired).

Measurements

Once you have selected a channel to work with, you can quickly and easily take measurements on each wave. The measurements appear in the row of boxes across the top of the graph window. You can specify the number of measurement boxes to show and the display precision in the "Preferences" dialog of the Display menu. Each measurement consists of three parts: (a) the channel selection, (b) the measurement function, and (c) the result or actual measurement value.



In this example, results for the selected channel (SC) are:

Time	17.28 sec
delta t	0.00000 sec
freq	0.10157 Hz
bpm	6.09446 BPM.

The pull-down channel selection allows you to calculate a measurement either for the selected channel (SC) or from a numbered channel in the record. To switch between the channel options, click in the channel window. The pull-down menu shows the channel numbers and labels for all channels in the file. By default, each measurement will reflect the contents of the selected channel.

The pull-down measurement menu allows you to choose between different types of measurements. To choose a measurement, click the measurement popup menu and select a measurement from the list.

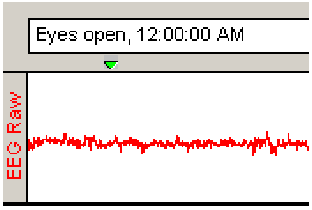
- Some measurements (such as Time or Value) look at only a single data point whereas other measurements (such as mean and delta T) examine a range of data on the selected channel.
- Some of the measurements that depend on a selected area (such as delta T) look at differences in the horizontal axis measurement whereas other range measurements (such as peak-peak) use the vertical scale information in calculating measurements.

For a complete description of each of the measurement functions, turn to page 87.

The final component of a measurement window is the measurement result.

- When an area is selected (or if the selected area is changed) the measurement result automatically updates to reflect the change.

Events (Markers)



In many instances it is useful to have the software mark an occurrence or event during an acquisition so it can be referenced later. For instance, you may want to note when a treatment began or when an external event occurred so you can examine any possible reaction. The software uses “Events”, which are marked in the data to record events.

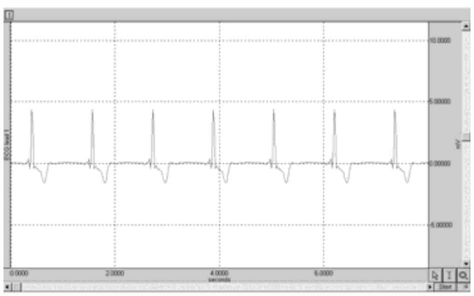
Event markers can be pre-established and automated. Event icons and labels appear at the top of the graph window, and can be edited, displayed, or hidden from view.

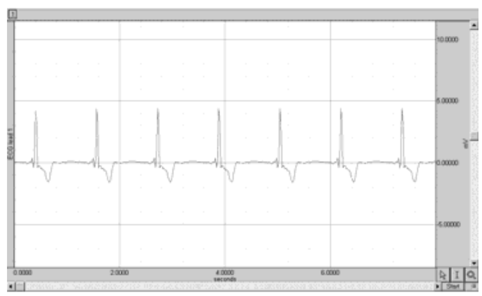
You can automatically insert event markers during an acquisition by pressing the Esc key. This will insert a marker at the exact time the key is pressed and will activate the text line entry so you can immediately enter a comment to be associated with the marker.

For a detailed description of markers and marker functions, including options to pre-establish marker labels and set function keys for different labels, see Set Up Event Hotkeys (page 207).

See also: Text Annotation, page 58.

Grids





Grid superimposes a set of horizontal and vertical lines on the graph window. The grid is designed to allow for easy measurements, since the grid lines correspond to horizontal and vertical scale divisions. The grid can be locked (analysis, printing) or unlocked (visual aid).

To activate the grid display, choose Display > Show > Grid or click the toolbar icon.

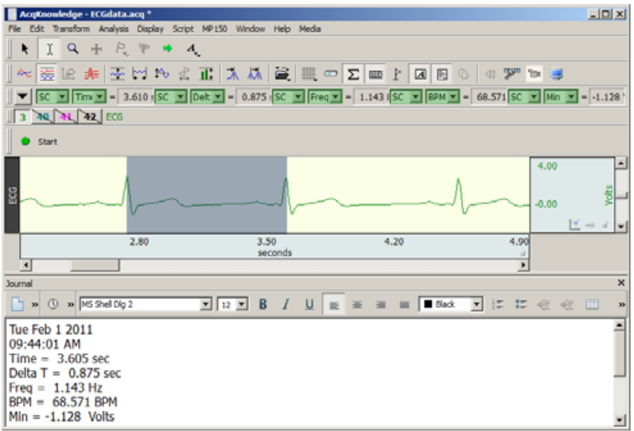
- To display minor grid lines, use Ctrl-.
- To customize grid line and color and optimize the display and print features, choose Display > Show > Grid Options.

For more information about using and printing grids, see page 75

Note: The Scale dialogs change when grid lines are locked. See page 72 for details on Horizontal Scale and page 73 for details on Vertical Scale.

Journals

The Journal is a general-purpose text editor built into Acq*Knowledge* that works like an "electronic notepad" for recording notes and data and saving text and/or numeric values for later review. The Journal can be used at the same time data is being acquired. Every graph file has a graph-specific Journal file permanently linked to it. There is also an option to generate independent Journals for data view, use with multiple graphs or protocols.



Graph-specific journal—Journal is saved with graph; preferable for retaining notes and analysis within a graph file. Display settings are independent. To save a graph-specific Journal independent of its graph, use File > Save Journal Text As option.

Independent Journal—Journal is saved into its own file, separately from graphs; preferable when performing analysis on multiple graphs at the same time. Independent journals allow multiple journal windows to be open at the same time (each graph view can have its own journal associated with it), but only one Independent Journal can be used at a time.

For more information on using Journals, see Journal Details on page 80.

Saving data

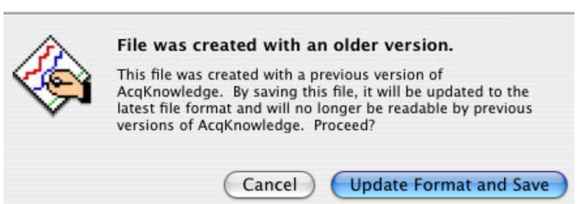
Once data has been collected, it can be saved as a file and opened later. The data file can be moved, copied, duplicated and deleted just like any other computer file. By default, files are saved as Acq*Knowledge* (.ACQ) files, which are a proprietary format designed to store information in a format as compact as possible. Although these files can only be opened from within Acq*Knowledge*, the data in these files can be exported either as a text file or as a graphic image.

Exporting data to a text file allows you to examine the data using other programs, such as a spreadsheet or statistical analysis package. Saving data as a graphic (.JPG) enables you to work with the data in graphic format.

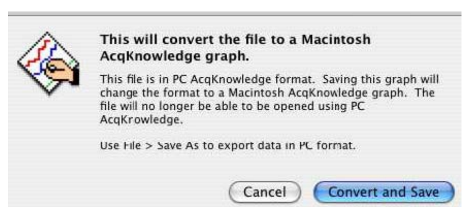
One of the most useful applications of this is the ability to edit and place Acq*Knowledge* data as it appears on the screen. You can use this feature to paste graphs into word processors, drawing programs, and page layout programs. To learn more about these options, turn to the Save As section beginning on page 246.

Format change warnings

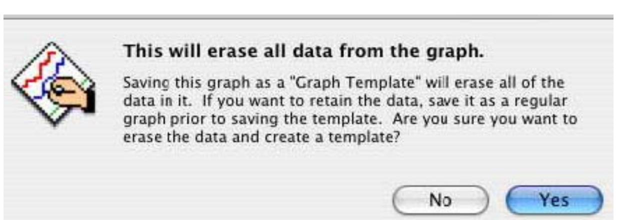
When a file save function requires a format change for compatibility or alters file content, a prompt will be generated to require the user to confirm the option to update format or convert and save.



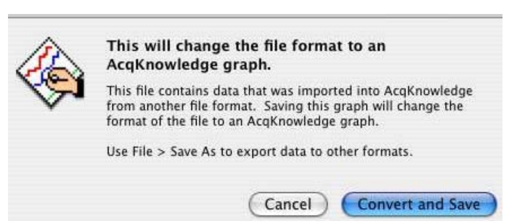
Created with a previous version of Acq*Knowledge*



Windows PC Acq*Knowledge* format



Saving as a "Graph Template" will erase all data



Imported from another file format

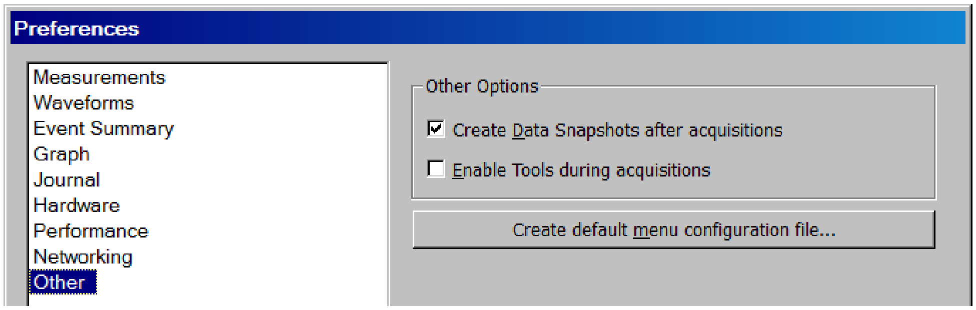
"Data Snapshot" — Embedded Archive

"Data Snapshots"are essentially embedded archives of the original acquired data that are stored with the graph file so you can easily view them together at a later time to compare results to original waveforms or intermediate stages of analysis.

IMPORTANT Archive functions do not create a new file—they are not backup functions.
Original data is copied and pasted to the end of the original file.
You cannot use this feature to recover lost or damaged original data.

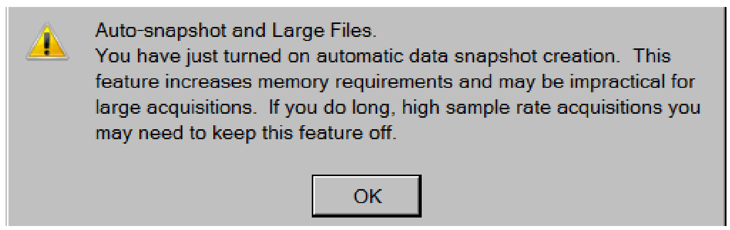
There are two ways to create a snapshot:

1. **Automatic after acquisition**: Display > Preferences > Other > Create Data Snapshots after acquisitions

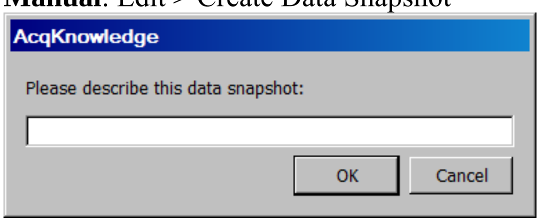


When this is enabled, a date-stamped archive of the data in the graph when acquisition stopped is created. In Append mode, the entire graph is archived with each Append, old data as well as the newly acquired data.

This is a memory intensive function; each archive that is added to a graph file will increase its size on disk by approximately 40%. When prompted, click OK to proceed.



2. **Manual**: Edit > Create Data Snapshot



A snapshot is then taken of the data at that point in time and stored with the graph. Manual archives allow you to preserve intermediate stages in a complex analysis for future reference. You will be prompted for a comment to describe the archive. This description will be used in the header when you display the archive.

To view the embedded archive(s) associated with a graph file, choose Display > Show All Data Snapshots.

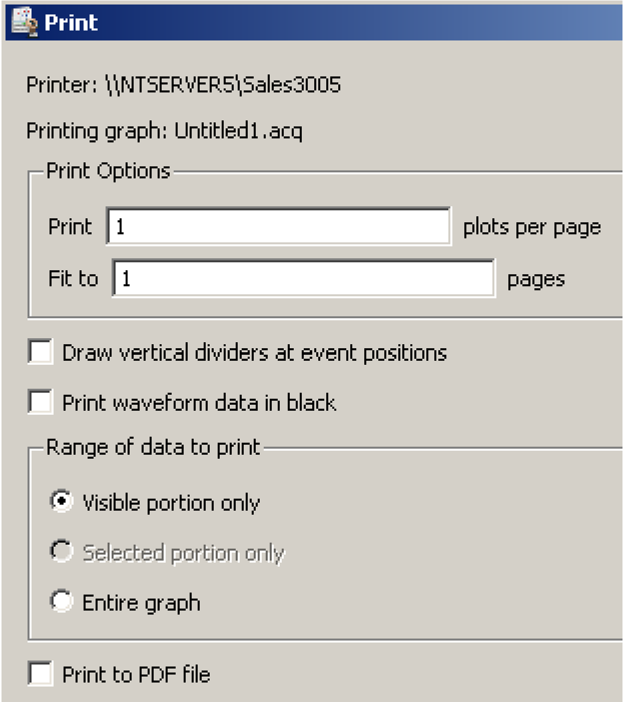
This will open a new graph window for each archive associated with the graph. The time portion of the Filename for each graph is from the computer clock (saved with semi-colons because you cannot save a file with colons in the filename). The "Data Snapshot from…" graph will open with no Start button.

Manual Archive: description and time
Original file
Automatic Archive: time only

Snapshots will also retain the following in addition to the data:

- Events - Text annotations
- Graph-specific journals
- Acq*Knowledge* GLP Modification logs (ACK100W-G and ACK100M-G only)

Print



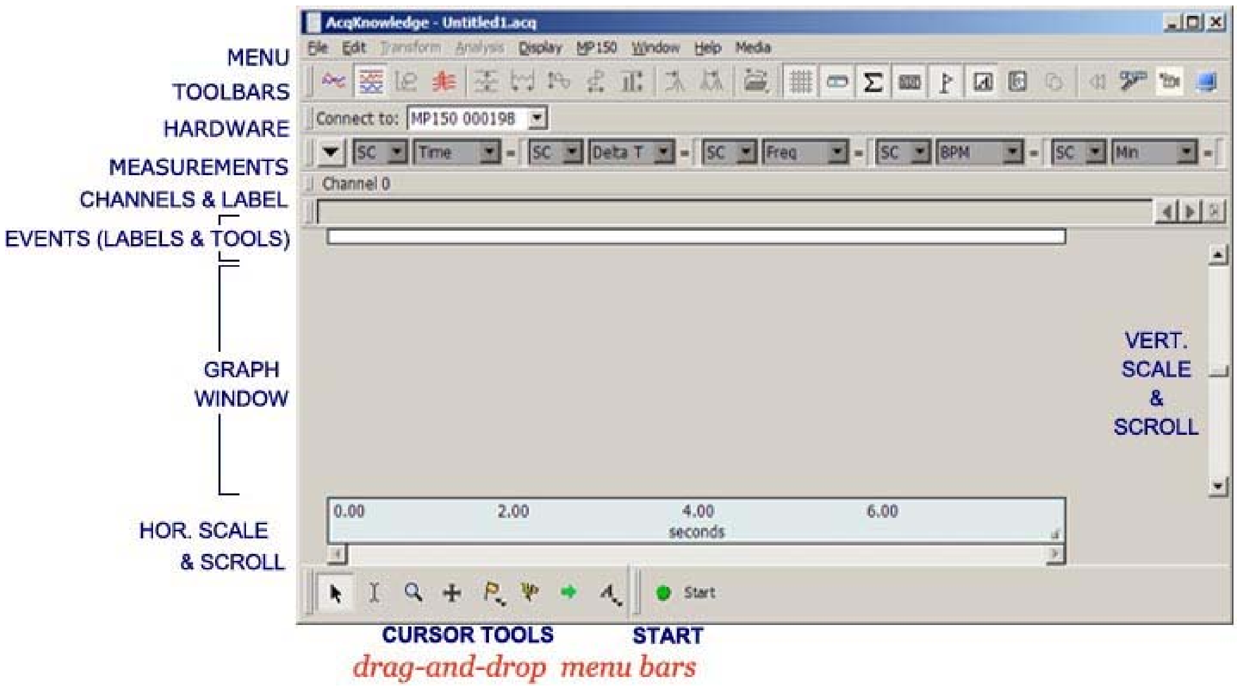
Acq*Knowledge* allows you to produce high-resolution hard copy plots of graphs much as they appear on-screen.

- To print a file, choose Print from the File menu. This will print the contents of the screen on the selected printer.
- To print the entire file, choose Autoscale Horizontal from the Display menu first.
- You must print a journal as a separate command from print graph file.

You may instruct Acq*Knowledge* to print the contents of a file across several pages by entering a value in the Fit to box. Entering “4” in this box, for instance, will place the length of the page evenly across four pages when printing.

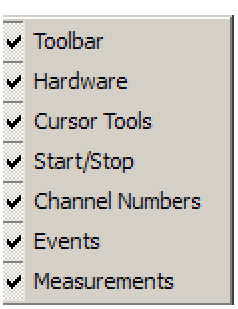
Print options are available after you click OK in the initial File > Print dialog; see page 254.

Chapter 3 User Interface & Context Menu Features



- Toolbars
- Keyboard Shortcuts
- Mouse Controls
- Custom toolbars for transformations and analysis
- Toolbar position retention and changes
- Event tool enhancements
- Typed event label drawing improvements
- Choose MP150 Help Button
- Button Transparency
- Customizable Chart Track Dividers
- Plotting Background Colors
- Vertical axis scaling buttons
- Long channel labels and units
- Graph window tooltip improvements
- Menu item tooltips
- Channel Info
- Transformation history
- Canceling Transformations
- Transformation Progress Bar

Toolbars



Many of the most commonly used features in Acq*Knowledge* can easily be executed with a mouse click. The toolbars contain shortcuts for some of the most frequently used Acq*Knowledge* commands.

Choose Display > Show or right-click outside the data window and enable Toolbars in the context menu. Click an icon to activate it; icons are grayed out when they are not applicable.

Toolbar position—Toolbars for Measurements, Channel number, and Hardware revert to the default location when a file is opened (position is not retained).

Toolbar (Display controls)

ICON FUNCTION

Change display to scope mode.

Change display to chart mode (default).

Change display to X/Y mode.

Toggle Stacked Plot (overlap segment) mode; see page 41

Autoscale selected waveform only.

Autoscale waveforms along the horizontal axis.

Center waveforms vertically in the active window.

Center waveforms horizontally in the active window (X/Y mode only).

For channels that have range information, set the vertical scale to match the maximum allowable input signal for the MP unit

Find the peak of a selected area.

Find the next peak (after peak has been defined).

Click and hold the mouse to produce a list of graph (.acq) files in the current folder.

Show/Hide gridlines in the graph window.

Show/Hide Hardware "Connected to:" in the graph display; also functions via Display > Show > Hardware.

Show/Hide measurement pop-up windows.

Show/Hide channel selection boxes.

Channel selection boxes appear above the data window and indicate the channel(s) being used to record data.

- To select a channel, depress the corresponding channel number box (CH 1 is selected here).
- To hide a channel, Alt-click (PC) or Option-click (Mac). A slash mark will cover the channel box and the channel will be hidden.

Show/Hide events (markers) and enable Event toolbar icons:

Text Annotation display (see page 58.)

Show/Hide graph-specific journal (Mac—Journal must be open for icon to work).

GLP—requires installation of AcqKnowledge GLP (Good Laboratory Practice)

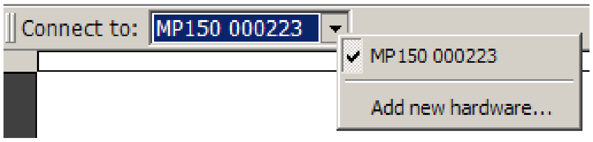
Rewind—deletes the last recorded segment. Alt+Rewind (Windows) or Option+Rewind (Mac OS X) deletes all recorded data, similar to the Append "Reset" button.

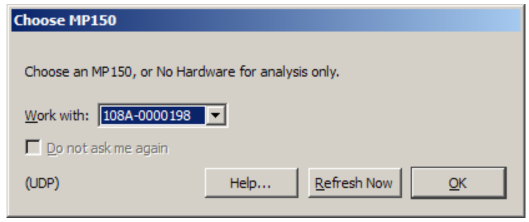
Open the customize toolbar menu.

Toggle display of the Media Capture viewer.

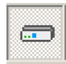
Toggle display of the Media Playback viewer.

Hardware Toolbar

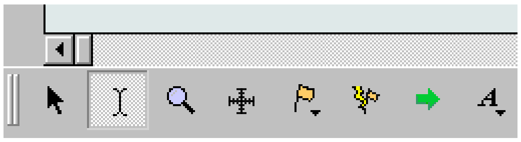




The hardware toolbar displays connected to information and includes quick access to add/change hardware. The Hardware toolbar reverts to the default location when a file is opened (position is not retained).

Also functional through the Toolbar icon 

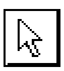
Cursor Toolbar



The cursor tool icons are in the lower corner of the graph window. These cursor tools are used in many of the on-screen functions described below, including editing, measurements, and the amount of data displayed.

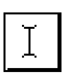
The cursor tools are also accessible via the Display menu (Display > Cursor Style)

CURSOR TOOLBAR



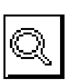
This is a general-purpose"arrow" cursor tool, used for selecting waveforms, scrolling through data, and resizing the chart boundaries between waveforms when in chart mode. All other cursors default to this mode when the cursors are moved outside the graph area. Use Alt-click to step through the channels; each click makes a new channel "active." The arrow cursor can also be activated by the Ctrl+B keystroke.

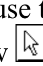
In Acq*Knowledge* 4.2 and higher, holding down the left mouse button with the arrow tool positioned over a graph channel will activate a single data point, which displays as a solid black vertical line. This is known as "spot measurement" mode. Dragging the mouse will then update selected measurement values to the new horizontal locations of the arrow's position in the graph. The mouse button shoud be depressed for approximately 0.5 seconds in order for spot measurement mode to become active. Releasing the button restores the arrow cursor to its normal status.



This is a standard "I-beam" editing tool. This tool is used to select an area of a waveform (or waveforms) to be edited or transformed. To select it, click the middle button in the lower right hand corner of the screen. Now move the cursor toward the waveform. You'll notice that the cursor changes from an arrow to an I-beam when it is placed over the graph area. Using this tool to edit data is analogous to editing text with a word processor.

When this cursor appears, you can select an area of data by holding down the mouse button and dragging the mouse to either the left or right. You can extend the selected area to include data that is not on the screen by positioning the cursor at the left edge of the area to be selected and clicking the mouse button. Next, use the scroll bars to scroll through the data until the desired data appears on the screen. Hold down the shift key while you position the cursor to select the right edge of the area to be selected. Click the mouse button to select the area. To extend the selection, hold the Shift key and move the cursor or the arrow keys. The I-beam cursor can also be activated by the Ctrl+I keystroke.



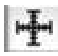
This is a standard "zoom" tool. The zoom tool lets you select and magnify any portion of any wave. Click the  icon (in the lower right portion of the screen) to use the zoom tool. As you move the mouse into the graph area, it will change from an arrow  to a crosshair (+). Start by positioning the cursor in one corner of the box, then hold down the (left) mouse button and drag the crosshair horizontally, vertically, or diagonally to form a "box" that

CURSOR TOOLBAR

encompasses the area you need to zoom in on. When you release the mouse button, Acq*Knowledge* will automatically adjust the horizontal and vertical scales. To “unzoom,” choose Zoom back from the Display menu.

Hold the “Alt” key to change the zoom mode to zoom out (“– “in the magnifier). The zoom tool can also be activated by the Ctrl+G keystroke.

Grid Control



Adjust the grid lines horizontal and vertical. Hold the option key for locked grids to drag to the end.

Event Definition

Inserts an event at the mouse click location. See page 213 for Event details.

- On a plot, the horizontal location matches the ‘x’ coordinate of the click
  - In Chart mode, the event will be placed on the channel track where the click took place.
  - In Scope mode, the event will be defined on the active channel.
- Within the marker bar, clicks define global events.

When Event Definition is active, the cursor changes to a flag and the cursor includes a downward pointing arrow to indicate where the event will be defined.

The Event Definition tool is disabled in X/Y mode and if events are not visible.

Event Removal “Zap”

Deletes event(s) from a graph with the mouse. It allows for quick editing to eliminate misclassified events found through visual inspection.

- If the user clicks on a single event, that event will be removed from the graph.
- If the user clicks and drags to define a rectangular area (similar to the zoom tool), all events between the left and right edges of the area will be removed; the event icon does not need to lie vertically within the bounded area in order to be removed.

When Event Removal is active, the cursor changes to a lightning bolt.

Jump-to

Data views and advanced analysis output display multiple representations of the same data at the same time. Sometimes this association may be abstract or difficult to visualize. The Jump-to tool is a green arrow, and is available in all display modes and during acquisitions.

Use the “Jump-to” tool to correlate data.

- Click the Jump tool on a data point to “jump”all of the open data views for that graph to the same time.
- Click the Jump tool on a point in an X/Y plot to jump data views in chart or scope mode to the point in time corresponding to the point in the X/Y plot. This can be useful for correlating PV loops back to other acquired signals.
- Rate analysis output graphs will jump back to the corresponding point of source data at the start of that cycle.
- Clustering scatterplots will select the appropriate segment of the source graph corresponding to the chosen data point.
- Change the active segment in Stacked Plot mode; once a trace is selected the display will adjust to show the new active segment.

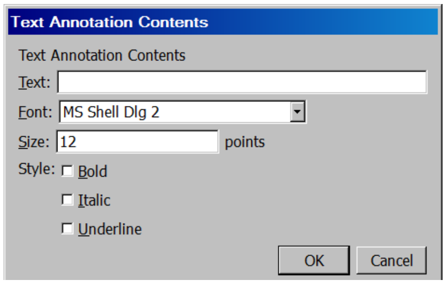
Text Annotation

Use Text Annotation to add floating text notes on top of data in a graph; the text notes move and scale with the data. During report or figure preparation, it is nice to be able to add additional textual information on top of signals to help clarify signals for readers or draw their attention to particular areas of visual interest. Acq*Knowledge* provides a text annotation facility to assist in figure preparation.

Click the *A* icon and then click in the graph window to generate the Text Annotation Contents dialog. Drag the red “handles” from the annotated text to add connector lines to

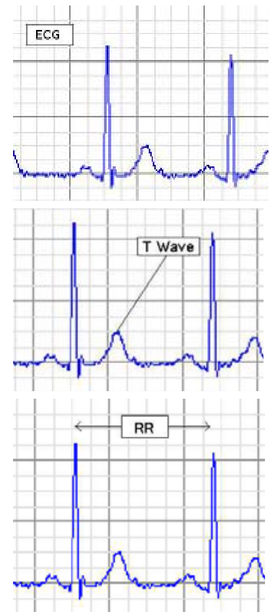
CURSOR TOOLBAR

connect the text to the data.

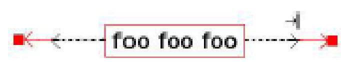


Text Annotation

continued

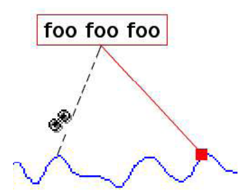


Connector handles

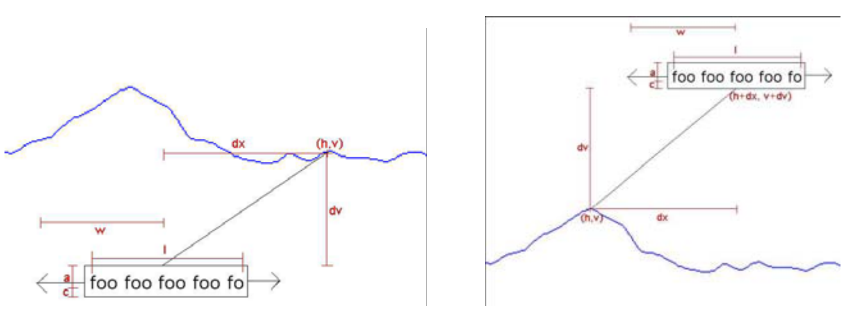


Resize a range

Add a range



Move a connector



Text annotations are short pieces of text that float above channel data and can be used to draw visual attention to particular areas of interest in a graph. These text annotations can be simple outlined text, can have a connector from the outline boundary to a specific sample point on the waveform, or have a range indicator of a specific width. Each text annotation is tied to a sample of data in a channel; when the data is moved by coping, pasting, or other waveform editing operations, text annotations remain fixed to their corresponding sample

CURSOR TOOLBAR

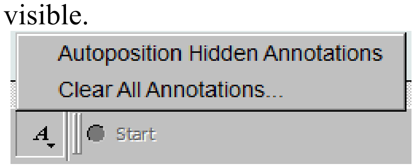
positions, similar to channel events.

Although text annotations are tied to horizontal locations like events/markers, they are displayed in a relative fashion. The relative pixel distance between the text annotation outline boundary and the sample of data remains the same under zoom and autoscaling operations.

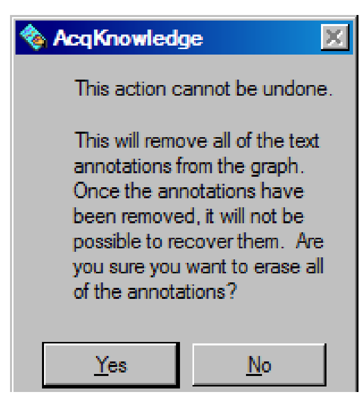
- For example, an annotation that is 20 pixels above a T-Wave peak position will continue to be drawn 20 pixels above regardless of zoom. This allows for flexible data viewing while maintaining text annotation visibility.

Text annotation controls

Create	Insert using the text annotation cursor tool. With the tool active, click in the graph to define a new annotation.
Select	Click an annotation once to select it.
Reposition	Drag a selected annotation to reposition it.
Add Connector	Connectors or range indicators can be added to selected annotations by using the editing handles on the edges of the selected annotation.
Edit Connector	If the selected annotation has a connector to a data point of the graph, an editing handle will appear on the end of the connector. The connector can be moved to a different data sample of the graph by dragging the editing handle on the end of the connector to the new position in the channel. To remove the connector, grab the editing handle on the end of the connector and drag the mouse inside the text annotation.
Range Indicator	If the selected annotation has a range indicator, editing handles will appear at both ends of the range indicator. To resize the range indicator, grab an editing handle and move the mouse. To remove the range indicator, grab an editing handle and move the mouse back inside the text annotation.
Autoposition	Resizing windows or adding channels may reposition text annotations outside of the visible area. Click and hold down the text annotation tool to activate the text annotation popup menu. The “Autoposition Hidden Annotations” option automatically repositions all annotations so they are visible.



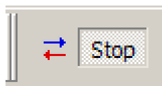
Clear all	Click and hold down the text annotation tool to activate the text annotation popup menu. The “Clear all annotations” option will clear all annotations. This action cannot be undone so you will be prompted to confirm your selection:



Selection palette

Many of the tools within the Acq*Knowledge* environment are based around the selection. The selected range of data in the graph is used as the source for measurements, waveform editing, transformations, and other operations. The Selection Palette is a floating dialog that can be used to precisely enter the selection. See page 413 for Selction Palette guidelines.

Start/Stop toolbar

toggles to


Channel Number Toolbar

Toggles the display of channel number and label region. The Channel Number toolbar reverts to the default location when a file is opened (position is not retained).

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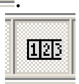
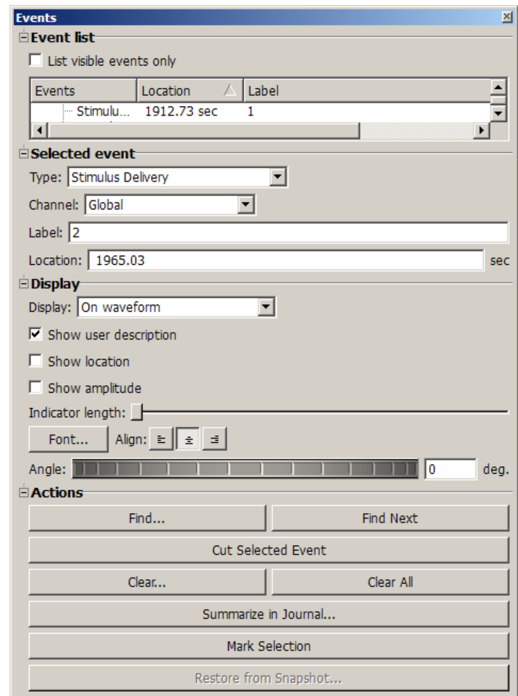
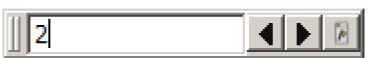
Also functional through the  Toolbar icon.

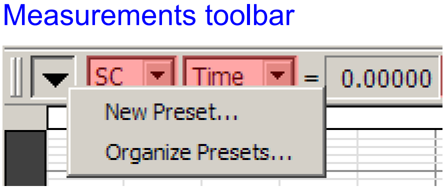


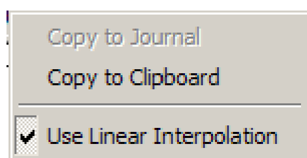
Events toolbar



Select a marker to enable the toolbar. Use the arrows to move forward or backward through all event marker types. Click the event palette icon to generate the event palette.

Measurements toolbar



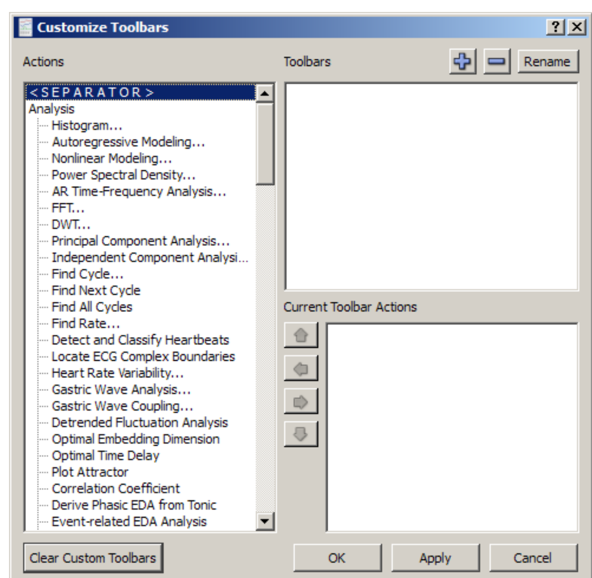


Click the down arrow for quick access to measurement preset functions. Right-click in the measurement bar for quick access to options for copying measurement and using linear interpolation. The Measurements toolbar reverts to the default location when a file is opened (position is not retained).

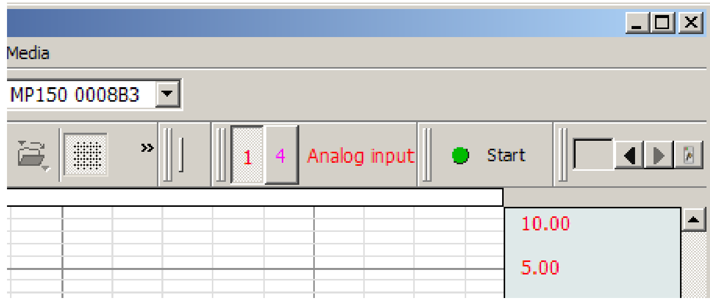
Custom toolbars for transformations and analysis

Acq*Knowledge* 4.1 and above allows users to construct new toolbars for triggering transformations and analysis. An arbitrary number of toolbars may be created and populated with buttons that can trigger any menu item in the Transform and Analysis menus. The contents of the text-only buttons match the menu item title. These toolbars will persist for each user and their positions and visibility within the graph window will be retained.

 Transformation toolbars may be accessed via the "Customize Toolbars" button next to the rewind button.

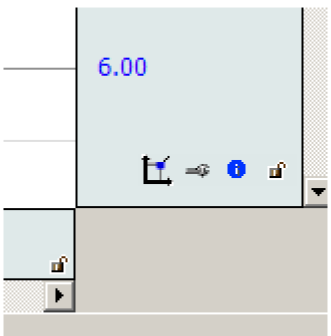


Toolbar position retention and changes

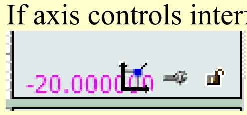


In Acq*Knowledge* 4.1, toolbars can be rearranged within the graph window or detached and turned into floating tool windows. Any modifications made by the user to the position of most toolbars within the graph window will be stored as an application preference and used for new graph windows as they are created and graph files that are opened from disk; however, toolbars for Measurements, Channel number, and Hardware will revert to the default location when a file is opened (position is not retained). Default toolbar positions have changed to move the Start button and cursor tools to the top of the graph window; users preferring the ordering in previous versions may manually reposition the toolbars. **Toolbar Tooltips** may be deactivated when toolbars are detached from a graph.

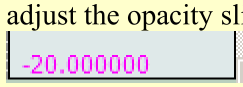
Axis Controls



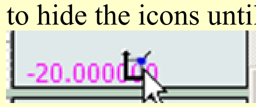
If axis controls interfere with scale values,



adjust the opacity slider in Preferences > Graph



to hide the icons until the cursor passes over them



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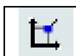
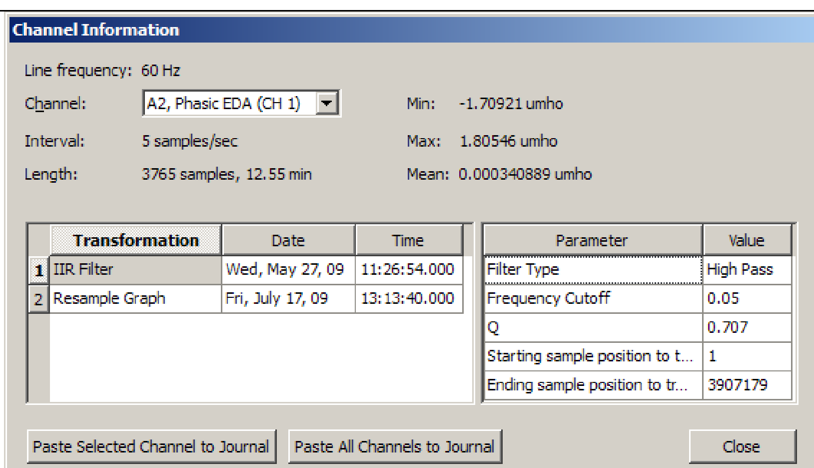
<table>
<tr><td></td><td>A “scaling” button acts as a shortcut for opening the grid and visible range dialog, similar to double-clicking the axis. If a channel corresponds to an analog channel that has calibration steps, a calibration wrench button be displayed and will open the hardware calibration dialogs. This allows visual access to commonly used operations for channels.</td></tr>
<tr><td></td><td>Module dependent: Generate the scaling or calibration dialogs for the channel input or calucation. Analog inputs will open to the scaling dialog and and channels that require calibration will initiate a repeat calibration routine.</td></tr>
<tr><td></td><td>

Use Display > Channel Info or use the channel’s contextual menu to display the Channel Information.</td></tr>
<tr><td></td><td>Toggle the lock icon at the right edge of the window to change the lock state of the grid for horizontal axis or the channel. Uncloked is open (latch to right); locked is closed.</td></tr>
</table>

Enable cursor tools during acquisitions

Enables access to cursor tools while recordings are in progress. (Acq*Knowledge* 4.2 and higher only, Display > Preferences > Graph)

Button Transparency

Scaling, calibration, transformation history, and grid lock buttons may be made semi-transparent to allow units, axis values, and other information underneath the buttons to remain visible. The Preferences > Graph panel includes an “Axis controls” slider to change drawing from fully transparent to fully opaque.

When the mouse is within the buttons, they will be drawn fully opaque regardless of transparency setting. The transparency is shared by the scaling, calibration, transformation history, and grid lock buttons and is the same for all open graphs as this is an application-level preference.

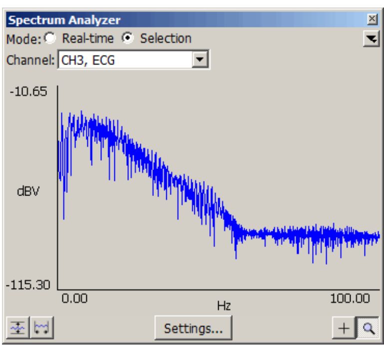
Customizable Chart Track Dividers

Starting with Acq*Knowledge* 4.1, users may change the color used to draw the dividers between channels tracks The Preferences > Graph panel contains "Chart Track Divider Appearance" options.

Plotting Background Colors

Starting with Acq*Knowledge* 4.2, customizable background colors for individual graph channels are available in Preferences > Graph > Plotting Background Colors.

Spectrum Analyzer Palette



The Spectrum Analyzier Palette provides a dynamic display of the frequency decomposition of data, in real time or post-acquisition.

See page 416 for details.

Keyboard shortcuts

Menu Option	Windows OS	Mac OS X
Program info	Help > About Acq*Knowledge*	Acq*Knowledge* menu
Quit	Ctrl + Q	⌘ Q
Hide Acq*Knowledge*	minimize (corner box)	⌘ H
File menu		
New	Ctrl + N	⌘ N
Open	Ctrl + O	⌘ O
Open for Playback		
Close	Ctrl + W	⌘ W Alt+left-click to close all
Save	Ctrl + S	⌘ S
Save As		
Save Selection As		
Save Journal Text As		
Send E-Mail Attachment		
Page Setup		
Print	Ctrl + P	⌘ P
Quit	Ctrl + Q	
Edit menu		
Undo (when applicable)	Ctrl + Z	⌘ Z
Cut	Ctrl + X	⌘ X
Copy	Ctrl + C	⌘ C
Paste	Ctrl + V	⌘ V
Clear (journal)	Delete key	none
Clear All		
Remove Last Appended Segment	Use the Rewind toolbar icon	
Insert Waveform		
Duplicate Waveform	Ctrl + D	⌘ D
Select All	Ctrl + A	⌘ A
Remove Waveform		
Create Data Snapshot		
Merge Graphs		
Clipboard > Copy Measurements > Copy Wave Data > Copy Graph > Copy Acquisition Settings > Copy Data Modification History for All Channels > Copy Data Modification History for Selected Channels	 Ctrl + K Ctrl + L Ctrl + U	

Menu Option	Windows OS	Mac OS X
Journal > Paste Measurements > Paste Wave Data > Paste Graph > Paste Acqusition Settings > Paste Modification History for All Channels > Paste Modification History for Selected Channels > Show Journal	 Ctrl + M Ctrl + / Ctrl + J	 ⌘ M
Transform Menu		
Recently Used		
Digital Filters		
Fourier Linear Combiners		
Math Functions		
Template Functions		
Integral		
Derivative		
Integrate		
Smoothing		
Difference		
Resample Waveform		
Resample Graph		
Expression		
Delay		
Rescale		
Waveform Math		
Analysis menu		
Find Cycle	Ctrl-F	⌘ F
Find Next Cycle	Ctrl-E	⌘ E
Find All Cycles	Ctrl-R	⌘ R
Find Rate	none	none
Display menu		
Tile Waveforms Autoscale Waveforms Overlap Waveforms Compare Waveforms Autoscale Horizontal	 Ctrl+Y Ctrl+H	
Zoom Back Zoom Forward	Ctrl + - (minus key) Ctrl + = (equal key)	⌘ - ⌘ +
Reset Chart Display		

Menu Option	Windows OS	Mac OS X
Reset Grid Adjust Grid Spacing Set Wave Positions Wave Color Horizontal Axis Show Customize Toolbars Channel Info Preferences Size Window Cursor Style Create Data View Organize Data Snapshots Show All Data Snapshots Load All Data Into Memory		
M150 menu		
Set Up Channels	Ctrl +]	
Set Up Acquistion	Ctrl + [	
Set Up Advanced Averaging	Not supported in Acq*Knowledge* 4.0. Supported in 4.1.1 and 4.2	
SetUp Triggering		
Set Up Stimulator		
Set Up Sound Feedback		
Set Up Manual Insertion Hotkeys		
Set Up Segment Labels		
Show Input Vales		
Show Manual Control		
Show Gauge		
Select MP150		⌘ T
MP150 Info	Ctrl + T	
Update Firmware		
Autoplotting		
Scrolling		
Warn On Overwrite		
Organize Channel Presets		
B-Alert Headset Check Impedance	*Licensed functionality*	
B-Alert Headset AMP Baseline	*Licensed functionality*	
B-Alert Headset Brain State Gauges	*Licensed functionality*	
Check for Hardware		
Exit Playback Mode		
Start/Stop Acquisition	Ctrl + spacebar	Ctrl + spacebar
Delete recorded data Delete all recorded data, similar to the Append "Reset" button.	Ctrl+Rewind button	Option+Rewind button
Window menu Bring All to Front		

Menu Option	Windows OS	Mac OS X
Help Application Notes from Web Open Acq*Knowledge* Manual Open MP Hardware Guide Open Acq*Knowledge* Tutorial About Acq*Knowledge*		
Cursors I-beam Arrow (pointer) Zoom Grid Event Jump to Annotation	 Ctrl-I Ctrl-B Ctrl-G	 ⌘ I ⌘ B ⌘ G
Horizontal Scroll Location	In chart, scope, or stacked plot mode (i.e., all but X/Y) these keyboard shortcuts can be used to scroll to various parts of the graph.	
Home	Jumps to t = 0 (i.e., places first sample of data flush with left of graph window)	
End	Jumps to the end of the currently selected waveform (i.e., places last sample of data of the selected waveform flush with right of graph window)	
Page Up	Scrolls backward in time one full screen (i.e., places leftmost sample of previous visible area at the right of the new visible area).	
Page Down	Scrolls forward in time one full screen (i.e., places rightmost sample of previous visible area at the left of the new visible area).	

Mouse Controls

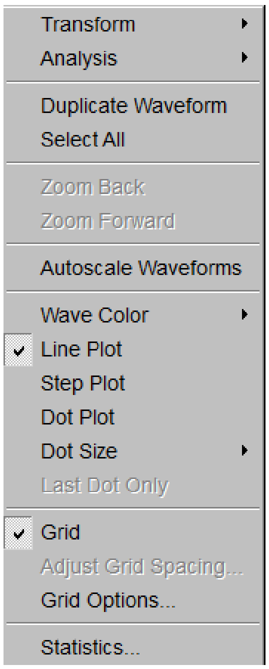
Contextual menu items correspond to the Acq*Knowledge* main menu state.

Application menu customization has a corresponding effect on contextual menu display. If a contextual menu item does not have a corresponding application menu item, the menu customization file identifier will begin with "IDM_CM."

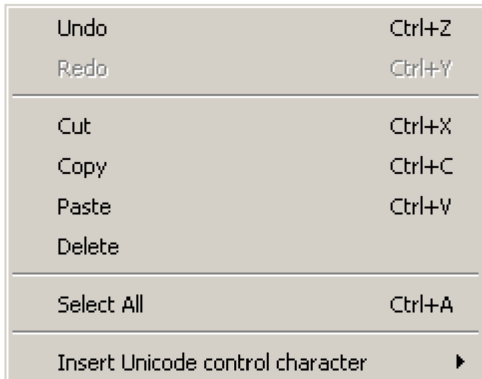
The following options can be accessed with a right-click for Windows or Control-click for Mac.

- *Mac OS X only*: If the mouse is over a portion of the graph that has a context menu available, the cursor will change to an arrow with a menu.

Graph window

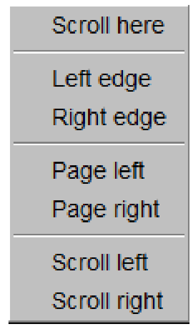


Journal window



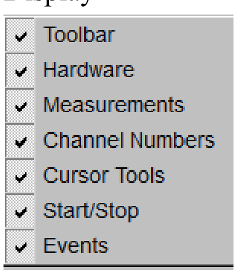
Unicode is the encoding standard used to insert control characters from keyboards for languages that use 2 byte characters.

Horizontal Scroll

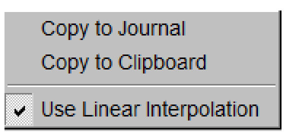


Vertical Scroll

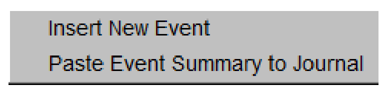
Display



Measurements



Events



Mouse Scrollwheel Support

The scrollwheel operates on whatever window is underneath the mouse; this window does not need to be the topmost window. Many third-party mice include scrollwheels, scrolling balls, or trackpads to allow for quick access to navigating through a document. Mice may provide two separate controls, one for scrolling vertically and one for scrolling horizontally.

Acq*Knowledge* supports horizontal and vertical scrolling using the scrollwheels on the mouse. Scrolling is supported in graph windows, journal windows, the event list in the event palette, and a number of other dialogs and windows that contain scrollable lists. A dynamic zoom operation can easily be performed in an Acq*Knowledge* graph channel by holding down the Ctrl key (PC) or the Option key (Mac). Scroll 'up' to zoom in and 'down' to zoom out. (Zoom operation supported in Acq*Knowledge* 4.2 and higher)

- Mac OS X: To increase the scroll speed, hold down the "Option" key while using the scrollwheel.

Transformation history

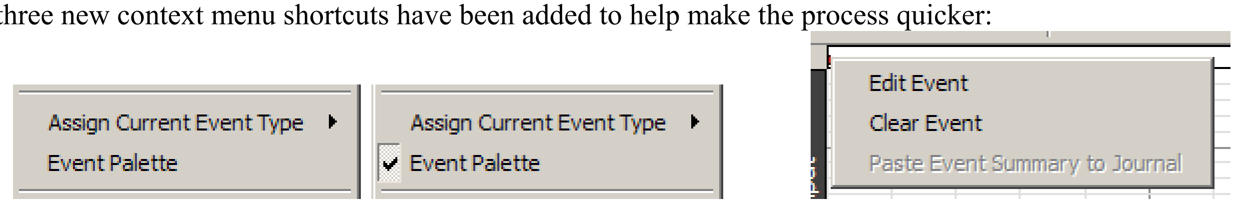
The transformation history functionality in Acq*Knowledge* 4.1 and higher provides the ability to track transformations that are performed on channel data. This gives a visual indicator of whether transformations have been applied to a channel and a record of the sequence of transformations and the parameters for the transformation. The history for the channel is viewed in the "Channel Info..." dialog. This dialog is accessible via the Channel Info option of the context menu or the Display > Channel Info menu item. This dialog replaces the "Statistics" dialog used in earlier versions.

Cancelling Transformations & Transformation Progress Bar

In Acq*Knowledge* 4.1 and higher, transformation cancel support has been restored to the software to offer Cancel buttons in progress dialogs that indicate the completion status of threaded transformations. Progress dialogs have also been enhanced so the textual message includes a graphical progress bar with the percentage that is completed. If the progress message does not contain a percentage, an indeterminate progress bar will be displayed.

Acq*Knowledge* 4.1 and higher extends the analysis package to display dialogs while analysis routines are in progress. This progress dialog contains a cancel button which may be used to terminate the analysis before it is complete.

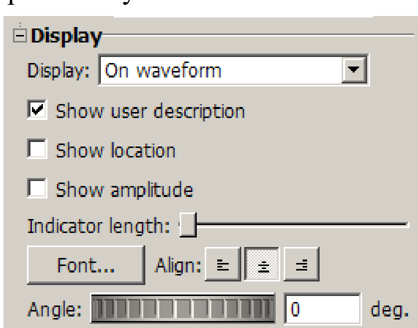
The event tool allows events to be inserted on a graph with the mouse. When performing event editing, three new context menu shortcuts have been added to help make the process quicker:



- Assign Current Event Type: Right-click an area with no data to set the type of event that will be inserted on the next left-click of the mouse.
- Event Palette: Toggles event palette displays.
- Edit event: Right-click a specific event to open the event palette to Selected Event controls for the event that was right-clicked.

Typed event label drawing improvements

Starting with Acq*Knowledge* 4.1, the Event system has been enhanced to allow different drawing options for channel-specific events when they are drawn in the data plotting area. These drawing options are applied to event labels, event amplitude markings, and event time location text. The following drawing options may be customized:



- Font (including family, size, italic/bold, and other options)
- Rotation angle of text baseline
- Text alignment (left, center, right)

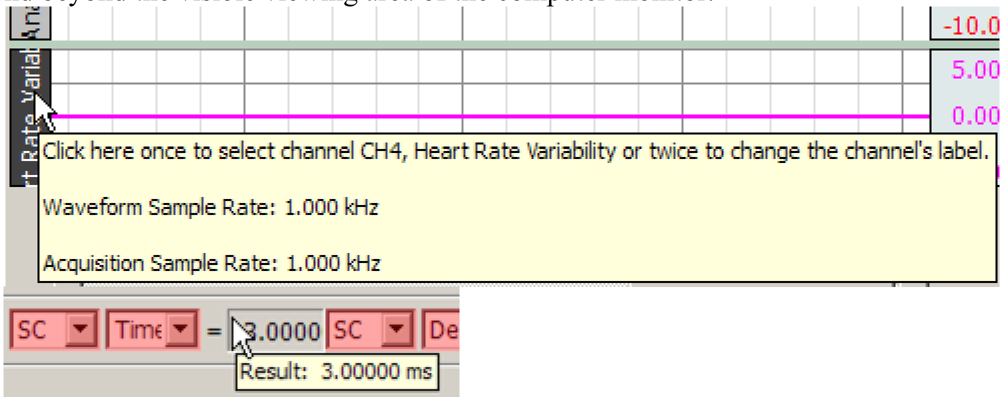
Choose MP150 Help Button

A Help button is available in the "Choose MP150" dialog that appears when the application is attempting to locate an MP150, either on initial application installation or on communications errors. The Help button opens a "Troubleshooting MP150 Communications.pdf" document from the application's User Support System. This troubleshooting guide provides common information from Technical Support for decoding the network blink states of the MP150 and other steps to take to troubleshoot why the MP150 and computer cannot communicate properly.

Tooltips

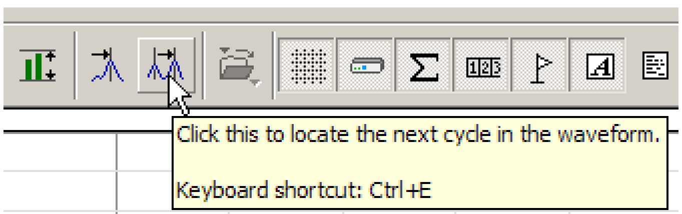
Channel label and units length and tooltips

Starting with Acq*Knowledge* 4.1, character length limitations for channel label and units have been expanded: labels may now be up to 1032 characters and units may be up to 511 characters. Tooltips have been added to display the full channel units when the vertical axis is moused over. Tool tips do not wrap, so long labels may extend beyond the visible viewing area of the computer monitor.



Graph window tooltip improvements

Several of the toolbar buttons and the Start/Stop button in the graph window are associated with keyboard shortcuts that may be used instead of the buttons. Tooltips for these toolbar buttons display the corresponding keyboard shortcuts. **Toolbar Tooltips** may be deactivated when toolbars are detached from a graph.



Menu item tooltips

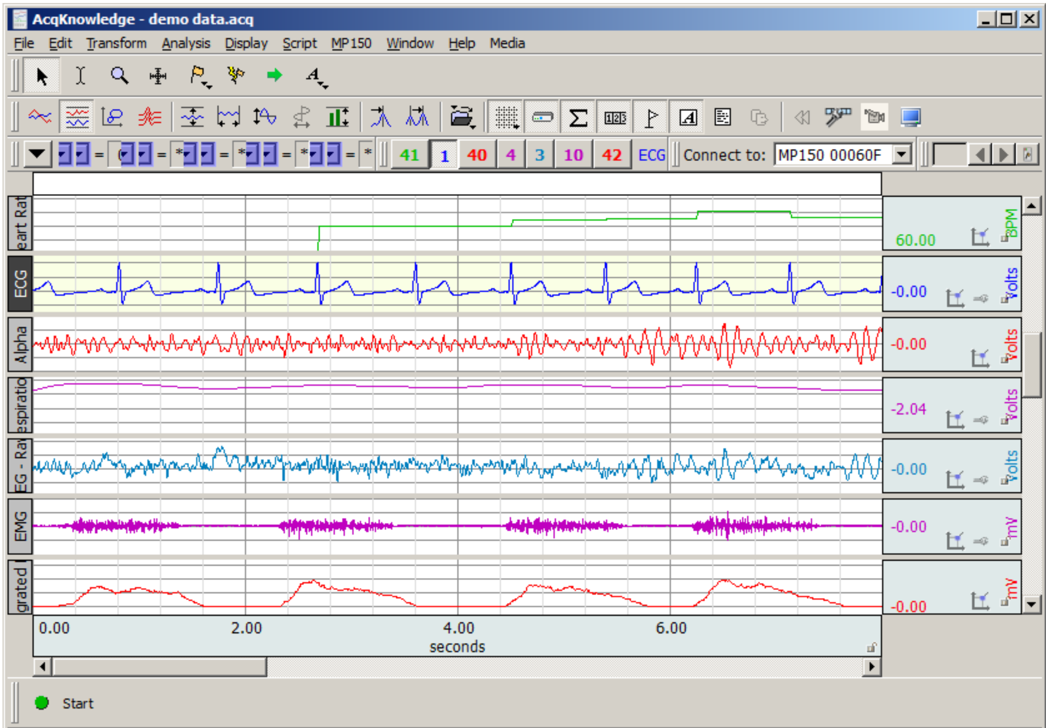
Starting with Acq*Knowledge* 4.1, menu item tooltips will display informational text about how menu items may be used. (Similar text was displayed in earlier versions of Acq*Knowledge* for Windows in the status area and in earlier versions of Acq*Knowledge* for Mac as Balloon Help). Analysis menu tooltips have been expanded to provide more detail regarding the types of analysis that are performed by the selected item.

Chapter 4 Editing and Analysis Features

Overview

This section provides a brief overview of some of the most frequently used Acq*Knowledge* features and functions. For more detailed information about specific features, turn to Chapters 9 through 13.

If you are not currently running Acq*Knowledge,* double click the Acq*Knowledge* icon to start it. Choose Open from the File menu and select the file called “demo data.acq”. Your screen should look like this:



Edit menu functionality during acquisition

The following Edit menu functions may move or alter memory and cannot be performed during acquisition: Undo, Cut, Clear, Clear All, Paste, Insert Waveform, Duplicate waveform, and Remove Waveform.

Scroll bars

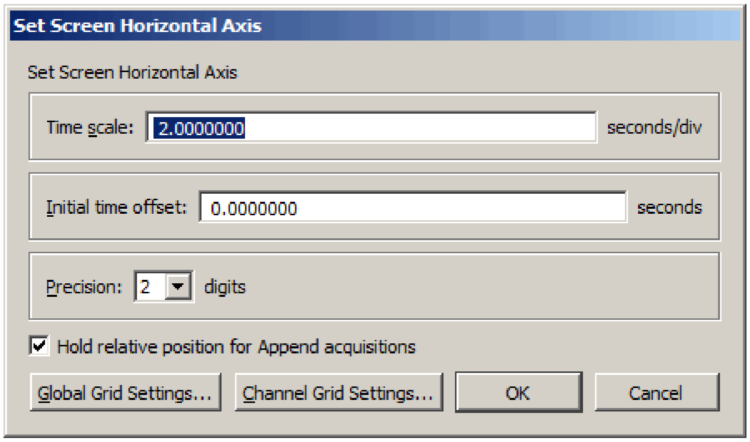
As you can see, there are four channels of data in this file (Heart Rate, ECG, EEG, Resp, EMG Raw, EMG, Integrated EMG). Although this record is 30 seconds long, only a few seconds are displayed on the screen at one time. You can move to different locations in the record by moving the scroll box at the bottom of the screen. Dragging the box left moves you to earlier points in time, and moving right displays events closer to the end of the record. Clicking on the arrows at either end of the horizontal scroll bar allows you to move to different points in time at smaller increments.

A vertical scroll bar is on the right side of the screen, and. If you click the scroll arrow at the top of the box, you’ll see that one waveform appears to move down within its “track” on the screen. Moving this scroll box changes the amplitude offset of a selected channel. As with the horizontal scroll bar, you may either move the box or click the arrows.

Scaling

Horizontal axis

Click the horizontal scale (above the scroll bar) to generate a dialog where values can be entered for units per division and horizontal scale offset.



Time Scale

The time interval (units per division) between the on-screen grid marks. There are four vertical divisions per screen, and the default is 2.00 seconds per division, so eight seconds of data will be displayed on the screen display. Entering a larger value will display more of the record, and entering a smaller value will display less.

Initial offset

The time corresponding with the first data point displayed. For example, to display the middle 1/3 of the data file (assuming the record is 30 seconds long), set the offset to 10 seconds and the seconds per division to 2.5 seconds.

Precision

Controls number of decimal places following whole units appearing in the horizontal axis.

Hold Relative Position for Append acquisitions

This option is available in Acq*Knowledge* 4.2 and higher, and active only in **Append** acquisition mode. When checked, the display for appended acquisitions will show the same relative position with respect to the start of acquisition. This is convenient when doing short-duration; high-speed acquisitions where you want to be able to zoom in on the signal of interest and have the relative position (from the start of acquisition) stay the same. If the acquisition is started with the horizontal scale such that it falls between acquisition segments, this feature is not implemented.

When **Hold relative position** is checked; after zooming in on a section of data that has been selected (highlighted) and is completely within one appended segment, the scale of the selected area changes with each appended segment such that it remains relative to the start of acquisition for that segment and updates the measurements. If the selected data area falls within two or more appended segments, this feature is not implemented.

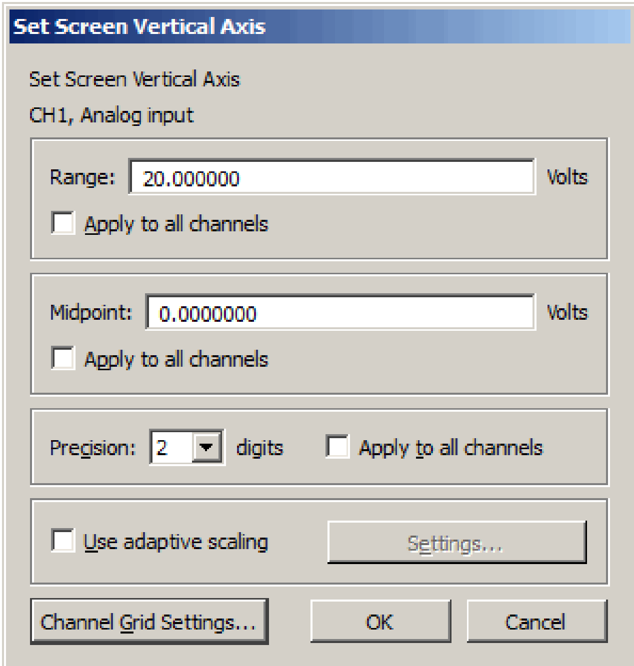
Global Grid Settings

Opens dialog for applying master grid settings for all channels. For more details, see Grids on page 75.

Channel Grid Settings

Opens dialog for selectively applying grid settings to one or more channels. For more details, see Grids on page 75.

Vertical (Amplitude) axis



Clicking the mouse in the vertical scale area (where the amplitude of each channel is displayed) generates the Set Screen Vertical Axis dialog, where values can be entered for units per divison and vertical scale offset.

Scale

Determines the limits of the viewable vertical axis scale (usually Volts). Acq*Knowledge* divides each channel into four vertical divisions. When data is displayed in chart mode, each "track" is divided into four divisions. When data is displayed in scope mode (or if there is only one channel of data) the entire screen is divided into four intervals. To increase the apparent amplitude for a given channel, set this value to a smaller number; entering a larger number will cause the waveform to appear to have less variability.

Midpoint

Refers to median displayed value for a particular channel. A checkbox to the left of each of these options allows you to apply these scaling options to all channels. By default, the scaling options you choose will only apply to the channel indicated in the dialog. If you want to apply these to all channels, click all the checkboxes.

Precision

Controls number of decimal places following whole units appearing in the vertical axis. Can be applied to selected or all channels.

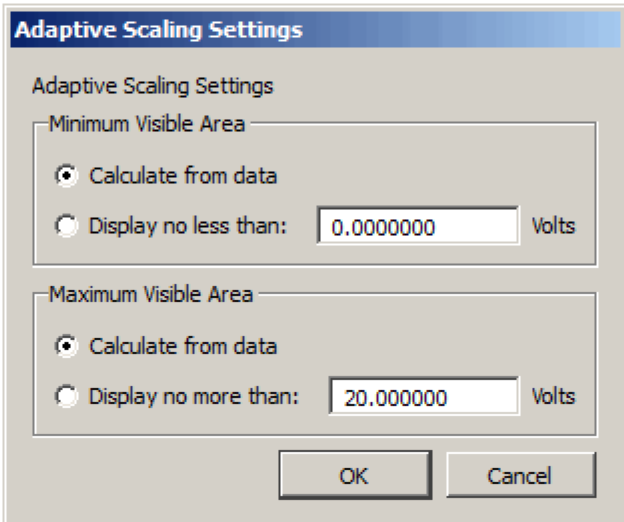
Apply to all channels

Applies settings selected in the various dialog options to all channels.

Adaptive Scaling

Adaptive scaling uses the data to automatically determine the appropriate visible range for the data. As the data changes or the baseline shifts, the visible area shifts along with the data to ensure that data will always be plotted on the screen. Rather than limiting data visibility to a fixed voltage range, the range adjusts for factors such as background noise, electrode movement, EMG interference, disconnection, etc.

Adaptive scaling can be applied to channels individually and can be unique for each Data View. A "settings" button is activated when to "Use adaptive scaling" is enabled.



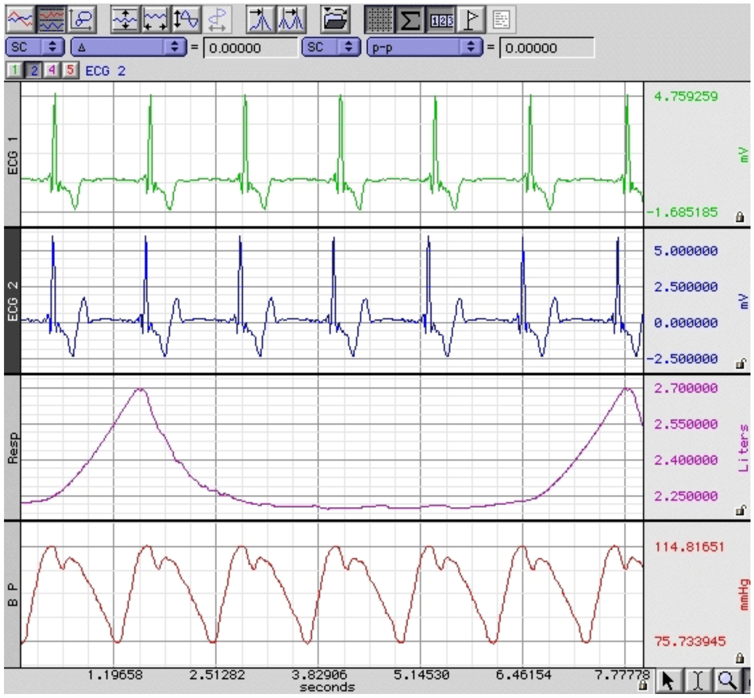
Scaling changes will be applied whenever the domain of the plot area is changed. This includes manual changes to the horizontal scale, horizontal scrollbar use, horizontal auto-scrolling when dragging out a selected area, auto-scrolling or auto-plotting during acquisition, initial enabling of adaptive scaling and auto-scrolling when executing Find Cycle/Peak functions.

Channel Grid Settings

Opens dialog for selectively applying grid settings to one or more channels. For more information, see Grid Details on page 75.

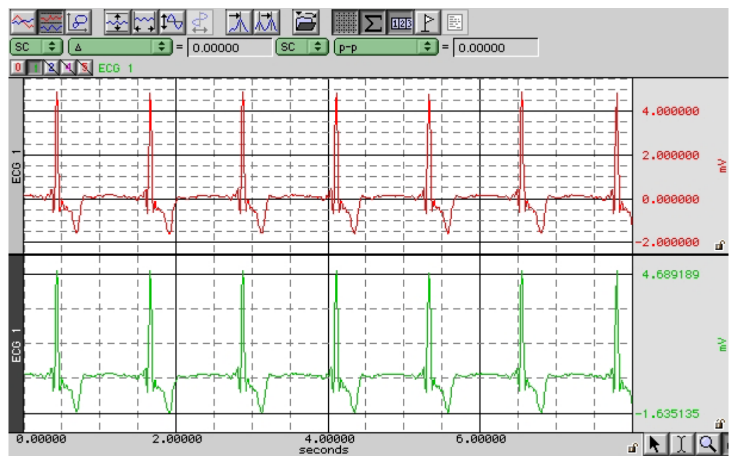
Grid Details

You can customize the grid behind the waveforms displayed in graph windows in a number of ways.



Grid Lock/Unlock

Each scale has a small padlock in the lower right hand corner that displays the current state of the grid lock for that axis and channel. Click the padlock to change the lock state.



-  Unlocked grid—the number of grid lines and their pixel spacing on screen is kept constant through zoom and scaling operations
-  Locked grid—the grid lines themselves are maintained at constant values through zoom operations, e.g. a grid line which is located at .753 volts when the grid is locked will continue to be located at .753 volts regardless of changes in scale.

Grids can be locked and unlocked on individual channels.

- The lock for the horizontal axis is shared by all channels.
- The vertical scale can be locked and unlocked independently.

The lock state of the grid can also be changed through the axis dialogs displayed when the mouse is clicked on the axis scale values in the graph window.

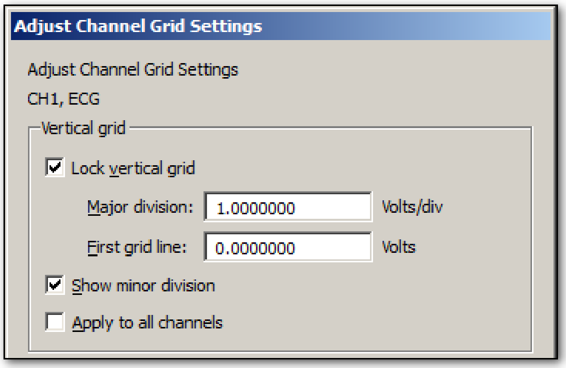
- Click the “Lock units/div” checkboxes.

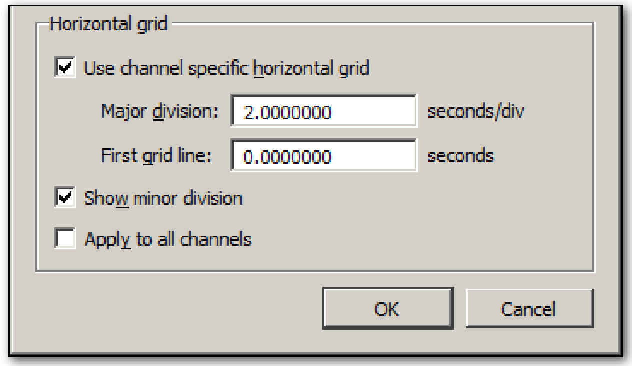
NOTE: All grid screenshots are from Acq*Knowledge* 4.2.

Grid Scaling

When the grid is locked, the scaling factors controlling how much data is visible on the screen (the distance between consecutive major lines of the grid and a fixed location for one of the lines of the grid) are specified differently. When the grid is unlocked, these scaling factors do not affect the grid.

The Grid Spacing option specifies the scaling factors and whether or not to "Show minor divisions" on the grid display. Changing these values only affects the grid display, not how the waveform is scaled.





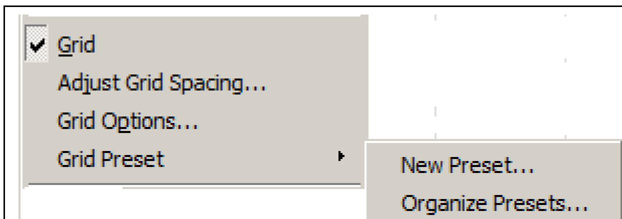
- Vertical grid: the total range of vertical units displayed per track is specified (Major division) along with the first value that should be displayed (First grid line).
- Horizontal grid: the scaling factors are specified in how many seconds of data should be visible on the screen (Major division) and the time offset of the left hand side of the display (First grid line).
- Settings can be applied to a selected channel or all channels. (Controlled by checking or unchecking 'Apply to all channels").

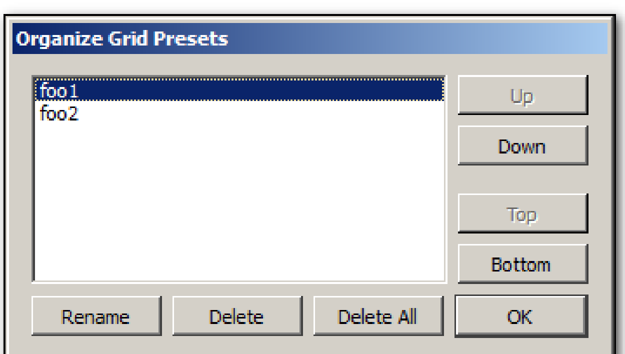
Adjust Grid Spacing

To modify the horizontal and/or vertical grid spacing, choose "Display > Adjust grid spacing." This will generate the aforementioned dialog for modifying the locked axes of the selected waveform. ("Lock vertical grid" and "Use channel specific horizontal grid" must be enabled in order for the gridline fields to become active). Enter the desired values and click OK.

- Settings can be applied to a selected channel or all channels. (Controlled by checking or unchecking 'Apply to all channels").

The following Grid items can also be selected by right clicking with a graph channel and using the contextual menu.



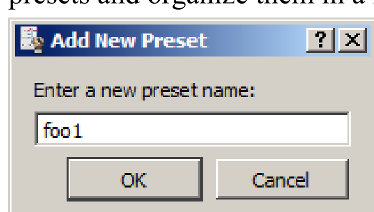


Grid: Toggles Grid display on and off.

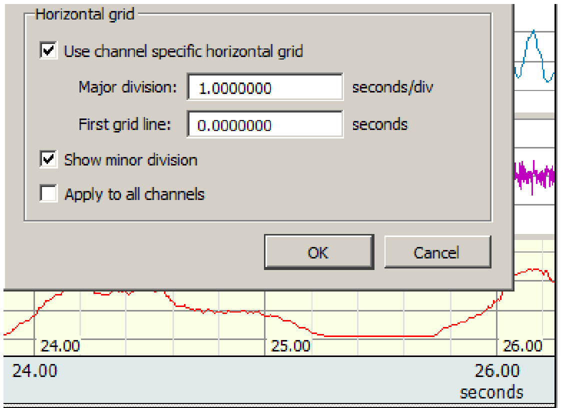
Adjust grid spacing: Use to change Grid spacing for one or all channels (divisions between gridlines and position).

Grid Options: Use to change Grid display for one or all channels (Color, width, style, dash length, dash spacing, and scale adjustment position).

Grid Preset: Use to create /save custom Grid presets and organize them in a list. (left)

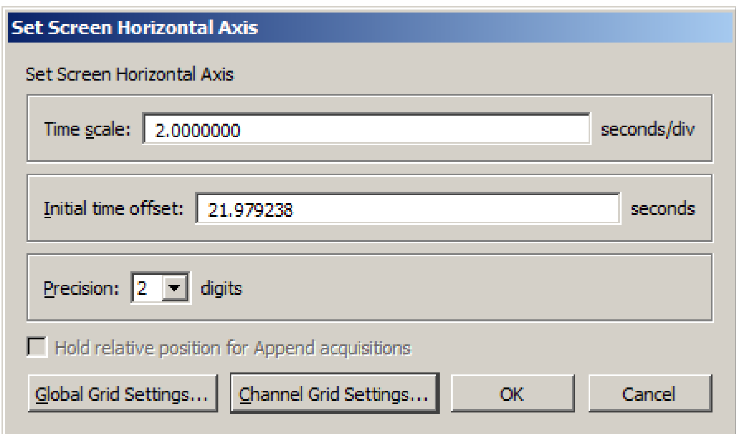


Example of channel specific horizontal grid



Note in figure on left, the horizontal time scale division is one second per division in the graph channel, but two seconds per division in the horizontal axis. (Green bar area)

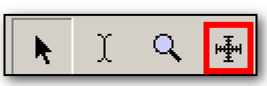
Horizontal Axis Grid Controls



- **Global Grid Settings**: Brings up dialog specifying grid settings used in the shared Horizontal Axis of the graph.
- **Channel Grid Settings**: Brings up the 'Adjust grid spacing dialog' referred to on previous page.

Individual channel-specific grid settings take priority over the Global Grid Settings. If no channel-specific grid setting exists, the Global settings are applied.

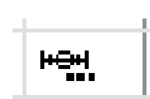
Grid Tool



The Grid Tool allows divisions of the grid to be specified with the mouse. This tool has four states:

Ø	Inactive	The cursor changes to a circle with a line running through it. The grid cannot be adjusted since both the horizontal and vertical axes are unlocked.
	Horizontal axis locked	The cursor changes to a horizontal line. A mouse click and drag will change the location of the horizontal lines of the grid.
	Vertical axis locked	The cursor changes to a vertical line. The tool can be used to adjust the vertical spacing of the grid.
	Both axes locked	The cursor changes to a crosshair. The rectangle of a full grid division can be drawn over the data. Adjust the spacing of locked grid lines underneath the waveform.

If the "Alt" (PC) or "Option" key (Mac) is held down for the Grid Tool in any of the active modes, an ellipsis will appear under the cursor. After a mouse click or drag, a Grid Settings dialog will be generated. This dialog is functionally similar to the grid dialogs accessible via the axis settings dialogs.



- Based on lock status, the dialog will allow you to adjust Horizontal, Vertical or combined settings.
- The values displayed in the dialog correspond to the grid ranges that were just drawn out on the screen with the grid tool if a mouse drag occurred.
- If the mouse was simply clicked, the current grid settings are displayed.
- This dialog allows the grid drawn out with the grid tool to be made more precise.

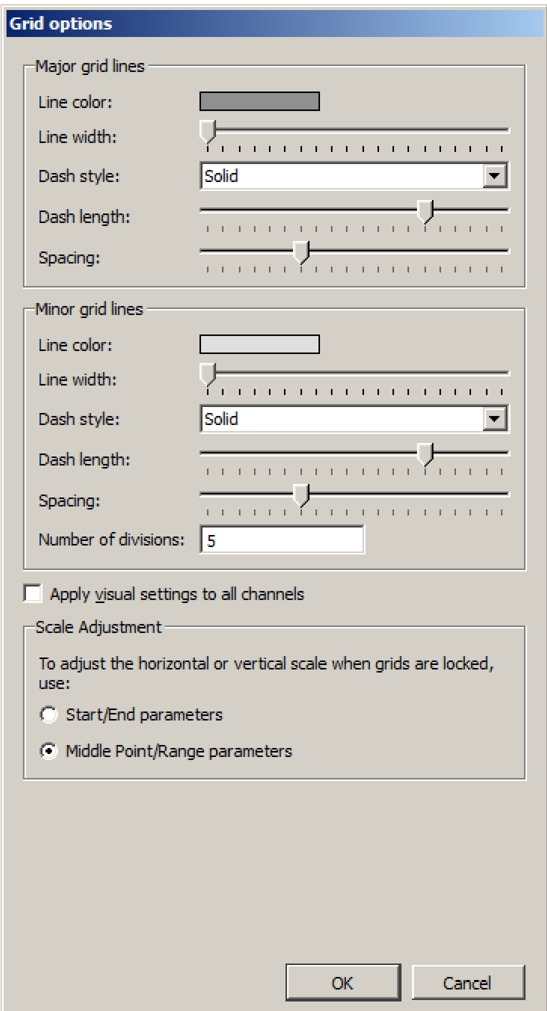
Grid Reset

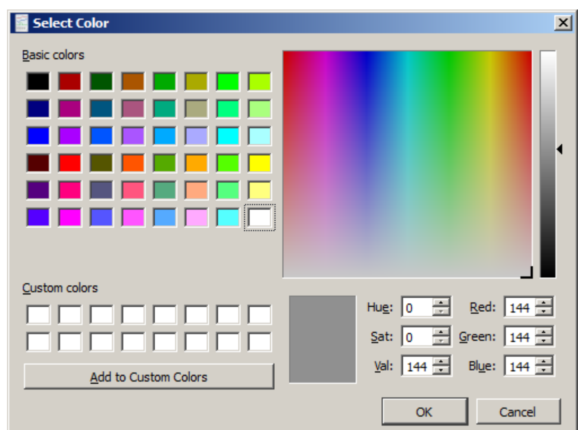
To return to the original grid, choose “Display > Reset grid.”

This will reconstruct the default, unlocked grid of four divisions per screen with solid light gray grid lines.

Grid Options

The major and minor grid lines can be further customized with spacing, number of divisions, an different colors and dashing styles. These are modified under the dialog generated via Display > Show > Grid options.





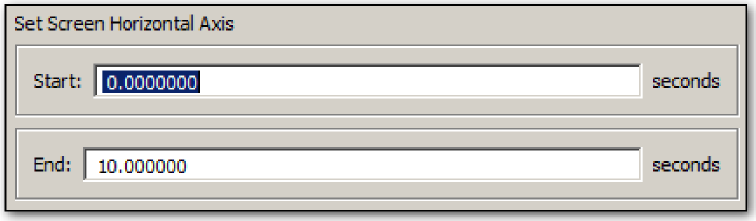
Line color	Click the color well to generate a color chooser.
Line width	Adjust the corresponding slider.
Dash style	Select a style (solid or broken) from the pop-up menu.
Dash length	Adjust the corresponding slider (for any dash mode that is not a solid line).
Spacing	Adjust the corresponding slider (for any dash mode that is not a solid line).
# of Divisions	Enter a value in the text field to set the maximum number of minor grid lines to be displayed in a single major grid division.

Apply visual settings to all channels

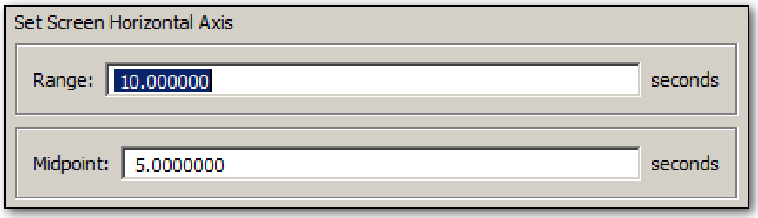
When checked, the visual settings for major and minor grid lines are applied to all channels. When unchecked, the settings will be applied to the selected channel only.

Scale Adjustment

Select whether to use Start/End or Range/Midpoint parameters to determine horizontal and vertical scale adjustments. Applied only when grids are locked.



10 sec. Horizontal Scale adjustment set to 'Start/End' parameters



10 sec. Horizontal Scale set to 'Middle Point/Range' parameters

To undo your selections and return to the original grid, choose "Display > Reset grid." This will reconstruct the default, unlocked grid of four divisions per screen with solid light gray grid lines.

Friendly Grid Scaling

Too much precision can create numbers that are difficult to quickly interpret, so "friendly" grid scaling adjusts the range to the nearest possible whole numbers. For example, it's easier to comprehend 4.1000000 than 4.1427385. Unlocked grids always restrict precision to the minimum needed for a given magnitude. This produces a "friendly" scale that makes it easier to determine the range between the gridlines when data is formatted for display or printing.

With unlocked horizontal grids, the horizontal scale values printed on a graph may not match the horizontal scale values displayed on the application screen. For example, horizontal scale values

Displayed in the application:	0.00000	7.50000	15.00000	22.50000
Printed:	0.00000	7.50125	15.00250	22.50375

The precision will only match when using the "Visible area" print option. With selected area or entire graph options, the precision will not match when grids are unlocked because friendly grid scaling is applied on screen, but is not used during printing where the range is fixed to fill the entire page.

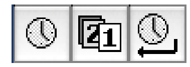
Note that the Zoom tool and vertical autoscale may produce different results. To accommodate the grid precision, the Zoom result may be slightly more than specified in the zoom box. For precise correlation from selected area to result, lock the grids (horizontal and vertical). Precision is not restricted for locked grids or display ranges manually entered in the axis setting dialogs.

Journal Details

To create a journal, select the  icon from the toolbar or choose **File** > **New** > **Graph-Specific Journal** or **Independent Journal**. To toggle the graph-specific journal display, select the  icon from the toolbar. Or after opening a new journal, choose **Edit** > **Journal** > **Show Journal.**

Once a Journal is open, text and data can be entered. To enter text, just begin typing when the journal is open. Acq*Knowledge* will automatically "wrap" the text to fit the screen width.

In addition to File and Edit menus, there are Time Stamp, Date Stamp and Auto Time functions available in the journal window.



- Time and Date stamps refer to the computer's clock to record the time and date, respectively, directly into the Journal.
- Auto Time function records the time at the instant the carriage return is pressed, which is useful for tagging commands as data is collected.

Measurements and data may also be pasted into an open Journal. To paste measurements into an open Journal, select an area and choose "**Paste measurements**" from the **Edit** > **Journal** menu. Paste to Journal functions only work if a Journal is open and vary for each journal type:

- Graph-specific journals can only receive measurements and wave data from their associated graph view
- Independent Journals can receive measurements and wave data from any open graph. Results will be put into both the graph-specific journal and the independent journal. Use Journal Preferences to auto-paste to an independent journal if desired.

Set the Journal Preferences (page 425) to simultaneously record measurement name and units or control Event (marker) paste functionality and detail.

To paste waveform data into a Journal, select an area and choose "**Paste Wave Data**" from the **Edit** > **Journal** menu. Allow several seconds for the text file to be written. The result is a text file of your wave data pasted into your active journal.

TIP: When pasting a graph into a Journal: Pressing the Ctrl key (PC) or the Alt key (Mac) will launch a dialog allowing the image to be resized prior to pasting.

A useful feature of the Journal is that it works in connection with the Cycle/Peak Detector and other measurement functions to paste in values from waveform data for further analysis.

In the example above, the *peak-to-peak* and *delta t* measurements were pasted from the open graph window to the Journal. See the Journal paste section on page 263 for more information on how to paste information to Journal files.

Use **Save as/Open Journal Template** to retain SOP text, or standardize lab/computer details for record keeping.

Rich Journals

The Acq*Knowledge* 4.2 Journal adds powerful rich text editing tools, offering advanced functionality common to most word processing programs. The following toolbar options are available within the Journal window:

- Font family
- Font style: bold, italic, underline
- Paragraph alignment: left, right, center, justify
- Font color

The following items can be pasted or embedded into the Journal text:

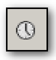
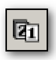
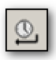
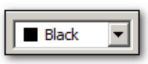
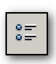
- Images
- Numbered lists
- Bulleted lists
- Tables
- Numerical statistics or expressions

Images must reside within a document in order to be pasted into the Journal. Pasting image files directly from a location such as the Desktop is not currently supported.

Journal Toolbar Buttons

The Journal toolbar controls all formatting functions within the Journal window. Although the settings customized in this toolbar are retained within a saved Journal, global default settings for subsequent Journals are not overridden. To change the global defaults, the overall Journal Preference settings must be modified. (Edit > Journal > Preferences). For more information, see Journal Preferences on page 425.

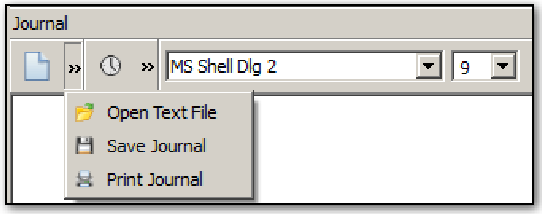
A full explanation of all Journal toolbar buttons appears on the following page.

Journal Toolbar Icon	Function	Explanation
	Clear	Clears text from Journal window
	Replace	Replaces Journal text with contents of external text file
	Save	Saves selected or full Journal text to an external text file
	Print	Prints the Journal text to the default printer
	Time stamp	Inserts current time into Journal
	Date stamp	Inserts current date into Journal
	Time AND Date	Inserts current time and date into Journal when Enter/Return key is pressed
	Font	Use to select font type and size for Journal session
	Text style	Use to bold, italicize or underline text
	Text alignment	Aligns paragraph text to left, center, right or justified position
	Font color	Selects color of Journal text
	Numbering	Toggles text numbering on and off
	Bulleting	Toggles text bulleting on and off
	Increase indent	Increases indent in a bulleted or numbered list*
	Decrease indent	Decreases indent in a bulleted or numbered list
	Table	Inserts a table into the Journal
	Table row	Adds a row to the table **
	Table column	Adds a column to the table
	Delete table row	Removes selected row from the table
	Delete table column	Removes selected column from the table
	Merge cells	Merges selected cells within the table
	Split cells	Splits selected cells within the table

*Active only when cursor is positioned within a bulleted or numbered list.

**Additional table tools are active only when a table is present.

NOTE: If the Acq*Knowledge* graph or Journal windows are decreased in size, the Journal toolbar will become truncated and some buttons may no longer be in view. Buttons no longer visible on the toolbar can be found in drop-down menus indicated by arrows. (*See below*)

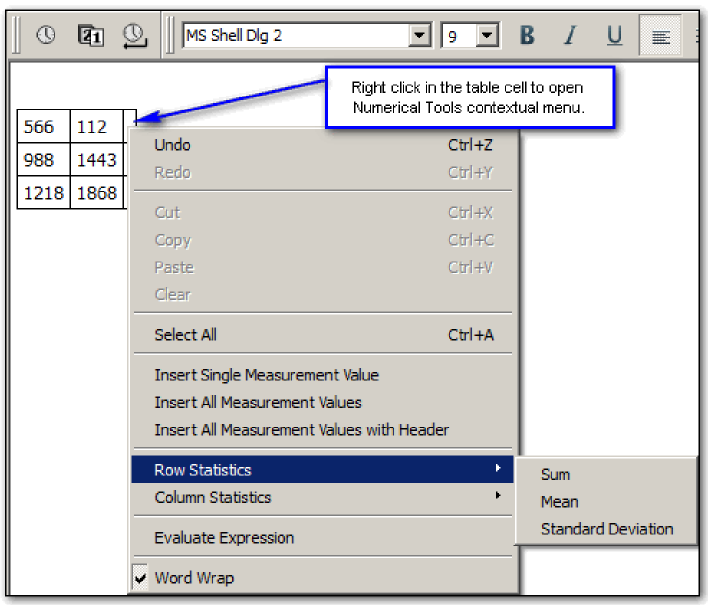


Journal Numerical Table Tools

The Numerical Table Tools function allows easy insertion of measurements and numerical data into a Journal table, which can then be computed and evaluated via basic mathematical operations and expressions. This eliminates the need to export data to a spreadsheet application in order to validate statistics gathered during the course of an experiment.

Numerical Tools operations permitted within a Journal table:

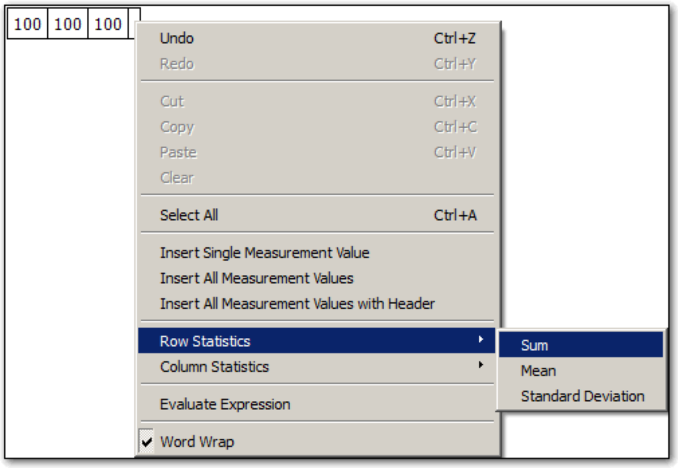
- Insert a single measurement value
- Insert all measurement values
- Insert all measurement values with header row
- Sum, Mean and Standard Deviation statistics for table rows and columns
- Expression evaluation

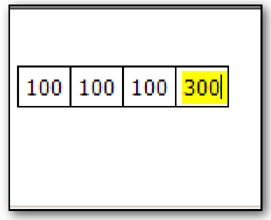


Menu Item	Function
Undo	Removes previous operation
Select All	Selects all cell contents
Insert Single Measurement Value	Pastes single selected measurement value into cell
Insert All Measurement Values	Pastes all measurement values into cells
Row Statistics	Performs Sum, Mean or Standard Deviation operations on row data
Column Statistics	Performs Sum, Mean or Standard Deviation operations on column data
Evaluate Expression	Performs mathematical operations and functions on cell contents
Word Wrap	Wraps text within visible Journal area. (Does not apply to table cells)

Example of Sum, Mean or Standard

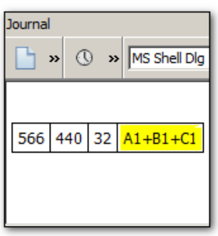
Sum, Mean or Standard Deviation operations can be easily performed on table data. Right clicking within a cell opens a contextual menu containing available operations under ‘Row’ or ‘Column’ statistics. Choose an operation, and the result will appear in the selected cell. *(See sum example below*)

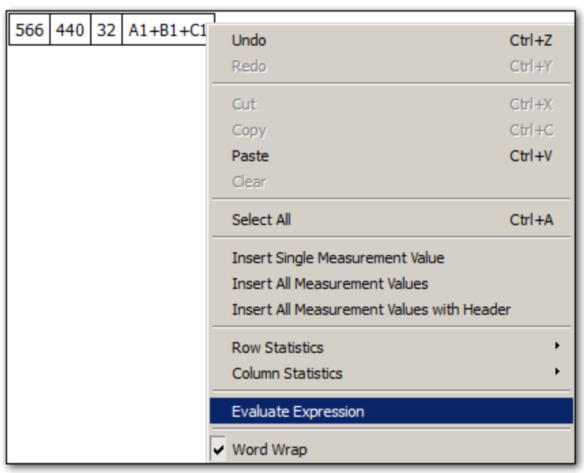


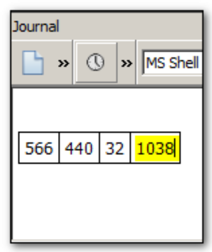


Example of Evaluate Expression:

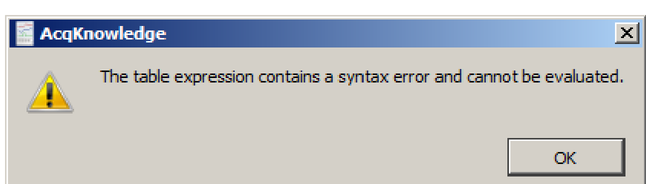
This feature works very much like Excel®. Simply enter the cell identifiers into an empty cell, then right-click and choose ‘Evaluate Expression”. The formula occupying the cell will be computed and be replaced by the result. The mathematical operations and functions available for standard Biopac Expression syntaxes may be used. (Transform > Expression). Expressions can be created beforehand then copied and pasted into a Numerical Tools Table cell.





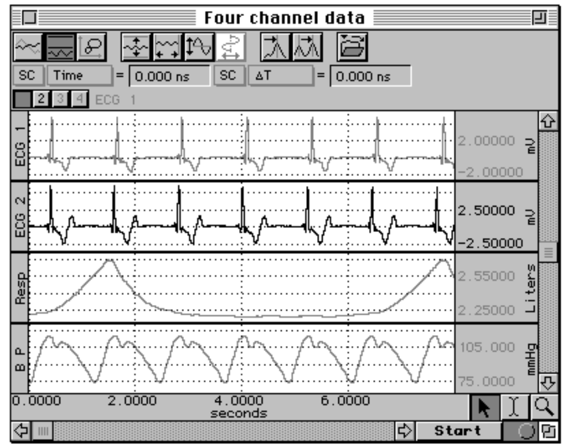


If the expression syntax used is incorrect or invalid, a warning dialog will appear.



TIP: To correct a mistake, use the Ctrl+Z (PC) or Command+Z (Mac) keystroke to restore the previous cell data. Multiple levels of undo are supported.

Select a waveform / channel



Although multiple waveforms can be displayed, only one waveform at a time is considered "active." Most software functions only apply to the active waveform, which is also referred to as the "selected" channel. Selecting a channel allows you to highlight all or part of that waveform, and enables you to perform transformations on a given channel.

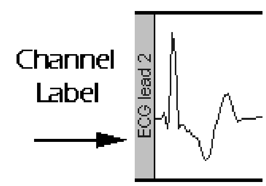
In the upper left corner of the graph window there is a series of numbered boxes that represent each channel of data. The numbers in the boxes correspond to the channel used to acquire the data (the specifics of setting up channels are discussed on page 36). In the sample file, ECG channels are represented by channels 1 and 2, with respiration on channel 3 and blood pressure on channel 4.

To select a channel, position the cursor over the channel box that corresponds to the desired channel and click the mouse button or position the cursor on the waveform of interest and click the mouse button.

Note that the selected channel box appears depressed and the channel label to the right of the channel boxes changes to correspond to the selected channel.

Additionally, the channel label in the display (on the left edge of the track) will be highlighted for the active channel.

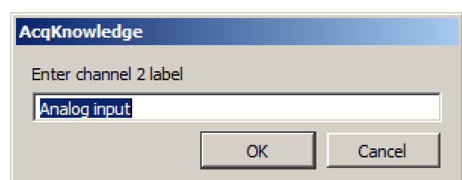
Channel Labels



Each channel has a label on the left and right edge of the graph window.

The left label is used to identify the contents of each channel (ECG, Respiration, etc.).

The right label is used to denote the units for each channel's amplitude scale (usually scaled in terms of Volts).

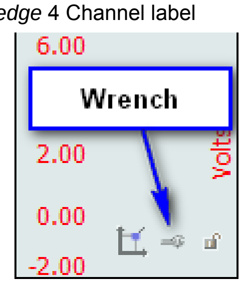


Acq*Knowledge* 4 Channel label

When a channel is active, its label is highlighted and also appears by the channel boxes.

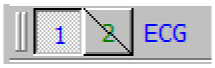
To change the label for a given channel

- <u>during or before acquisition</u>
  (including Append mode)
  revise the MP150 menu > Set Up Channels label text
- <u>post-acquisition / analysis only</u>
  click the left label enter the desired text in the dialog



Label and Units change prompts are separate. Click the left to change the label and on the right (wrench icon in vertical scale) to change the units. The label can be up to 40 characters.

Show/Hide Channel

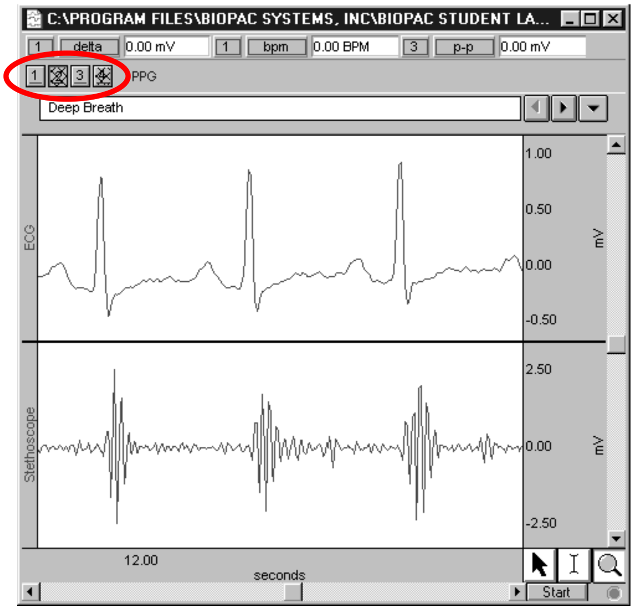


You can "hide"a waveform display without changing the data file. To hide a channel,

Windows: Alt+click in channel box.

Mac OS X: Option+click in channel box.

When a channel is hidden, the channel box will have a slash through it. You may view a hidden channel by holding down the Alt or Option key and clicking in the channel box again. Channels 2 and 4 are hidden in the following display:



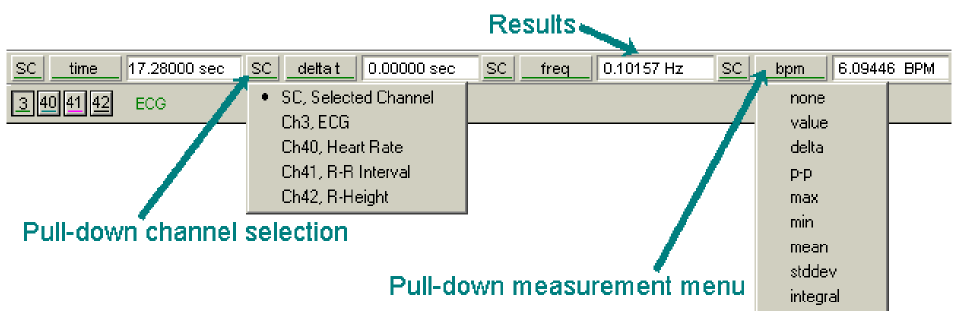
Measurements

A convenient feature in Acq*Knowledge* is the popup measurement windows. A variety of different measurements can be taken, and you can display different measurements from the same channel and/or similar measurements from different waveforms. Acq*Knowledge* can display measurements for the selected channel or for any other channel. By default, Acq*Knowledge* displays measurements from the selected channel (as denoted by the "SC" in the measurement boxes).

To select a channel for measurement, position the cursor over the part of the measurement window that reads "SC." Click the mouse button and choose a channel number from the pull-down menu. The channel numbers in the pull-down menu correspond to the numbers in the channel boxes in the upper left corner of the graph window.

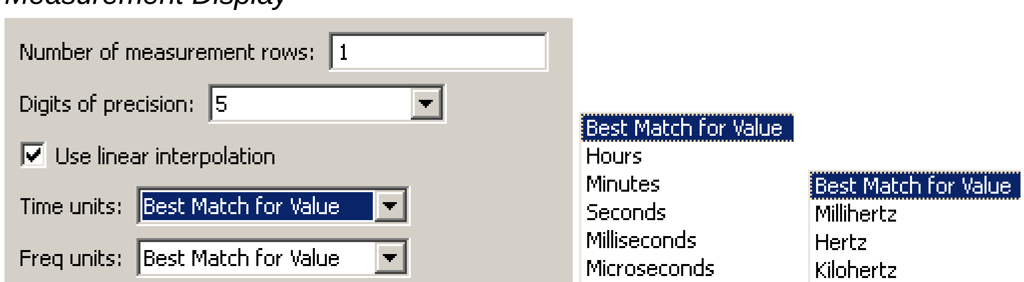
To select a measurement, position the cursor on a measurement box and click the mouse button. Choose a measurement from the pull-down menu; see page 91 for measurement functions and the minimm samples for each (some of the values are single point measurements while others require at least two points to be selected).

The measurements in the upper half of the menu reflect amplitude measurements, or measurements which contain information about the vertical (amplitude) scale. Other measurements use information taken from the horizontal axis (usually) and are found on the section of the pull-down menu below the dividing line. Some of the measurement options change (or are disabled) if units are selected for the horizontal scale.



In some cases, the computations involved in the measurement can produce nonsensical results (such as dividing by zero, or calculating a BPM from a single point). In those cases, you may get a measurement value like INF or ****. This means that the result was undefined at this point.
Measurement menus are tinted to match the color of the corresponding waveform.

Measurement Display



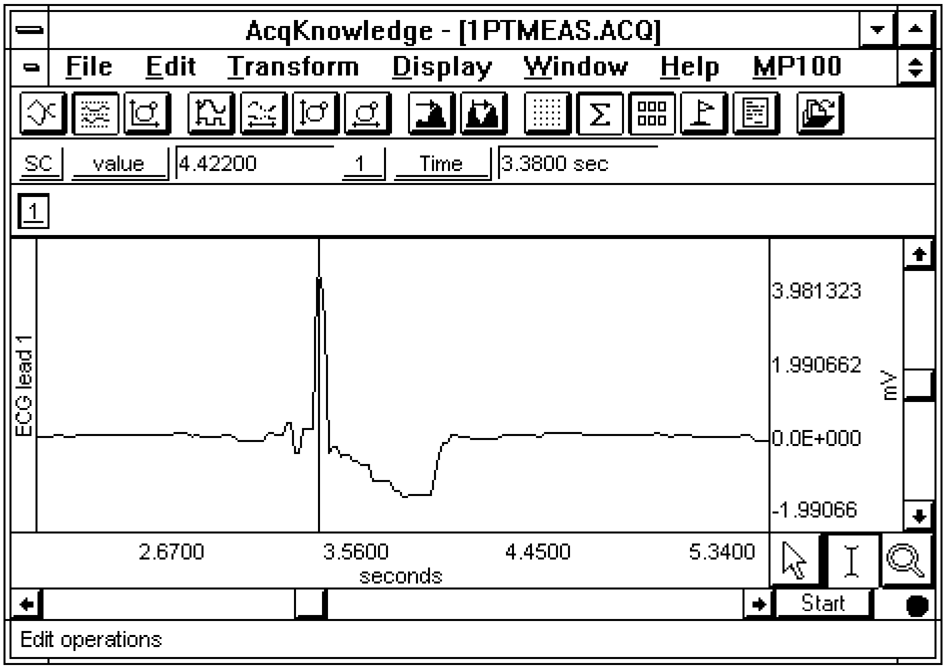
The number of measurement rows is set in Preferences > Measurements, as well as the precisiona dn units.

Measurement Area

It is important to remember that Acq*Knowledge* is always selecting either a single point or an area spanning multiple sample points. If an area is defined and a single point measurement (such as *Time*) is selected, the measurement will reflect the last selected point.

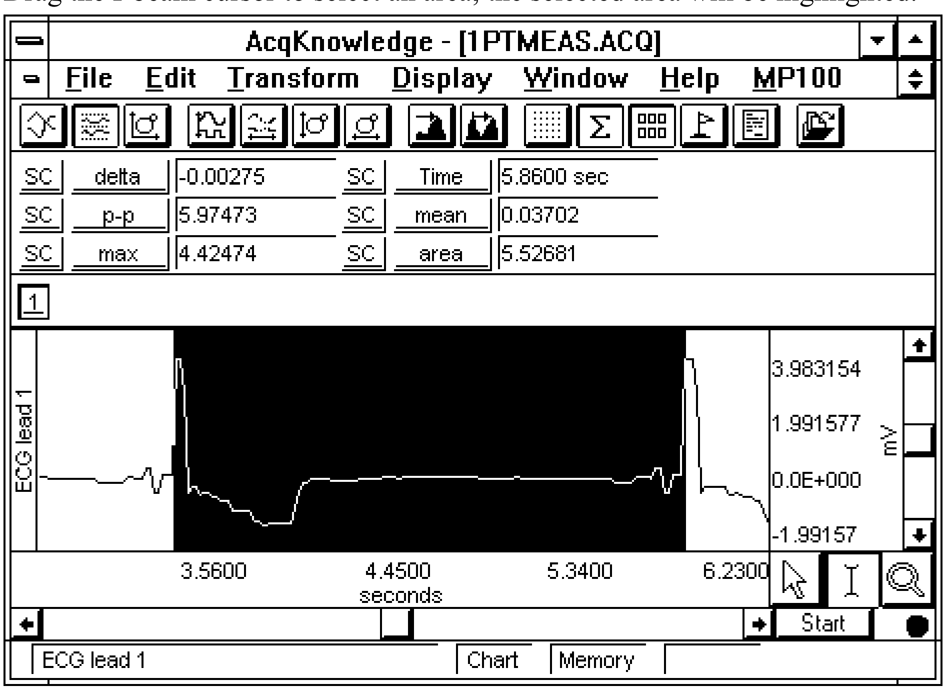
- Single-point measurements

  When a single point is selected, the cursor will "blink." The graph on the left shows how the I-beam is used to select a single point for measurements.



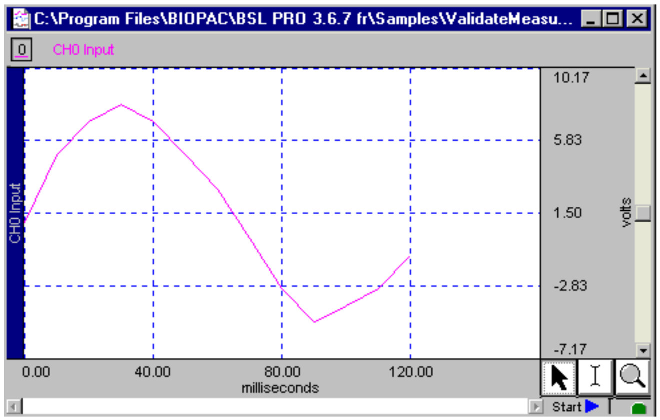
- Selected range measurements

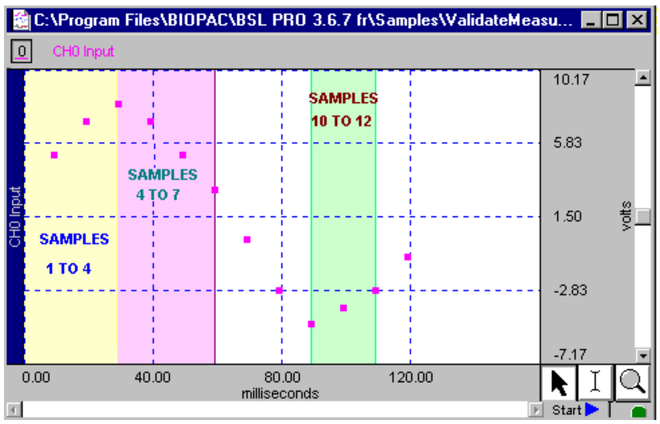
  Drag the I-beam cursor to select an area; the selected area will be highlighted.

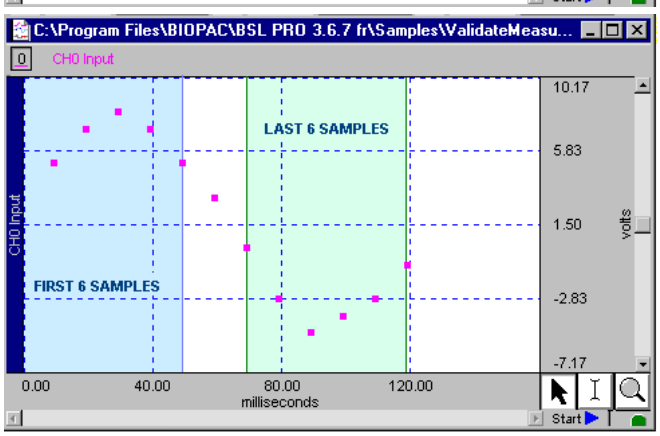


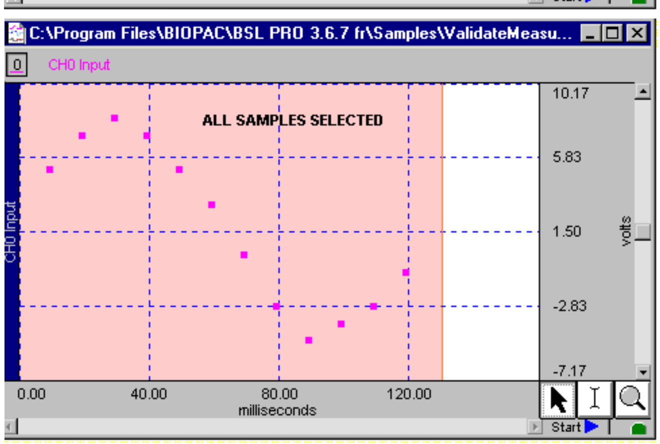
IMPORTANT!

The first data point is "plotted" at zero (on the left edge of the graph); the first visible data point is sample point 2. The selected areas below demonstrate this concept.









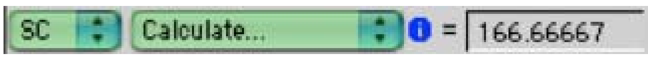
Measurement presets

Measurements are commonly used in conjunction with the cycle detector and other analysis protocols to perform data reduction. In complex data analysis using the cycle detector, often multiple different sets of measurements may be used to perform multiple extraction passes on the data. The measurement presets feature allows users to create multiple predefined measurement configurations and apply them to the graph to change between different configurations. All aspects of the measurement configuration are stored, including measurement functions, any parameters for the measurement, source channel, and number of measurement rows.

Measurement Validation

You can validate measurements with the ValidateMeasurements.acq sample file that was included with the software. Pay attention to the "*Sample data file*" section of the measurement definitions that begin on page 91, and where included, note which sample points to use for validation (i.e., the first four sample points are used to validate the Correlate measurement using the ValidateMeasurements.acq file).

Measurement Info / Parameters



Measurements that have parameters have an "i" for info button next to the measurement type in the measurement bar. Click the button to generate a dialog to edit the parameters. To paste parameters, enable the Journal Preference via Display > Preferences > Journal > Measurement paste settings > Include measurement parameters.

Measurement Interpolation

On a down-sampled channel, the cursor can fall on a point between physical samples. In such cases, in the Line Plot mode only, some measurements will display interpolated values; the value is obtained by linear interpolation with respect to the two adjoining samples.

- To disable measurement interpolation, uncheck the "Use linear interpolation" option in the Display > Preferences dialog.
- If interpolation is disabled for Line Plot, or any time Step Plot or Dot Plot is selected, measurements take on the value of the first physical sample immediately to the left of the cursor or edge of the selection.
- When measurements are pasted to the Journal, there is no indication of interpolated measurements.
- A Calculation measurement can be an interpolated value. When a measurement uses an interpolated value, the result box background changes from gray to light purple.
- The "Delta S" and "Samples" measurements are never interpolated.
- Measurements will not be interpolated if all measurements are set to "SC" (selected channel); the cursor will snap to the left for the measurements.
- Measurement tooltips will reflect measurement interpolation.

Exporting measurements

One of the most important reasons to take measurements is to save them; Acq*Knowledge* allows you to store and export these measurements in different formats.

- Copying measurements to the journal:

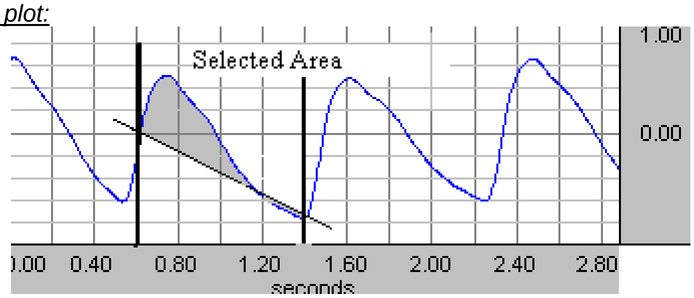
  To copy measurements (exactly as they appear in the measurement windows) and paste them to the Journal, select Edit > Journal > Paste measurement. Under the default settings, only the values themselves are copied to the journal; you can change the settings to include the measurement name and other options under Display > Preferences > Journal

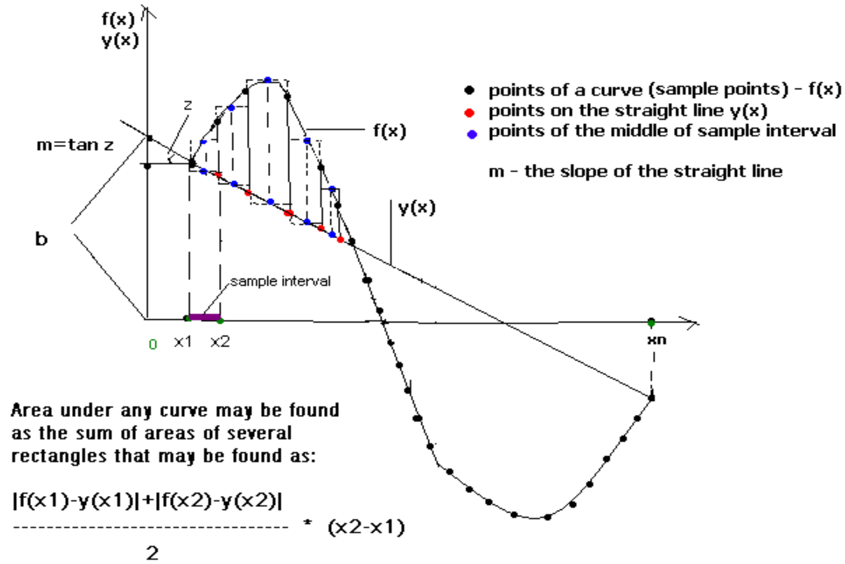
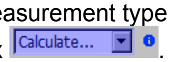
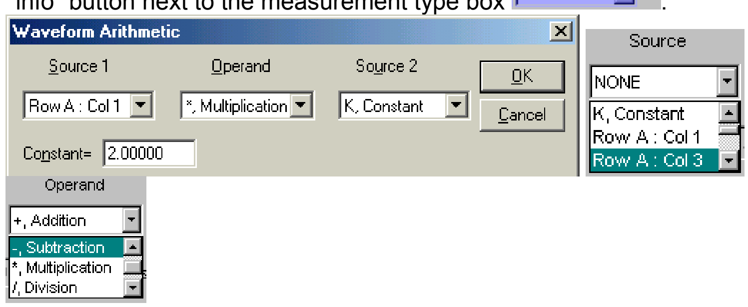
- Copying measurements to the clipboard:

  To copy measurements (exactly as they appear in the measurement windows) to the clipboard and paste them into a word processor or other application, select Edit > Clipboard > Copy measurements. Under the default settings, only the values themselves are copied to the clipboard; you can change the settings to include the measurement name and other options via Display > Preferences > Journal.

Measurement Definitions

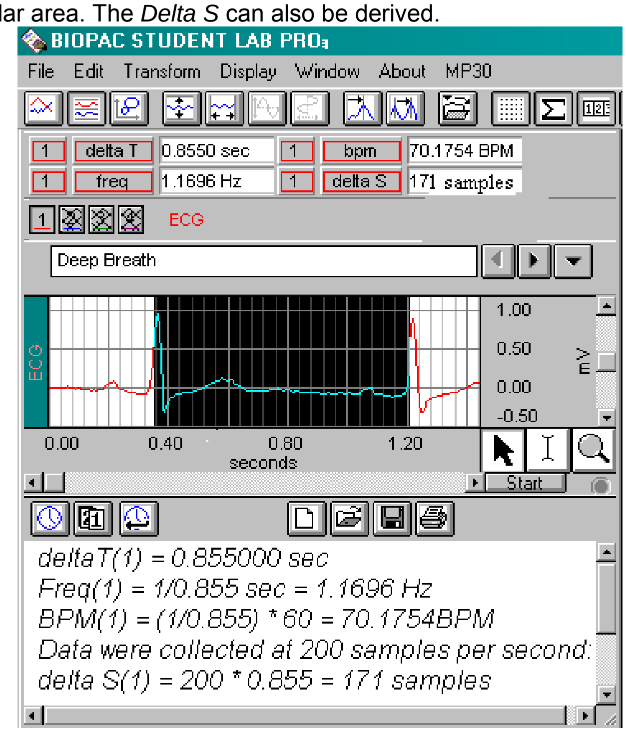
The table below explains the measurement options available and the range required for each. The default option is for time to be displayed on the horizontal axis, although it can be set to display frequency or arbitrary units (see page 411 for details on how to change the horizontal scaling options). Unless otherwise noted, all of the measurements described here relate to those displayed when the horizontal scale reflects time.

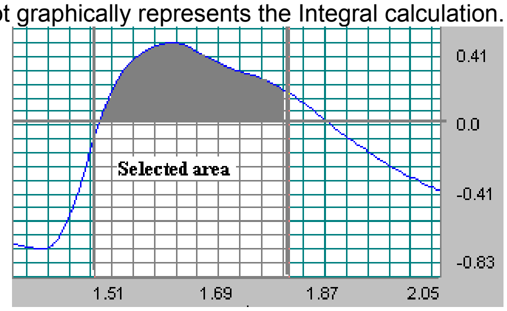
Measurement	Area	Explanation
Area	<u>Minimum area</u>: 3 samples <u>Uses</u>: All points of selected area	Area computes the total area among the waveform and the straight line that is drawn between the endpoints. Area is expressed in terms of (amplitude units multiplied by horizontal units) and calculated using the formula: $$Area = \sum_{i=1}^{n-1} \left(\left| f(x_i) - y(x_i) \right| + \left| f(x_{i+1}) - y(x_{i+1}) \right| \right) * \frac{\Delta x_i}{2}$$ *<u>Where:</u>* *n—number of samples;* *i—index (i = 1.n-1);* x_i, x_{i+1} *- values of two neighboring points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);* $f(x_i)$, $f(x_{i+1})$ *- values of two neighboring points of a curve (vertical axis);* $y(x_i)$, $y(x_{i+1})$ *- values of two neighboring points of a straight line (vertical axis).* *At the endpoints y(* x_1*)= f(* x_1*) and y(* x_n*)= f(* x_n*).* $\Delta x_i = \frac{\Delta X}{n-1}$ *- horizontal sample interval;* *The value of a straight line can be found by formula:* $$y(x_i) = m * x_i + b$$ $b = f(x_1) - m * x_1$ *- intercept;* $m = \frac{\Delta Y}{\Delta X}$ *- slope of the straight line;* $\Delta Y = f(x_n) - f(x_1)$ *- vertical distance of increase at vertical axis;* $\Delta X = x_n - x_1$ *- horizontal distance of increase at horizontal axis.* *<u>Sample plot:</u>*  The area of the shaded portion is the result. *<u>Note:</u>* The Area measurement is similar to the *Integral* measurement except that a straight line is used (instead of zero) as the baseline for integration.

Measurement	Area	Explanation
		 *Results:* This calculation will always return a positive result. *Units:* *Volts - sec.* *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 0.4533 Volts - sec.*
BPM (Time domain only)	Minimum area: 2 samples Uses: Endpoints of selected area	BPM (beats per minute) computes the time difference between the first and last points and extrapolates BPM by computing the reciprocal of this difference, getting the absolute value of it and multiplying by 60 (60 sec). The formula for calculation of BPM is: $$BPM = \left(\frac{1}{\lvert x_n - x_1 \rvert}\right) * 60$$ *Where:* x_1, x_n - *values of the horizontal axis at the endpoints of selected area.* *Note:* As mentioned, this measurement provides essentially the same information as the *Delta T* and *Freq* measurement. *Results:* Only a positive value. *Units:* *BPM.*
Calculate	Minimum area: 2 sources Uses: Results of measurements used in calculation	Calculate can be used to perform a calculation using the other measurement results. For example, you can divide the mean pressure by the mean flow. When Calculate is selected, the channel selection box disappears.  The result box will read "Off" until a calculation is performed, and then it will display the result of the calculation. As you change the selected area, the calculation will update automatically. To perform a calculation, generate the "Waveform Arithmetic" dialog via Ctrl-Click or right mouse click the Calculate measurement type box or click the "info" button next to the measurement type box .  Use the pull-down menus to select Sources and Operand. Measurements are listed by their position in the measurement display grid (i.e., the top left measurement is Row A: Col 1). Only active, available channels appear in the Source menu.

Measurement	Area	Explanation
		Calculation measurement Source operands are updated before a Calculation is performed, which means that Calculations can be based on measurements that are located after them in the measurement row/column ordering. *Metachannels*—Calculation measurements can include other Calculation measurements as their operands. • If a cyclic dependency is introduced, the result reads "Error." • When interpolation is being used, a Calculation measurement can also be an interpolated value. • If either of the operands of a Calculation is interpolated, the result will be displayed as an interpolated value (with a light purple background). The Operand pull-down menu includes: Addition, Subtraction, Multiplication, Division, Exponential. The Constant entry box is activated when you select "Source: K, constant" and it allows you to define the constant value to be used in the calculation. To add units to the calculation result, select the Units entry box and define the unit's abbreviation. Click OK to see the calculation result in the calculation measurement box.
Cap_Dim		Capacity Dimension; fractal dimension estimate. (Fractals measure the amount of self-similarity in a data set. Acq*Knowledge* offers three alternate estimates for fractal dimension: Cap_Dim, Corr_Dim, and Inf_Dim. The estimates will not agree, based on the heuristic and the parameters.)
Corr_Dim		Correlation Dimension; fractal dimension estimate. Always greater than capacity if parameters are the same. (See fractals note at Cap_Dim.)
Correlate	<u>Minimum area</u>: 2 samples <u>Uses</u>: All points of selected area	Correlate provides the *Pearson* product moment correlation coefficient, r, over the selected area and reflects the extent of a linear relationship between two data sets: x_i - values of horizontal axis and $f(x_i)$ - values of a curve (vertical axis). You can use Correlate to determine whether two ranges of data move together. *<u>Association</u>* — *<u>Correlation</u>* Large values with large values — Positive correlation Small values with large values — Negative correlation Unrelated — Correlation near zero The formula for the correlation coefficient is: $$\text{Correlate} = \frac{n*\sum_{i=1}^{n}(x_i * f(x_i)) - \left(\sum_{i=1}^{n} x_i\right)*\left(\sum_{i=1}^{n} f(x_i)\right)}{\sqrt{\left[n*\sum_{i=1}^{n}(x_i)^2 - \left(\sum_{i=1}^{n} x_i\right)^2\right]*\left[n*\sum_{i=1}^{n}(f(x_i))^2 - \left(\sum_{i=1}^{n} f(x_i)\right)^2\right]}}$$ *<u>Where:</u>* *n—number of samples;* *i—index (i = 1..n);* x_i *— values of points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);* $f(x_i)$*- values of points of a curve (vertical axis).* *<u>Results:</u>* Returns a dimensionless index that ranges from -1.0 to 1.0 inclusive. *<u>Units:</u> None* *<u>Sample data file:</u>* *"ValidateMeasurements.ACQ"* *Result: -0.74825(for whole wave) and 0.95917 (for first four sample points).*
Delta	<u>Minimum area</u>: 2 samples <u>Uses</u>: Endpoints of selected area	Delta returns the difference between the amplitude values at the endpoints of the selected area. $$\text{Delta} = f(x_n) - f(x_1)$$ *<u>Where:</u>* $f(x_1)$, $f(x_n)$*—values of a curve at the endpoints of selected area.*

Measurement	Area	Explanation
		Results: If the data value at the starting location is greater than the data value at the ending location of the cursor, then a negative delta will result. Otherwise, a positive delta will result. *Units: Volts* *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: -2 Volts (for whole wave). This result shows the absolute value of change of amplitude (2) and the minus sign means a decrease of amplitude.*
Delta S	Minimum area: 1 sample Uses: Endpoints of selected area	Delta S returns the difference in sample points between the end and beginning of the selected area. *Results:* This calculation will always return a positive result. *Units: Samples*
Delta T(time) Delta F (frequency) Delta X (arbitrary unit)	Minimum area: 2 samples Uses: Endpoints of selected area	The Delta T/F/X measurement shows the relative distance in horizontal units between the endpoints of the selected area. *Only one of these three units* will be displayed in the pop-up menu at a given time, as determined by the horizontal scale settings. *Measurement* — *Horizontal Axis* Delta T — Time Delta F — Frequency (FFT) Delta X — Arbitrary units (Histogram Bins) The formula for Delta T/F/X is: Delta T $= x_n - x_1$ *Where:* x_1, x_n *- values of horizontal axis at the endpoints of selected area.* *Results:* If the data value at the starting location is greater than the data value at the ending location of the cursor, then a negative delta will result. Otherwise, a positive delta will result. For Delta T measurements with the horizontal axis format set to HH:MM:SS. ✓ For values less than 60 seconds, you will get a value in decimal seconds. ✓ For values greater than 60 seconds, you will see an HH:MM:SS format value (See page 72 for details on how to change the horizontal scaling). *Units:* Delta T: *Seconds (sec.)* Delta X: *"arbitrary unit"* Delta F: *Hz* *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 0.12 sec. (for whole wave).*
Evt_amp		Extracts the value of the measurement channel at the times where events are defined. The measurment result is unitless. Specify Type, Location, and Extract; see page 217 for details. ▪ The amplitude is always taken from the measurement channel, which may be different from the channel on which events are defined. Evt_amp can be useful for extracting information such as the average T wave height within the selected interval.
Evt_count		Evaluates the number of events within the selected area. The measurement result is unitless. Specify Type and Location; see page 218 for details.
Evt_loc		Extracts information about the times of events. The measurement result uses the units of the horizontal axis. Specify Type, Location, and Extract; see page 218 for details.
Expression		Generates the Expression transformation dialog (page 133) and offers Source "MC" Measurement Channel instead of "SC" Selected Channel to build recursive formulas, i.e. result of the expression as it was evaluated x samples ago. Data within the selected area is not changed.

Measurement	Area	Explanation
Freq (time domain only) It is important to note… This does not compute the frequency spectra of the data. To perform a spectral analysis, use the FFT function (see page 301).	Minimum area: 2 samples Uses: Endpoints of selected area	Freq computes the frequency in Hz between the endpoints of the selected area by computing the reciprocal of the absolute value of time difference in that area. The formula for Freq is: $$\text{Freq} = \left(\frac{1}{\lvert x_n - x_1 \rvert} \right)$$ *Where:* x_1, x_n *- values of horizontal axis at the endpoints of selected area.* The information provided by this measurement is directly related to the *Delta T* and *BPM* measurements, and is related to a lesser extent to *Delta S* measurement. That is, if the *Delta T* interval between two adjacent peaks is calculated, the *BPM and Freq* measurement can be extrapolated. If the sampling rate is known, the *Delta S* can also be derived. In the following example, you can see *Delta T, Freq* and *BPM* measurements for the particular area. The *Delta S* can also be derived.  *Selected area with measurements that describe the same interval in different terms.* *Note:* It is important to note that this does not compute the frequency spectra of the data. To perform a spectra analysis, use the FFT function (described on page 301). *Freq (or frequency) is only available in time domain windows.* *Results:* This calculation will always return a positive result. *Units: Hz* *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 8.33 Hz (for whole wave).*
Inf_Dim		Information Dimension; fractal dimension estimate. (See fractals note at Cap_Dim.)
Integral	Minimum area: 2 samples Uses: All points of selected area	Integral computes the integral value of the data samples between the endpoints of the selected area. This is essentially a running summation of the data. Integral is expressed in terms of (amplitude units multiplied by horizontal units) and calculated using the following formula. $$\text{Integral} = \sum_{i=1}^{n-1} \left[f(x_i) + f(x_{i+1}) \right] * \frac{\Delta x_i}{2}$$ *Where:* *n—number of samples;* *i—index (i = 1.n-1);*

Measurement	Area	Explanation
		x_i , x_{i+1} *- values of two neighboring points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);* $f(x_i)$, $f(x_{i+1})$ *- values of two neighboring points of a curve (vertical axis);* $\Delta x_i = \frac{\Delta X}{n-1}$ *- horizontal sample interval;* $\Delta X = x_n - x_1$ *- horizontal distance of increase at horizontal axis.* The following plot graphically represents the Integral calculation.  The area of the shaded portion is the result. <u>*Results*</u>*:* The Integral calculation can return a negative value if the selected area of the waveform extends below zero. <u>*Units*</u>*: Volts—sec.* <u>*Sample data file:*</u> *"ValidateMeasurements.ACQ"* *Result: 0.300 Volts -sec.(for first 6 sample points) and –0.155 Volts -sec.(for last 6 sample points—the wave below zero).*
Kurtosis		Kurtosis indicates the degree of peakedness in a distribution, e.g. the size of the "tails" of the distribution. Distributions that have sharp peaks in their center have positive kurtosis; flatter distributions have negative kurtosis. A normal distribution has a kurtosis of 0. The following formula is used to extract kurtosis $$kurtosis = \frac{\dfrac{\sum_{i=1}^{n}(x_i - \bar{x})^4}{n}}{\left(\dfrac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}\right)^2}$$ *Where* from a signal (x) containing n points:
Lin_reg	<u>Minimum area</u>: 2 samples <u>Uses</u>: All points of selected area	Linear regression is a better method to calculate the slope when you have noisy, erratic data. ▪ For advanced modeling options, see Nonlinear modeling on page 298. Lin_reg computes the non-standard regression coefficient, which describes the unit change in <u>*f (x)*</u> (vertical axis values) per unit change in <u>*x*</u> (horizontal axis). *For the selected area*, Lin_reg computes the linear regression of the line drawn as a best fit for all selected data points using the following formula: $$\text{Lin\_reg} = \frac{n * \sum_{i=1}^{n}(x_i * f(x_i)) - \left(\sum_{i=1}^{n} x_i\right) * \left(\sum_{i=1}^{n} f(x_i)\right)}{n * \sum_{i=1}^{n}(x_i)^2 - \left(\sum_{i=1}^{n} x_i\right)^2}$$ <u>*Where*</u>*:* *n—number of samples;* *i—index (i = 1.n);* x_i *— values of points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);* $f(x_i)$*- values of points of a curve (vertical axis).*

Measurement	Area	Explanation
		Note: *For a single point*, Lin_reg computes the linear regression of the line drawn between the two samples on either side of the cursor. Results: If the data value at the starting location is greater than the data value at the ending location of the cursor, then a negative delta will result. Otherwise, a positive delta will result. Units: *Volts/sec.* This value is normally expressed in unit change per second (time rather then samples points) since high sampling rates can artificially deflate the value of the slope. If the horizontal axis is set to display *Frequency* or *Arbitrary units*, the slope will be expressed as unit change in corresponding vertical axis values (frequency or arbitrary units, respectively). Sample data file: *"ValidateMeasurements.ACQ"* *Result: 230.00 Volts/sec. (for 1-4 samples) and –170.00 Volts/sec. (for samples 4-7).*
Lyapunov		Lyapunov exponent describes the exponential rate of divergence of a system when perturbed from its initial conditions. For instance, if the system is started from two slightly different locations, this indicates how different their results will be with time. Stable experiments have exponents equal to zero. Specify an embedding dimension and a time delay; produces a single-valued measure. This measure is quite dependent on the amount of data used.
Max	Minimum area: 1 sample Uses: All points of selected area	Max (maximum) shows the maximum amplitude value of the data samples between the endpoints of the selected area. To compare peak heights, select each peak—you can easily see the maximum peak values or paste the results to the journal. Also, since you can simultaneously obtain measurements for different channels, you can easily compare maximum values for different channels. Note: For a single point, Max shows the amplitude value in this point. Units: *Volts*
Max T	Minimum area: 1 sample Uses: All points of selected area	Max T shows the time of the data point that represents the maximum value of the data samples between the endpoints of the selected area. Note: For a single point, Max T shows the time value in this point. Units: *Seconds*
Mean	Minimum area: 2 samples Uses: All points of selected area	Mean computes the mean amplitude value of the data samples between the endpoints of the selected area, according to the formula: Mean = $\frac{1}{n} * \sum_{i=1}^{n} f(x_i)$ Where: *n—number of samples;* *i—index (i = 1.n);* x_i *— values of points at horizontal axis; (* x_1 *– the first point,* x_n *– the last point);* $f(x_i)$*- values of points of a curve (vertical axis).* Units: *Volts* Sample data file: *"ValidateMeasurements.ACQ"* *Result: 1.538462 Volts (for whole wave).*
Median	Minimum area: 2 samples Uses: All points of selected area	Median shows the median value from the selected area. Note: The median and calculation is processor-intensive and can take a long time, so you should only select this measurement option when you are actually ready to calculate. Until then, set the measurement to "none." Units: *Volts*
Median T	Minimum area: 2 samples Uses: All points of selected area	Median T shows the time of the data point that represents the median value of the selected area. Note: The median and calculation is processor-intensive and can take a long time, so you should only select this measurement option when you are actually ready to calculate. Until then, set the measurement to "none." Units: *Seconds.*

Measurement	Area	Explanation
Min	<u>Minimum area</u>: 1 sample <u>Uses</u>: All points of selected area	Min (minimum) shows the minimum amplitude value of the data samples between the endpoints of the selected area. *<u>Note</u>:* For a single point, Min shows the amplitude value in this point. *<u>Units</u>: Volts.*
Min T	<u>Minimum area</u>: 1 sample <u>Uses</u>: All points of selected area	Min T shows the time of the data point that represent the minimum value of the data samples between the endpoints of the selected area. *<u>Note</u>:* For a single point, Min T shows the time value in this point. *<u>Units</u>: Seconds.*
Moment	<u>Uses</u>: All points of selected area	Central Moment is a general-purpose statistical computation that can be used to compute central variance and other higher-order moments of the data within the selected area. Specify the order as an integer (generally). The central moment is computed using the following formula: $$\mu_m = \frac{\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^m}{n}$$ *<u>Where</u>:* *x—signal;* *n—points;* m—order.
Mut_inf		Mutual Information determines how much could probabilistically be known about an unknown signal given a known variable. Specify a time delay. Produces a single valued result.
NLM		Nonlinear modeling (also called "arbitrary curve fitting") determines the "best fit" model for the selected data of the selected channel. The measurement result corresponds to the value of one of the parameters of the best fit. NLM can be used to extract Tau (time delay LVP constant) for assessing cardiac condition. See page 298 for nonlinear modeling details. ▪ If a Model Expression uses MMT() syntax to reference a measurement and that referenced measurement is linearly interpolated, the results of the NLM measurement will also be displayed as being linearly interpolated. ▪ When combined with the Cycle/Peak Detector (on page 308), the NLM measurement can be useful for extracting cycle-by-cycle best fit models for an entire waveform.
None	n/a	None does not produce a measurement value. It's useful if you are copying a measurement to the clipboard or journal with a window size such that several measurements are shown and you don't want them all copied.
P-P	<u>Minimum area</u>: 2 samples <u>Uses</u>: All points of selected area	P-P (peak-to-peak) shows the difference between the maximum amplitude value and the minimum amplitude in the selected area. *<u>Results</u>:* The result is always a positive value or zero. *<u>Units</u>: Volts* *<u>Sample data file:</u>* *"ValidateMeasurements.ACQ"* *Result*: 13 Volts (for whole wave).
Samples	<u>Minimum area</u>: 1 sample <u>Uses</u>: All points of selected area	Samples shows the exact sample number of the selected waveform at the cursor position—the first data point is not displayed, but is plotted at zero. See page 89 for examples of selected area Samples. *<u>Note</u>:* When an area is selected, the measurement will indicate the sample number at the last position of the cursor. <u>Units</u>: Samples.
Skew		Skew is a statistical measure of the degree of asymmetry in a distribution (away from normal Gaussian distribution), e.g. if the distribution is weighted evenly or trends toward an edge. • A normal distribution has a skew of 0. • A distribution with a prominent left tail has a negative skew. • A distribution with a prominent right tail has a positive skew The following formula is used to extract skew:

Measurement	Area	Explanation
		$$skew = \frac{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^3}{n}}{\left(\sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}}\right)^3}$$ *Where* a signal (x) contains n points:
Slope	Minimum area: 2 samples Uses: All points of selected area	Slope computes the non-standard regression coefficient, which describes the unit change in *f (x)* (vertical axis values) per unit change in *x* (horizontal axis). *For the selected area*, Slope computes the slope of the straight line that intersects the endpoints of the selected area, using the formula: Slope = $\frac{f(x_n) - f(x_1)}{x_n - x_1}$ *Where:* $f(x_1)$, $f(x_n)$—*values of a curve at the endpoints of selected area.* x_1, x_n - *values of horizontal axis at the endpoints of selected area.* This value is normally expressed in unit change per second (time rather then samples points) since high sampling rates can artificially deflate the value of the slope. *Note:* Lin_reg (linear regression) is a better method to calculate the slope when you have noisy, erratic data. *For a single point,* Slope computes the slope of the line drawn between the two samples: the selected sample point and the sample point to its left. *Results:* If the data value at the starting location is greater than the data value at the ending location of the cursor, a negative delta will result. Otherwise, a positive delta will result. *Units: Volts/sec.* (or corresponding to Freq or Arbitrary setting) *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 233.33333 Volts/sec. (for samples 1-4)* *-166.66667 Volts/sec. (for samples 4-7) and* *-16. 66667 Volts/sec. (for whole wave).*
Stddev	Minimum area: 2 samples Uses: All points of selected area	Stddev computes the standard deviation value of the data samples between the endpoints of the selected area. Variance estimates can be calculated by squaring the standard deviation value. The formula used to compute standard deviation is: Stddev = $\sqrt{\frac{1}{n-1} * \sum_{i=1}^{n}\left(f(x_i) - \bar{f}\right)^2}$ *Where:* *n—number of samples;* *i—index (i = 1.n);* x_i — *values of points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);* $f(x_i)$- *values of points of a curve (vertical axis);* $\bar{f} = \frac{1}{n} * \sum_{i=1}^{n} f(x_i)$ - *the mean amplitude value of the data samples between the endpoints of the selected area.* *Results:* The result is always a positive value or zero. *Units: Volts* *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 3.09570 Volts (for samples 1-4),* *1.000 Volts (for samples 10-12).*

Measurement	Area	Explanation
Sum	Minimum area: 2 samples Uses: All points of selected area	Sum extracts a mathematical sum of the amplitudes of all of the samples within the selected area. This straight sum can be used as a building block for more complicated formulas. Examples of its utility include HRV measurements, various statistical measurements, and simple criteria for clustering. Sum is available from within the measurement popup menus and from analysis scripts that allow for extraction of measurements.
Time	Minimum area: 1 samples Uses: All points of selected area	See the X-axis: T measurement for explanation.
Value	Minimum area: 1 sample Uses: All points of selected area	Value shows the exact amplitude value of the waveform at the cursor position. *For the selected area,* Value indicates the value at the last position of the cursor, corresponding to the direction the cursor was moved (the value will be the left-most sample point if the cursor was moved from right to left). *Units: Volts*
X-axis:T/F/X (horizontal units)	Minimum area: 1 sample Uses: All points of selected area	The X-axis measurement is the exact value of the selected waveform at the cursor position, based on the Horizontal Axis setting: Measurement Horizontal Axis Setting Units X-axis: T Time Sec. X-axis: F Frequency Hz. X-axis: X Arbitrary units Arb. units For X-axis: T measurements, the time value is relative to the absolute time offset, which is the time of the first sample point. The X-axis: F measurement applies to frequency domain windows only (such as FFT of frequency response plots). The Freq function for time domain windows is described on page 95. *Note:* If a range of values is selected; the measurement will indicate the horizontal value at the last position of the cursor. *Results:* This calculation will always return a positive result.

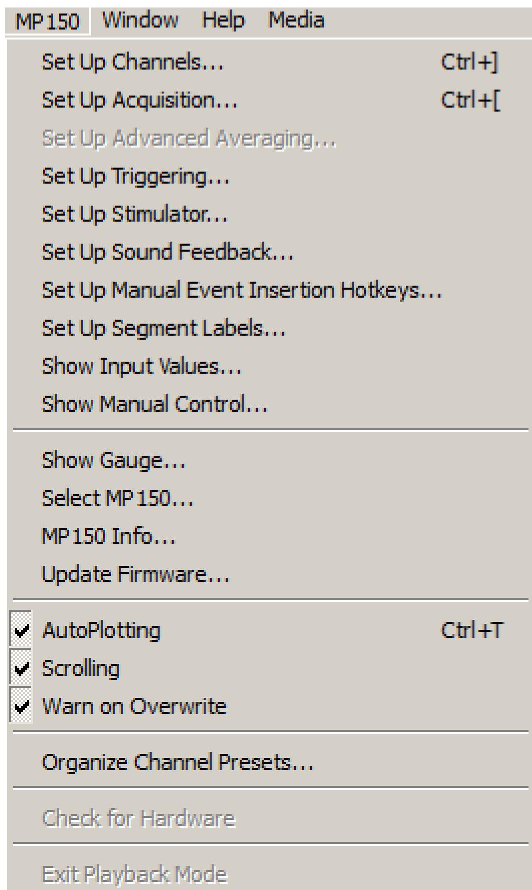
Part B—Acquisition Functions: The MP menu

Overview

The Acq*Knowledge* software adds acquisition and control capability to the complete MP System (MP150 or MP36R). This section describes the commands and procedures used to establish the various acquisition parameters for the MP System (MP150 or MP36R), including how to:

- Set Up channels for data acquisitions
- Control acquisition parameters such as sampling rate and duration
- Perform online calculations and digital filters
- Set acquisitions to begin on command from a mouse click or external trigger
- Display values numerically and graphically during an acquisition
- Output waveforms and digital signals during an acquisition
- Control the on-screen waveform display characteristics

Some of the basic functions involved in setting up an acquisition were covered in *Part A—Getting Started*, but this section will cover them in more detail, as well as describe some additional features. All the commands covered here can be found under the MP150 menu.



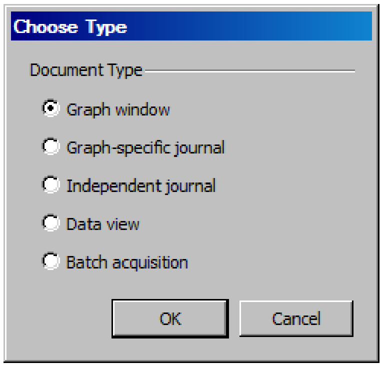
Acquisitions

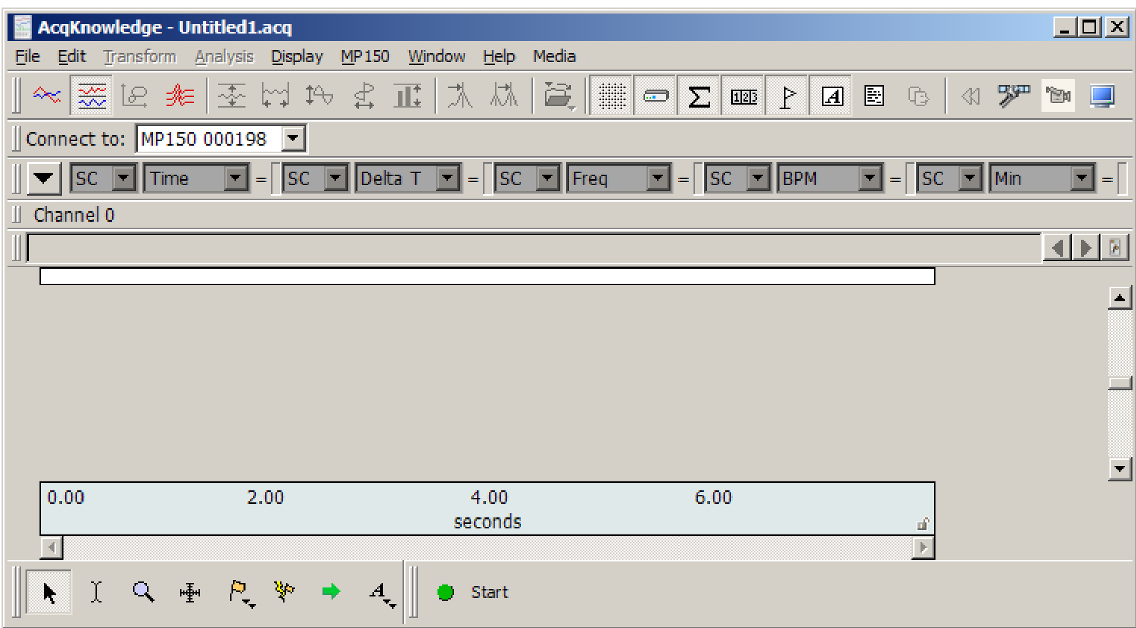
Acquisition is defined as data collection from an external source (such as electrodes connected to an amplifier).

- Before you begin an acquisition, make sure the MP data acquisition unit is turned on and connected to your computer. Please refer to the BIOPAC Hardware Guide for more information on connections.

To begin collecting data and display data as it is being collected:

1. Launch the Acq*Knowledge* application (you can double click the Acq*Knowledge* icon).
2. Choose File > New and select document type "Graph Window" :





3. Set up the specific channels you want to acquire before starting the acquisition.
   - See the Set Up Channels chapter (page 103) for details.
4. Set up the acquisition parameters (such as sampling rate, acquisition length, and data storage options.
   - See the Set Up Acquisition chapter (page 148) for details.

Edit menu functionality during acquisition

The following Edit menu functions may move or alter memory and cannot be performed during acquisition: Undo, Cut, Clear, Clear All, Paste, Insert Waveform, Duplicate waveform, and Remove Waveform.

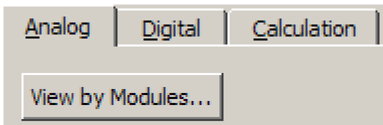
Chapter 5 Set Up Channels

Set Up Channels—The Basics

Before you collect data, you need to specify how many channels you will be collecting data on, and at what rate data is to be collected. Both of these functions are accomplished through menu items and dialoges. To enable collection on a given channel, select Set Up Channels from the MP150 menu.

Acq*Knowledge* 4.1 offers two methods of analog channel setup:

New! Module-based setup



View by Channels *see page 105 for details*

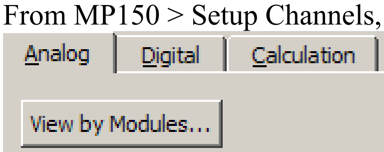
If using Acq*Knowledge* 4.1 with **BioHarness™** or Acq*Knowledge* 4.2 with **B-Alert**™, Analog channels can be turned on/off but not changed.

Module-based analog channel setup

New! For MP150 units, Acq*Knowledge* 4.1 introduces a module-oriented analog channel setup option. In module mode, setup prompts the user to add modules/transducers and establish parameters, plus it detects potential channel conflicts between software assignment and the module channel switch setting and scales the signal to the correct value and units.

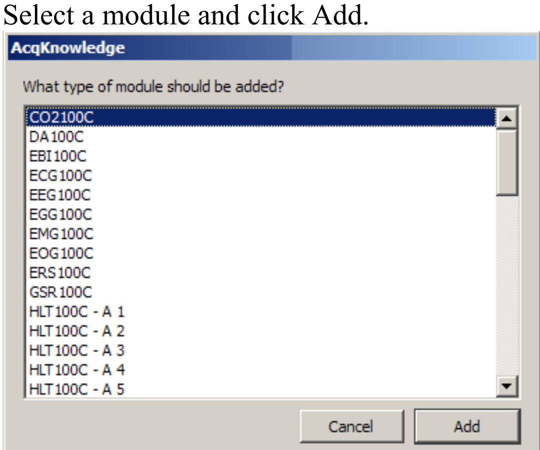
The new module setup is recommended for easier setup and automatic scaling. In module mode, setup prompts the user to add individual modules based upon the module number. For modules with transducers, the unique transducers are added. The user is then prompted to input the settings of all of the switches on the modules and then perform any calibration steps, if required. Using this information, the module setup automatically sets the scaling and initial visual range to match the physical input units from the module or transducer. Additionally, module-based setup detects potential channel conflicts between software channel assignment and module channel assignment (red switch position).

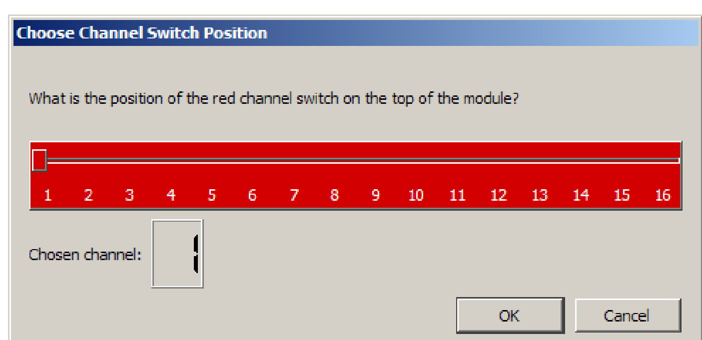
1. From MP150 > Setup Channels, select the analog tab and click View by Modules...



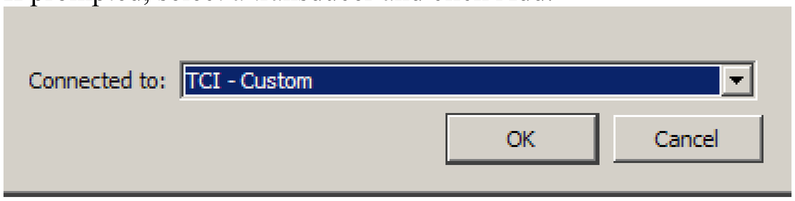
2. Click Add New Module from the bottom of the dialog.

3. Select a module and click Add.

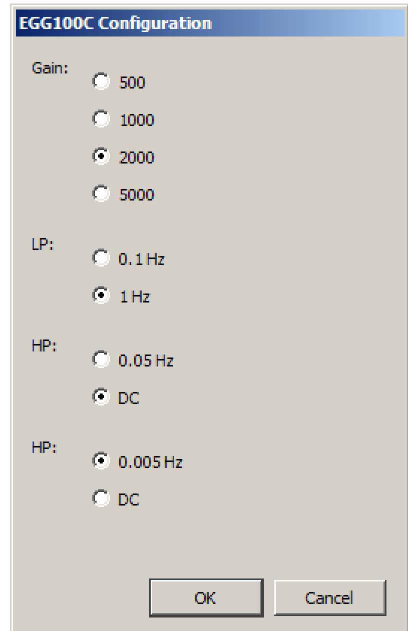




4. If prompted, select a transducer and click Add.



5. Input the settings of the switch on the selected module and click OK. Set the choose channel switch to the number set on the amplifier (some amplifiers, such as the OXY100C, have a switch on the front of the module).
   - Setup detects any potential channel conflicts between software assignment and the module's red channel switch position.

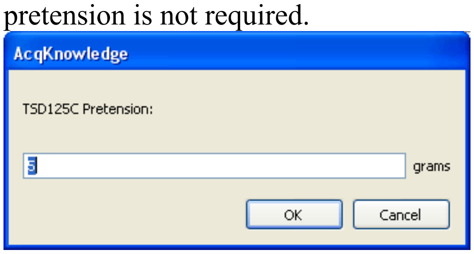


6. Establish the configuration parameters (gain and filters) and click OK. It is important to set the Gain and Filter settings to correspond to the switch settings on the amplifier. The software uses this information to scale the signal to the correct units. If the Gain is not set to match, the signal will be scaled incorrectly.

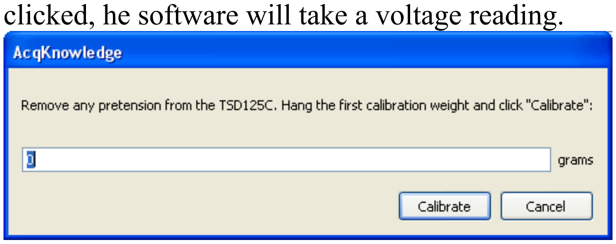
7. Perform calibration steps, if required. The software will automatically scale certain signals, if they only require a zero setting. However, some signals require a two-point calibration. In this case, the software will generate additional prompts for the scale values.

   The following examples show the dialogs for setting up a force transducer.

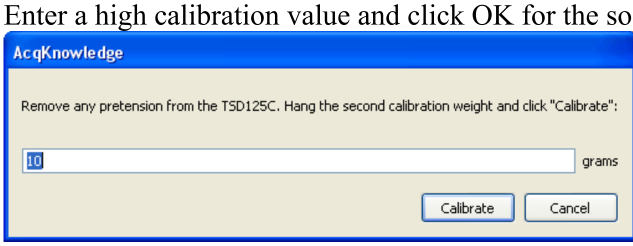
   a. The software prompts the user for pretension amount; enter "0" if pretension is not required.



   b. Enter a low calibration value or "0" if calibrating between zero and a second weight, when OK is clicked, he software will take a voltage reading.



   c. Enter a high calibration value and click OK for the software will take a voltage reading.



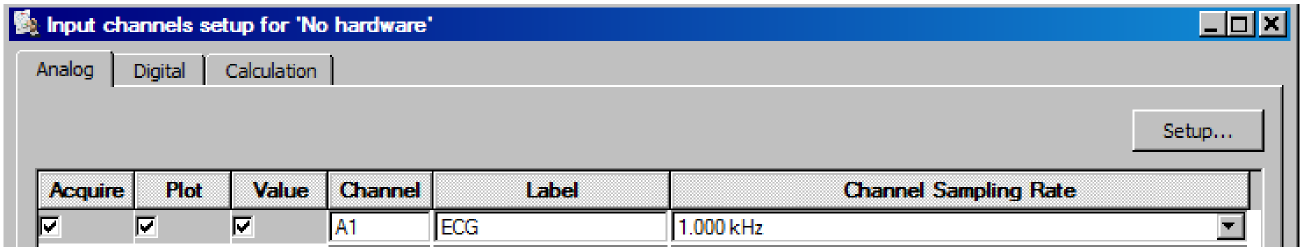
Note When recording is started, the data may show an offset. This offset is the amount that was entered in the pretension dialog. Adjust the tension applied to the transducer to center the signal on zero.

Using this information, the module setup automatically sets the scaling and initial visual range to match the physical input units from the module or transducer.

View by Channels

Channel Type

To specify the channel type—Analog, Digital, or Calculation—click its tab at the top of the dialog.



For each channel you wish to collect data on, there are three options for channel setup: acquire, plot, and values. These options appear as boxes on the left side of the Input Channels dialog.

Acquire

The first option is whether or not you wish to collect data on that channel. The default MP150 setup is not set to acquire any channels; the default setup will only collect data on channel 1. To collect data on other channels, position the cursor over the Acquire box (on the far left) and click the left mouse button.

To leave hardware connected to the data acquisition unit, but have the software essentially “ignore” the channel, leave the acquire box unchecked. For example, if an input device (such as an ECG100C amplifier) is set to channel 7, data from that channel will not be collected unless the Acquire box is checked.

Plot

The second option is for plotting data. You will need to specify a Plot option for each channel. The Plot option determines whether or not data will be plotted on the screen for each channel. Checking this option instructs the software to plot data on your computer’s screen.

When this box is left unchecked, data will still be collected (assuming the Acquire box is checked) but it will not be displayed during the acquisition.

In most cases, you will want to check this option. However, in large-scale acquisitions (i.e., many channels and/or high sampling rates) you may want to uncheck this option for some channels to allow for faster display rates or to increase the display area for important channels (see Appendix B—Hints for working with large files). Alternatively, use a separate data view and enable channels for as desired for optimum viewing.

The Plot state is applied only on initial acquisition into a graph or template. If data has been previously acquired, use the channel buttons in the graph window to change channel visibility.

Values

The third option enables incoming data values to be displayed either numerically and/or in a “bar chart” format in a separate window during an acquisition. Checking this option allows you to open a window (by selecting Show Input Values... under the MP150 menu) that displays the numeric value for each input with the “Values” option checked. This option is especially useful for tracking slowly changing values such as heart rate, respiration rate, or concentrations of chemicals in a substance. For more information on how input values are displayed, please turn to page 221.

Channel

Click in the channel number box (i.e. A1) to make that channel active (“selected”) so its settings can be established or edited.

Label

You may attach an editable "label" to each channel. These labels allow you to provide a brief name for each channel. To change the label for any channel, position the cursor in the area to the right of the channel numbers (A1 through A16) under the label heading and enter a text label. You may key up to 38 characters and these labels will appear next to the channel label boxes in the graph window. To edit the label after setup, use the Set Up Channel dialog at any time, or right-click the active channel label in the graph window to generate the Assign Channel Label dialog.

Presets

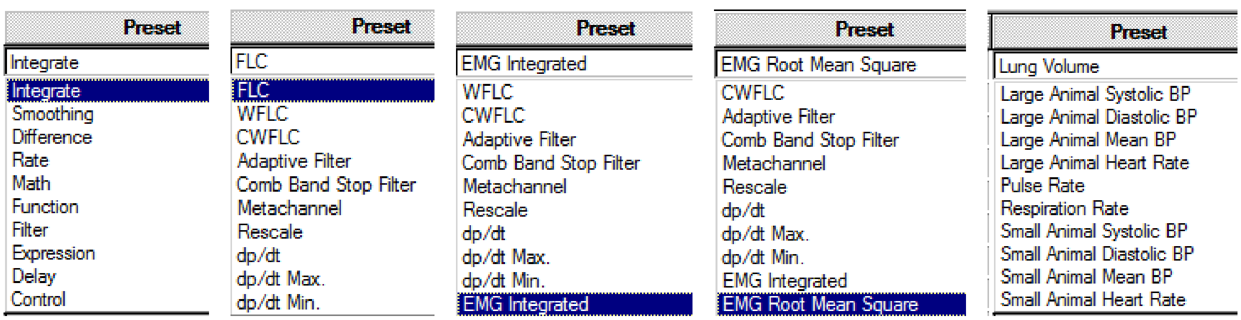
Calculation Presets are like "templates" for calculation channels. Each Preset stores:

a) Calculation channel type
b) parameters for that Calculation
c) channel-specific scaling
d) channel-specific sampling rate
e) channel name.

Calculation Presets establish settings to target application-specific analysis. Presets exist for a broad range of analysis functions, including Fourier Linear Combiners and Adaptive Filtering. Start with existing presets for a specific species or protocol—for example, human vs. small animal, or stationary vs. exercising measurements.

The Channel Setup dialog contains a "Preset" pop-up menu by each channel that lists the current Preset or, if no Preset has been selected for that channel, the Calculation type (Integrate, Difference, etc.). When you select a Preset for a particular channel, the channel is configured with the settings associated with that Preset.

The Setup dialog has a "Presets" pop-up menu that contains all of the Presets for the Calculation type being configured. For instance, if a Difference Calculation channel is being configured, all Presets for the Difference Calculation will be listed. Just click the Presets head and scroll to select the desired preset.



Calculation Presets

When you select a Preset, the Setup dialog is updated with the corresponding information.

- The Setup dialog reads "none" if the channel configuration doesn't match any Preset. The menu will flip to "none" when the settings for a channel are changed such that they no longer match a Preset.
- You can create a new Preset from existing Calculation channels. Click "Setup" to display the Calculation Setup dialog and click the "New Preset" button. The settings will be applied to the current channel, and you will be prompted to enter a name for the new Preset. You cannot duplicate a Preset name, which also means that you cannot use the default name of a Calculation channel type (Integrate, Difference, etc.). The new Preset will be included in the pop-up menus and saved with the file.
- To reorder channel Presets (by type, use, etc.), choose MP150 > Organize Channel Presets and then use the up/down buttons as appropriate (see page 233).
- Presets are not applicable to and therefore not selectable on Analog or Digital channels.

Channel Sampling Rate

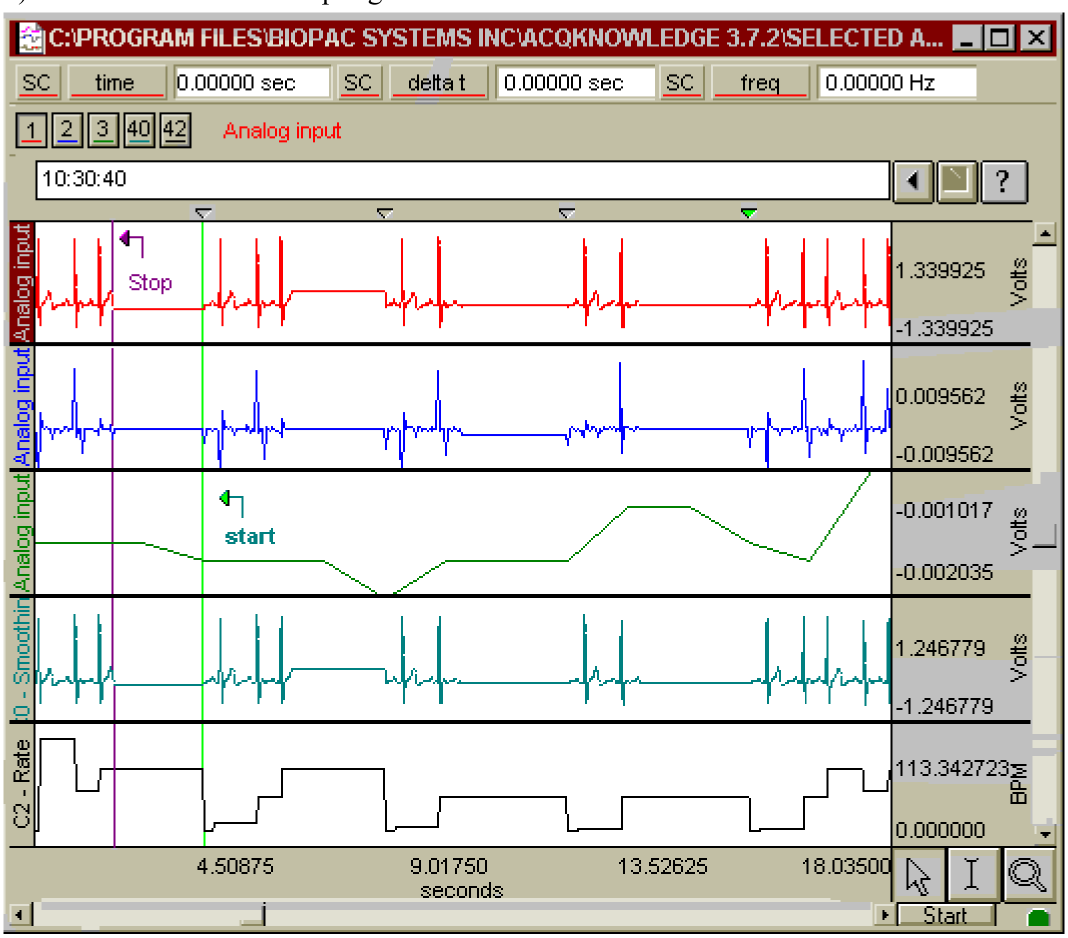
The Variable Sampling Rate feature allows different channels of data to be down-sampled from the acquisition sampling rate; calculation channel must use sampling rate less than or equal to the source channel. Choosing lower sampling rates for signals where meaningful data falls below the Nyquist frequency of the acquisition sampling rate allows more data to be stored in memory or on disk.

- Offline operations that involve multiple channels must use the same sampling rate for all Source and Destination channels. These operations include waveform editing, Waveform math, Expression calculations and Template functions; notable exceptions are "Off-line Averaging" under Find Cycle/Peak and "Reset via a Control Channel" under Integrate.
- When wave data is copied to the clipboard or journal, data values will be inserted at the highest sampling rate (channels with a lower sampling rate will snap to the left).
- To set an arbitrary channel sample rate for analysis, use Transform > Resample (see page 292).
- There is no restriction on the acquisition length when using Variable Sampling Rates.
- When Variable Sampling Rates are used in conjunction with the Append mode, and the mode is started and stopped manually, it is statistically possible that, prior to the next pass of the Append, extra data points may be inserted in various data channels to "line up" the data (see sample on page 107). These extra data points simply replicate the last sample in any affected channel.

  To minimize the impact of the extra data points:

  a) Make sure the lowest sampling rate is on the order of 10 Hz or higher, or

  b) Don't use Variable Sampling Rates.



Set Up Channels—Advanced

The previous section covered the basic options used in almost all acquisitions. In addition to the features described above, a number of other options are available in terms of setting up channels. These advanced features are also found under the Set Up Channels menu item.

Most acquisitions involve collecting analog signals and then displaying them on screen. It is frequently useful, however, to collect other types of data (digital data, for instance) or to perform transformations on analog data as it is being acquired. Channels containing digital signals and transformed analog signals can be collected in addition to the 16 analog channels.

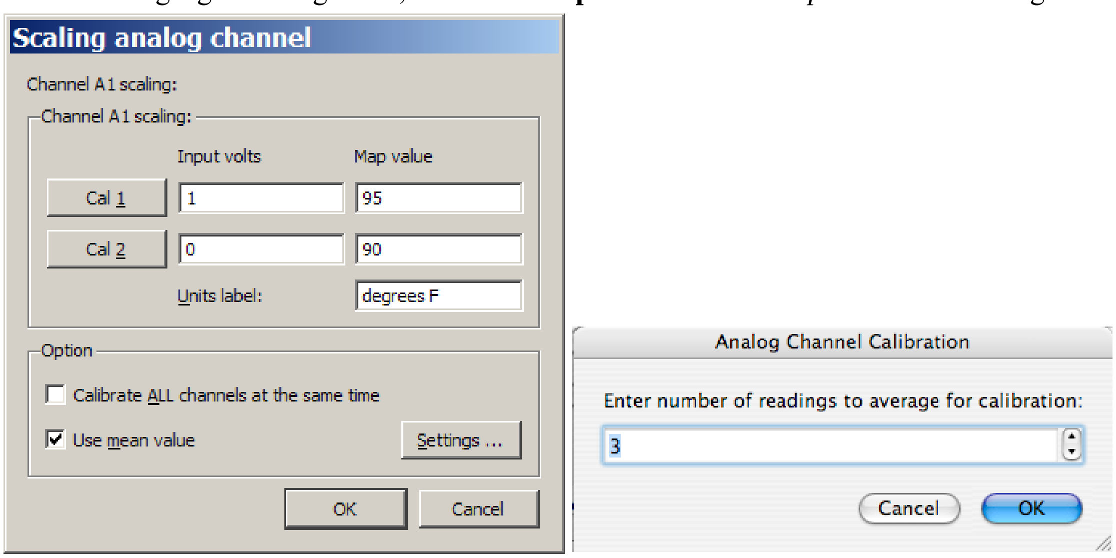
In the upper right hand corner of the Set Up Channels dialog, you will see the words Analog, Digital, and Calc. These refer to (respectively) analog channels, digital channels, and Calculation channels. The general features (acquiring, plotting, and the like) are the same for each type of channel, although there are considerable differences between the type of data each channel is designed to handle. You may acquire up to 16 channels each of analog, digital, and Calculation channels. Analog and digital channels may be acquired in any combination, and the only requirement for Calculation channels is that you have at least one input channel (either analog or digital).

Analog channels

Analog channels are the most common type of acquired channel and should be used to acquire any data with "continuous" values. Examples of this include nearly all physiological applications where input devices (transducers and electrodes) produce a continuous stream of varying data. The range of values for analog channels is ±10 Volts.

Acq*Knowledge* also allows you to rescale the signal on analog channels to more meaningful numbers. As an example, imagine a temperature transducer is connected to an SKT100C amplifier with a gain setting of 5°/Volt, and output set to channel 1. Ordinarily, the values from the amplifier would be read in as Volts or milliVolts. For this acquisition, you need to express the signal from the transducer in terms of degrees Fahrenheit. To calibrate the transducer, bring it to two known temperatures. At the first temperature, take a voltage reading by selecting Show input values from the MP150 menu (see page 221 for a description of the Show Input Values options). At 90° F, you will get a reading of 0 Volts. The transducer is then brought to a temperature of 95° F, and you will get a reading of +1 Volts.

To scale the incoming signal to degrees F, click the **Setup…** button in the *Input Channels* dialog.



Scaling dialog set to rescale Volts to degrees Fahrenheit and Use Mean Value Settings dialog

The Input Volts and Map (Scale) Value boxes reflect the value of the incoming signal and how it will be plotted on the screen, respectively. Thus, an incoming signal of +1 Volts would be plotted as 95° F, whereas a signal of 0 Volts would be plotted as 90° F. Acq*Knowledge* will perform linear extrapolation for signal levels falling outside this range (i.e., -2 Volts will be scaled to 80 ° F), as well as perform similar interpolation for values between this range. Enter these numbers in the scaling dialog, type in "degrees F" for Units, and click OK.

As a shortcut for scaling channels, use the Cal 1 and Cal 2 buttons. Click either of these buttons to read in the current voltage for the selected channel. In the above example, the transducer could simply be set to a known temperature, then Cal 1 could be clicked, and then the temperature could be entered in the Map (Scale) value box for Cal 1.

Next the the transducer could be brought to another known temperature that is considerably higher or lower than the first and click Cal 2 and the new known temperature could then be enter in the Map (Scale) value box for Cal 2. Acq*Knowledge* calculates the slope and offset from the two points entered. Each data sample from channel 1 will now be scaled according to the slope and offset calculations previously made. When an acquisition is performed, the amplitude scale (vertical axis) will reflect the rescaled units.

> *It is important to note* that Cal 1 and Cal 2 cannot be used when data is being acquired. In other words, a channel must be calibrated before it can be acquired. To set the calibration for a given channel, connect the input device to the MP data acquisition unit and power up the MP System (MP150 or MP36R), and then perform your calibration before starting data acquisition.

The Calibrate all channels at the same time option is used when identical types of transducers or signals are being simultaneously recorded on two or more channels.

If this option is selected, when Cal 1 or Cal 2 is pressed:

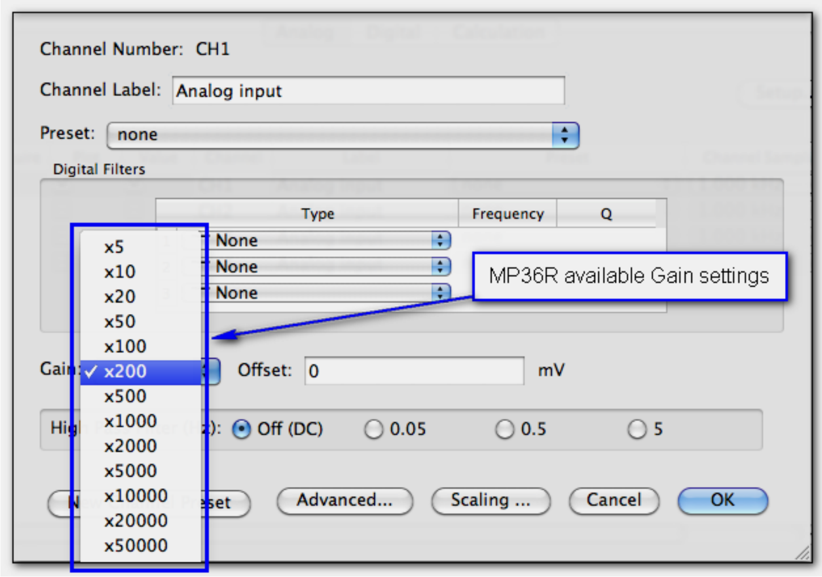
- Map (Scale) Value will be updated for all active channels
- Input Volts need to be updated for each channel individually.

The **Use mean value** option is useful if the input voltage signal is noisy around a mean value. The “Input Volts” value returned will be the mean value over the specified number of readings. When this option is selected, a Settings… button is activated and generates an “Analog Channel Calibration” prompt for the number of readings.

The data is read the number of times indicated in the prompt and then the readings are averaged. The rate of obtaining these readings is indeterminate because the rate depends on the actual hardware unit as well as the communication type.

Analog channels MP36R

The MP36R analog channel scaling setup works as shown above, but additionally allows the channel gain to be configured directly with a variety of input ranges. Gain settings are accessible via a pop-up menu in the Channel setup dialog. (MP36 > Set Up Channels) The **Gain** setting specifies the extent to which an incoming signal is amplified. The Gain is automatically set when a data type is selected from the available **Presets**. The preset Gain settings are only educated guesses and should be used as initial starting values. You may need to adjust the gain settings depending on how the amplified signal appears once sample data is collected.



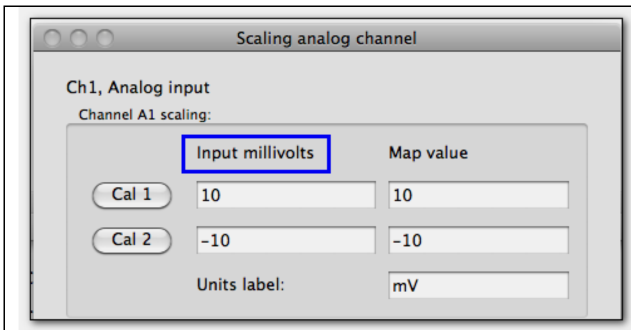
Offset

To correct the offset of an incoming analog signal, you can add or subtract a constant to the signal prior to amplification. Offset can occur if a transducer or electrode has inherent offset. By default, **Offset** is set to zero, and the allowable entry range will vary depending on the **Gain** and **Scaling** values.

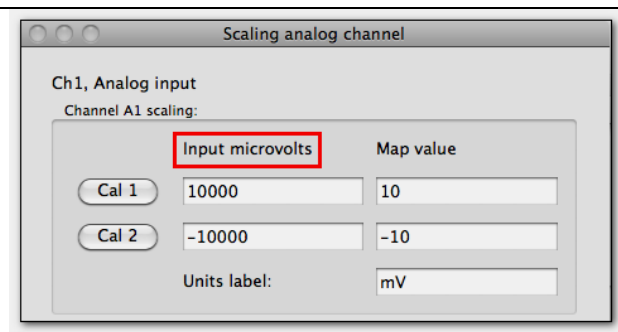
To make inputting voltages easier, the analog channel scaling dialog for the MP36R displays the input voltages in units that adapt to the gain setting. (x200 is the default)

The scaling units will adjust dependent upon the gain setting as follows:

- If the gain is set to < x1000, the Scaling input units will display as millivolts (mV).
- If the gain is set to > x1000, the Scaling input units will display as microvolts (µV).



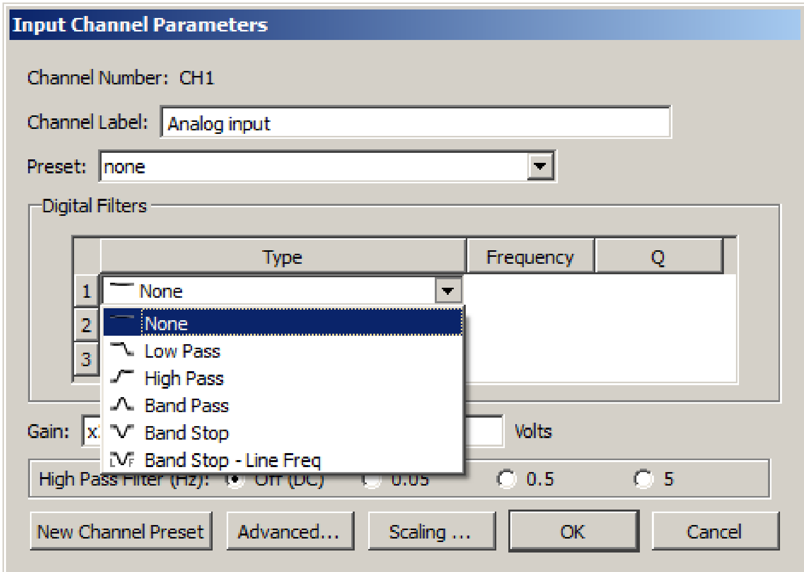
Channel gain set to **< x1000** displays mV input units



Channel gain set to **> x1000** displays µV input units

Fixed Hardware Filters MP36R

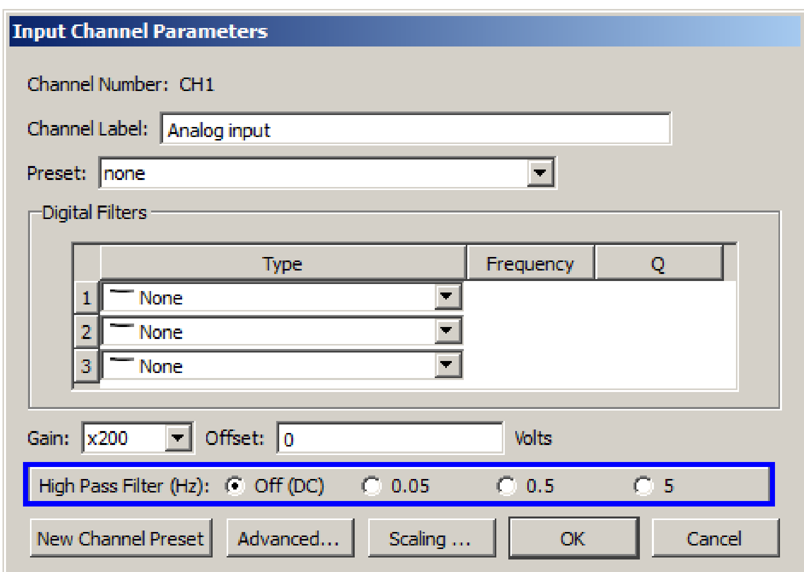
The MP36R Unit allows up to three user-configurable, sequential, biquadratic (second order) Infinite Impulse Response (IIR) filters. These filters are typically configured by choosing a **Preset** but can be changed manually via the Input Channel Parameters dialog (MP36 > Set Up Channels > Setup button).
In the "Digital Filters" section, select Filter 1, 2, and/or 3 and then adjust the *Type*, *Freq*, and *Q*.



The default setting is no filters applied.

Adjustable Hardware Filters MP36R

These filters are implemented using resistors and capacitors in the front end circuitry of the MP36R unit. They are set via the "**High Pass**" section of the Input Channel Parameters dialog (MP UNIT > Set Up Channels > Setup").



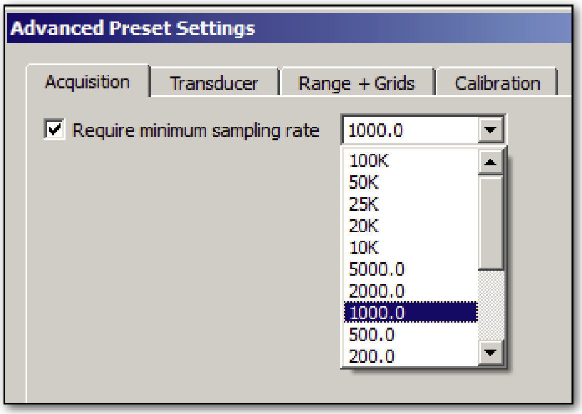
High Pass Filter	Appropriate use
0.05 Hz HP	ECG Respiration data
0.5 Hz HP	ECG when there is a lot of motion artifact causing a shifting baseline EEG Pulse plethysmograph Most other types of AC Coupled data
5 Hz HP	EMG Heart Sounds

Additional controls in MP36R Input Channel Parameters

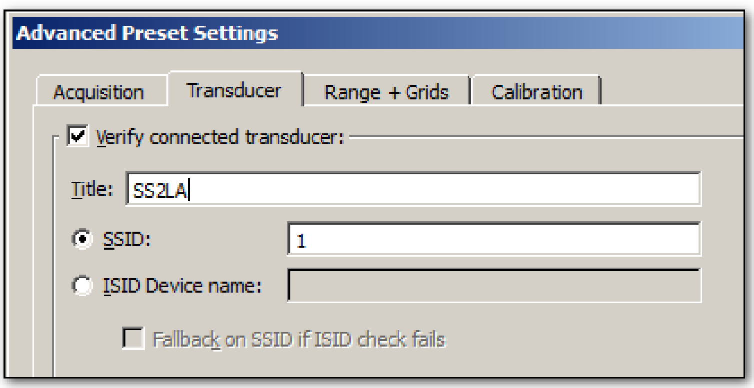
Button	Explanation
New Channel Preset	Allows a custom Preset to be saved under a unique name
Advanced	Opens Advanced dialog. The Advanced dialog may be used to specify additional settings, requirements, and dependencies for the preset. See below for complete explanation of all Advanced options.
Scaling	Use to configure the value of the incoming signal and how it will be plotted on the screen

MP36R Advanced Preset Settings

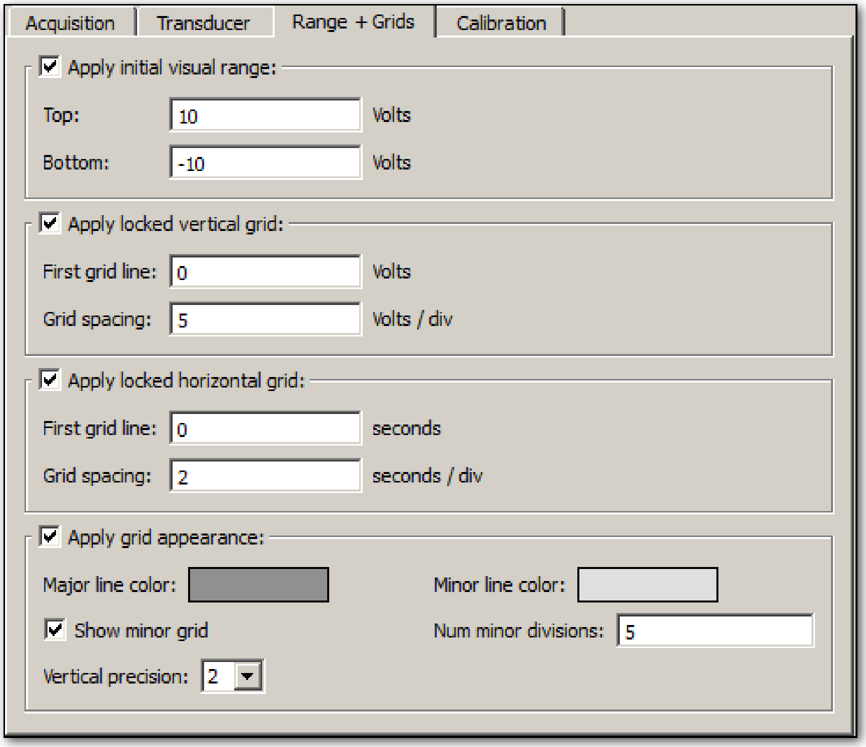
Click the Advanced button to open a dialog containing the following optional preset configuration options.



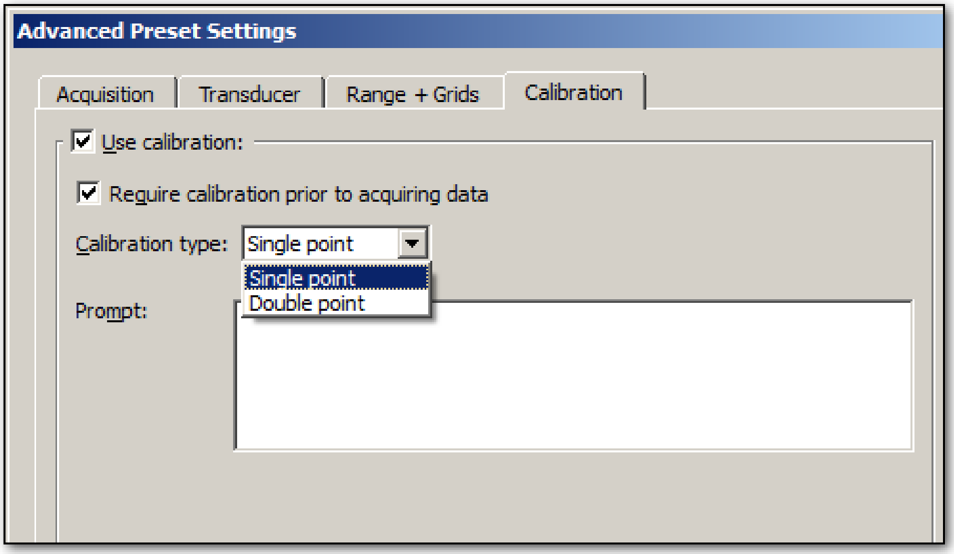
Acquisition Tab	Explanation
Require minimum sampling rate	When enabled, specifies that a minimum sampling rate must be selected in order for acquisition to continue.



Transducer Tab	Explanation
Verify connected transducer	When enabled, the software will check for a specific transducer according to the settings in this group box prior to the start of each appended segment
Title	Editable text field used to identify transducer name.
SSID	If checked, indicates which SmartSensor resistor ID should be validated for this channel prior to each acquisition. The ID must be an integer between 1 and 23.
ISID Device Name	If checked, indicates that the internal transducer description should be validated for this channel prior to each acquisition.
Fallback on SSID if ISID check fails	If the ISID device name check is unsuccessful for a connected transducer, fall back and check the SmartSensor resistor ID.



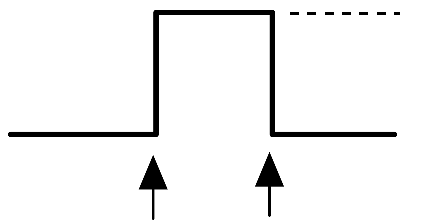
Range + Grids Tab	Explanation
Apply initial visual range	The initial vertical axis range of plotted data will be set as indicated at acquisition start of the first data segment.
Top	Indicates the maximum vertical visual range in destination channel units.
Bottom	Indicates the minimum vertical visual range in destination channel units.
Apply locked vertical grid	Locked vertical grid settings are applied for the channel. For more details on grid setups, see Grid Details on page 75.
First grid line	Provides the fixed location of the origin of the vertical grid.
Grid spacing	Sets the spacing interval between major vertical grid divisions.
Apply locked horizontal grid	A channel-specific independent horizontal grid will be applied when the channel is added to a graph.
First grid line	Sets the origin location of the horizontal grids.
Grid spacing	Sets spacing between major horizontal grid lines based on the time domain.
Apply grid appearance	Enables options for setting grid color/appearance of major and minor grid lines.
Major line color	Alllows customization of major grid line color.
Minor line color	Alllows customization of minor grid line color.
Show minor grid	Shows/hides minor gridlines
Vertical precision	Indicates number of digits displayed on vertical axis.
Num minor divisions	Sets the number of minor grid divisions for the channel.



Calibration Tab	Explanation
Use Calibration	Additional calibration procedures will be applied to adjust the channel scaling based on values read from a physical transducer.
Require calibration prior ro acquiring data	When checked, calibration will always be required for this channel prior to acquiring the first segment of data.
Calibration Type	Specifies calibration option to be performed on the channel. Two types are available: • Single point – records a single input voltage and adds it to the Input Volts value of both Cal1 and Cal2 • Double point – records two independent voltages in a sequence of two dialog steps and records the first in the input volts for Cal1 and the second for the input volts in Cal2
Prompt	Displayed only for “single point” calibration. Field for inputting dialog text to be displayed to the user for acquiring the single voltage input to apply to the scaling input voltage values.

Digital channels

In contrast to analog channels, digital channels are designed to collect data from a signal source with only two values (0 and 1). This type of data can be useful in recording whether a switch is open or closed, and ascertaining if a device is on or off. Input values for digital channels have two values, +5 Volts and 0 Volts. The MP150 interprets +5 Volts as a digital 1 and interprets 0 Volts as a digital 0. Since digital channels have a fixed value, the scaling option is disabled for these channels. The main function of digital channels is to track on/off devices such as push-button switches and/or to receive digital signals output by timing devices. Similarly, these channels are also used to log signals from devices that output auditory/visual stimulus for examination of stimulus response patterns.



Calculation channels

Compared to either analog or digital channels, Calculation channels do not collect external data, but transform incoming data in some way. These channels do not alter the original data, but create new channels (with channel numbers starting at CH40) that contain the modified data.

You can use Calculation channels to compute a host of new variables by using transformations (including BPM, integration calculations, and math functions). The channels are Set Up in much the same way (using Acquire/Plot/Values boxes) as analog or digital channels, with the exception of the pull-down menu next to the Calc button and the Setup dialog.

To acquire a Calculation channel, click the Calc button and check the Acquire box for each Calculation channel you want to compute (the Plot and Value boxes are optional). By default, all Calculation channels have the label “Calculation” and entering more descriptive channel labels might prove useful, especially when multiple Calculation channels are being acquired.

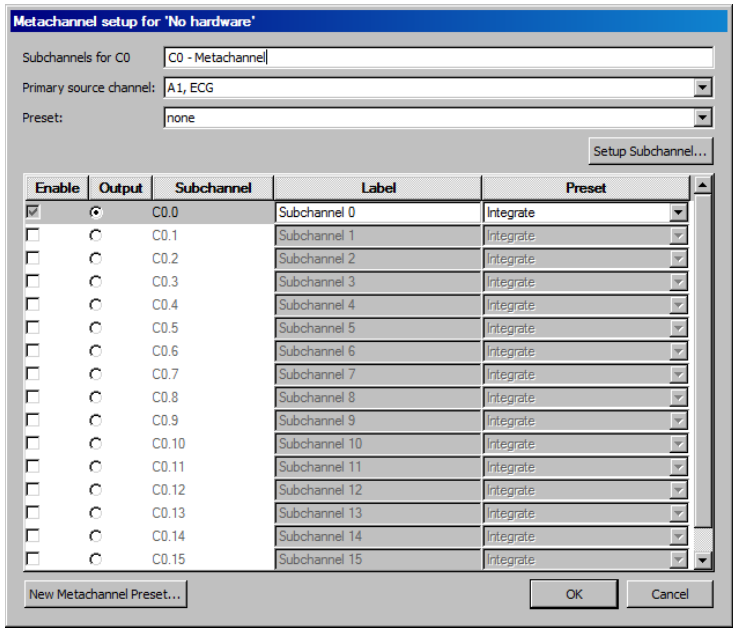
Each of these functions requires some additional parameters to be specified, and these options can be set by clicking the Setup button in the Input Channels dialog. For any Calculation channel, you will (minimally) need to specify the source channel to be transformed and the nature of the transformation.

Up to 16 Calculation channels can be acquired, and you may use the output of one Calculation channel as the input for another channel, as long as the output channel has a higher channel number than the input channel. In other words, it’s possible for Calculation channel 3 to include the result of Calculation channel 1, but not the other way around. This allows for complex Calculations to be performed that involve two or more Calculation channels such as filtering ECG data then computing BPM.

Although Calculation channels can be useful in many cases and indispensable in others, each Calculation channel acquired will somewhat reduce the maximum possible sampling rate, and add to the amount of memory required to store data both during and after an acquisition. Thus, you may want to consider performing some of these functions after the fact if high sampling rates are needed for your particular application.

> TIP: All of the operations (except Control) that can be performed online can also be performed after an acquisition has been completed. These options are available under the Transform and Analysis menus.

Metachannel



Calculation metachannels provide a method for expanding the 16 available calculation channels to allow for more complex online analysis. The metachannel calculation channel type combines multiple steps into a single calculation channel so that a chained computation can be performed using a single calculation metachannel.

- Acq*Knowledge* can display the results of up to 16 metachannels, allowing for a total of 256 intermediate subchannel steps.

One metachannel can contain up to 16 subchannels, each of which can be individually configured. Subchannels can perform any of the functions of top-level calculation channels.

Each metachannel has one user-defined output channel. The output subchannel is the only waveform data that will be recorded in the graph for that metachannel. All other subchannels associated with that metachannel are temporary; they do not display in the graph and require no extra space in the graph file to compute.

Metachannels alleviate the need to use top-level calculation channels for computing intermediate steps where only the final computation is desired. Metachannels also can be used as the basis of presets, allowing multi-step analyses to be applied with a single preset.

Computation takes place at the lowest waveform sampling rate of all of the referenced source channels, and all subchannels are computed at this rate.

Metachannels labels display in the graph as C#.#

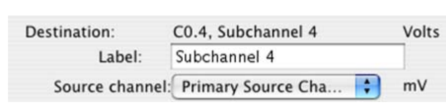
To have Acq*Knowledge* perform a Metachannel calculation in real time:

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Metachannel.
5. Click the Setup button in the Input Channels dialog to generate the Metachannel dialog.

Primary Source

The primary source for a metachannel can be set to any analog, digital, calculation, or subchannel with a lower index (index 0-15, with 15 being lowest).

Set Up Subchannel



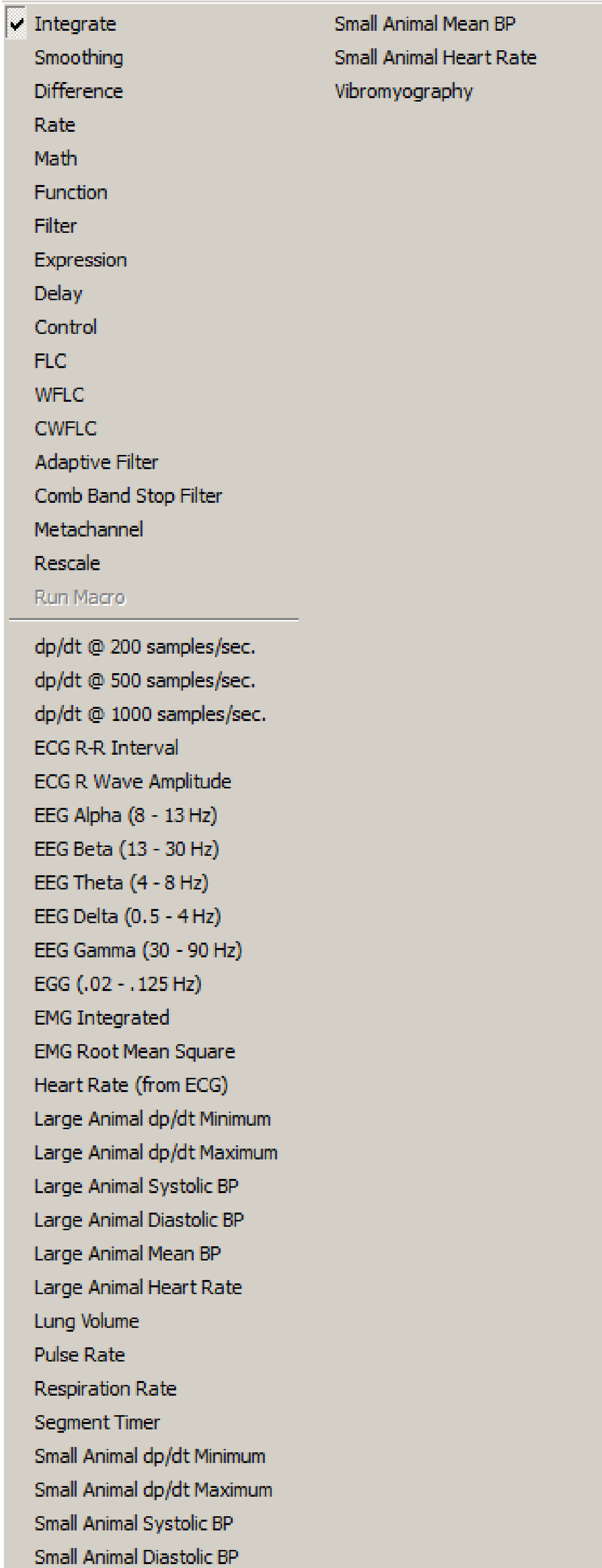
Click this button to display the calculation setup dialog for the selected subchannel and then set the calculation parameters and the source channel.

Source channel: Each subchannel can be set to use the primary source channel as its data source or another channel (analog, digital, or lower-index calculation channel). When the primary source channel for the metachannel is changed, the source channel of each subchannel will implicitly be changed.

Acq*Knowledge* ***QUICK STARTS***

Quick Start templates (.gtl graph template files) were installed to the Sample folder for PC users. You can use a ***Quick Start*** file to establish the settings required for a particular application or as a good starting point for customized applications. *See* Open As Graph Template on page 240 for details.

Q##	Application(s)	Feature
1	EEG Sleep Studies	Real-time EEG Filtering Real-time EEG Filtering
2	EEG	Evoked Responses
3	EEG Evoked Response	Event-related Potentials Event-related Potentials
4	Evoked Response	Nerve Conduction Studies
5	Evoked Response	Auditory Evoked response & Jewett Sequence
6	Evoked Response	Visual Evoked Response
7	Evoked Response	Somatosensory Evoked Response
9	Evoked Response	Extra-cellular Spike Recording
10	Psychophysiology	Autonomic Nervous System Studies
12	Psychophysiology	Sexual Arousal Studies
13	EBI Cardiovasc. Hemodynamics Exercise Physiology	Cardiac Output Noninvasive Cardiac Output Measurement Noninvasive Cardiac Output
15	EOG	Nystagmus Investigation
16	EOG	Saccadic Eye Movements
17	Plethsymography	Indirect Blood Pressure Recordings
18A	Plethsymography	Arousal - Female
18B	Plethsymography	Arousal - Male
19	Sleep Studies	Multiple-channel Sleep Recording
20	Sleep Studies ECG Cardiovasc. Hemodynamics	Online ECG Analysis Online ECG Analysis ECG Analysis
21	Sleep Studies	SpO_2 Analysis
22	ECG	Einthoven's Triangle & 6-lead ECG
23	ECG	12-lead ECG Recordings
24	ECG	Heart Sounds
25	Cardiovasc. Hemodynamics	Online Analysis
26	Cardiovasc. Hemodynamics	Blood Pressure
27	Cardiovasc. Hemodynamics	Blood Flow
28	Cardiovasc. Hemodynamics	LVP
31	NIBP	Psychophysiology
32	*In vitro* Pharmacology	Tissue Bath Monitoring
33	*In vitro* Pharmacology	Pulsatile Tissue Studies
34	*In vitro* Pharmacology	Langendorff & Working Heart Preparations
35	*In vitro* Pharmacology Pulmonary Function	Isolated Lung Studies Animal Studies
38	Pulmonary Function	Lung Volume Measurement
39	Exercise Physiology	Respiratory Exchange Ratio
40	EMG	Integrated (RMS) EMG
41	EMG	EMG and Force
42	Biomechanics	Gait Analysis
43	Remote Monitoring	Biomechanics Measurements
44	Biomechanics	Range of Motion



Chapter 6 Calculation Channel Presets

Calculation Presets establish settings to target application-specific analysis. Presets exist for a broad range of analysis functions, including Fourier Linear Combiners and Adaptive Filtering. Start with existing presets for a specific species or protocol—for example, human vs. small animal, or stationary vs. exercising measurements.

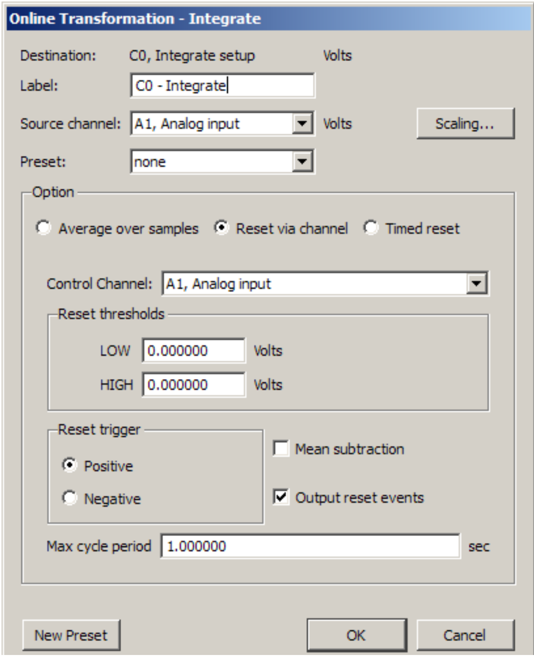
The Channel Setup dialog contains a "Preset" pop-up menu by each channel that lists the current Preset or, if no Preset has been selected for that channel, the Calculation type (Integrate, Difference, etc.). When you select a Preset for a particular channel, the channel is configured with the settings associated with that Preset.

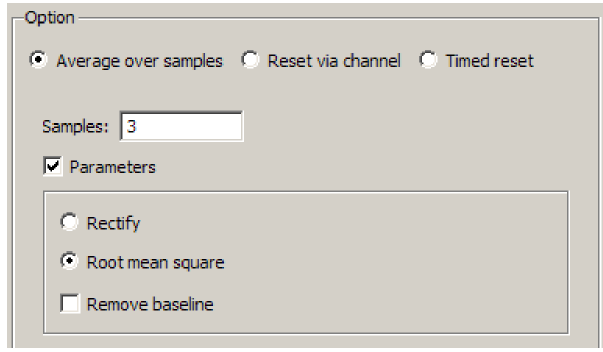
The Setup dialog has a "Presets" pop-up menu that contains all of the Presets for the Calculation type being configured. To enable the Preset pop-up menu, set at least one analog channel to "Acquire" (calculation channels require a source channel). For example, if a Difference Calculation channel is being configured, all Presets for the Difference Calculation will be listed. Just click the Presets head and scroll to select the desired preset.

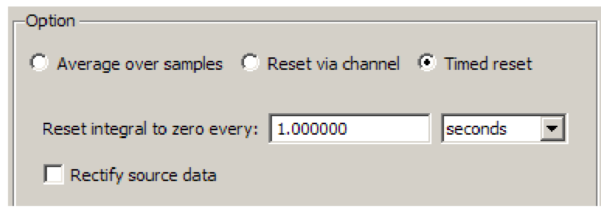
When you select a Preset, the Setup dialog is updated with the corresponding information.

- The Setup dialog reads "none" if the channel configuration doesn't match any Preset. The menu will flip to "none" when the settings for a channel are changed such that they no longer match a Preset.
- You can create a new Preset from existing Calculation channels. Click "Setup" to display the Calculation Setup dialog and click the "New Preset" button. The settings will be applied to the current channel, and you will be prompted to enter a name for the new Preset. You cannot duplicate a Preset name, which also means that you cannot use the default name of a Calculation channel type (Integrate, Difference, etc.). The new Preset will be included in the pop-up menus and saved with the file.
- To reorder channel Presets (by type, use, etc.), choose MP150 > Organize Channel Presets and then use the up/down buttons as appropriate (see page 233).
- Presets are not applicable to and therefore not selectable on Analog or Digital channels.

Integrate Calculation







The online Integrate Calculation offers three basic options:

Reset via channel. Perform a real-time integration of input data over a variable number of sample points. This option is extremely useful for converting flow signals into volumetric equivalents. The integral of flow is volume. For example, when recording airflow with a pneumotach, volume can be precisely calculated as the flow varies in a cyclic fashion:

a) Real-time conversion of flow signals into volume signals (i.e., Blood flow → Blood volume; Air flow → Air volume).

b) Any processing involving a need for a cyclic, continuous integral calculated in real time. For example: Acceleration → Velocity; Velocity → Distance; Frequency → Number of cycles; Power → Energy.

Average over samples. Perform a moving average (mean) and associated processing (Rectify; Root mean square) over the specified number of sample points. This option is useful to process EMG signals to:

a) Smooth noisy data

b) Display the real-time “integration” (rectified, then sample averaged) of the raw EMG data

c) Display the real-time “root mean square” calculation of the raw EMG data.

d) Return real-time windowed standard deviation.

Timed reset. This option is available in Acq*Knowledge* 4.1 and above in the Integrate calculation channel and transformation. This mode computes a straight sum of the source data points and resets this sum after a fixed amount of time has elapsed. This periodic integral is used in several types of analysis, such as EMG analysis where it can generate an EMG signal or estimate the power in fixed time intervals. The time interval at which the integral resets to zero may be specified in seconds or in samples. The timed integrate reset functionality may also be used in calculation channel presets and by the Mac OS X Integrate automator action.

To have Acq*Knowledge* perform an Integrate calculation in real time:

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Difference.
5. Click the Setup button in the Input Channels dialog to generate the Difference dialog.

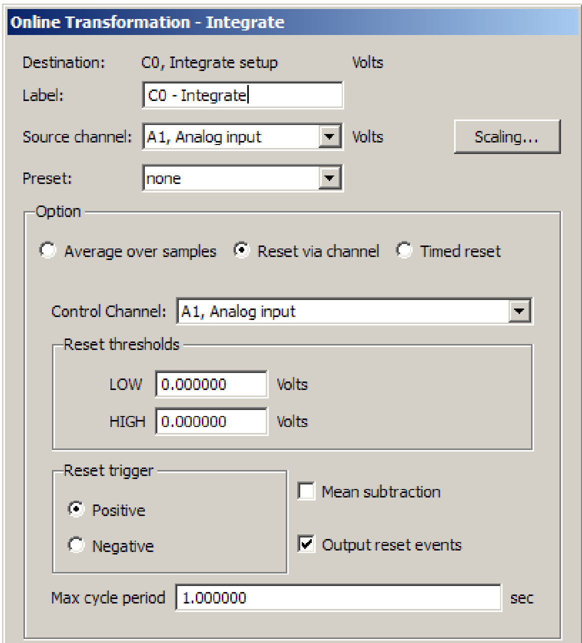
Destination

Determined by the calculation channel selected when the Scaling button was pressed.

Source

The source channel is selected from a popup menu that includes any channels being acquired and any enabled Calculation channels.

Reset via channel (Integrate option)



This feature is used to integrate data over a data-dependent interval. Either the source channel or a different channel can control the integration process.

<u>Control channel</u>

Allows user to select any active channel as the integration control channel.

<u>Reset Thresholds</u>

The threshold is to be set at points surrounding the flow level. Typical values are:

LOW: a negative value close to 0.00
HIGH: a positive value close to 0.00

For airflow to volume conversion, the flow signal will vary positively and negatively around zero flow.

<u>Reset trigger</u>

The Reset trigger polarity determines on which slope (Positive ↑ or Negative ↓) the integration process will begin and end.

<u>Mean Subtraction</u>

This option will subtract the mean from the data evaluated during the integration period. If this option is selected, the integration will only proceed after all the data in the integration period has been collected. When collected, the mean value of all the data is subtracted from each data point in the integration period. In this fashion, the integral of the corrected data points will result in the integral returning to exactly zero at the end of the integration interval. Although this option will result in "well-behaved" integrations, the integrated data will be delayed by a fixed amount of time, as specified by the max cycle period.

Online — Enabling mean subtraction delays the signal by the mean cycle length. It waits for that period of time to pass so it can determine a mean value for the initial cycle, and it then tries to re-compute this mean for each cycle. If the resets are too short or too long, the window expires and the processing halts again until a new mean can be recomputed. Online processing may reset from threshold crossing in the control channel or window expiration when it loses mean tracking.

Offline — Since all the data is available, the mean is computed from the data in the channel and the signal is not delayed. Also, since it isn't doing windowed means, there are no window expiration events that are inserted. Offline processing may reset from threshold crossing in the control channel.

<u>Max cycle period</u>

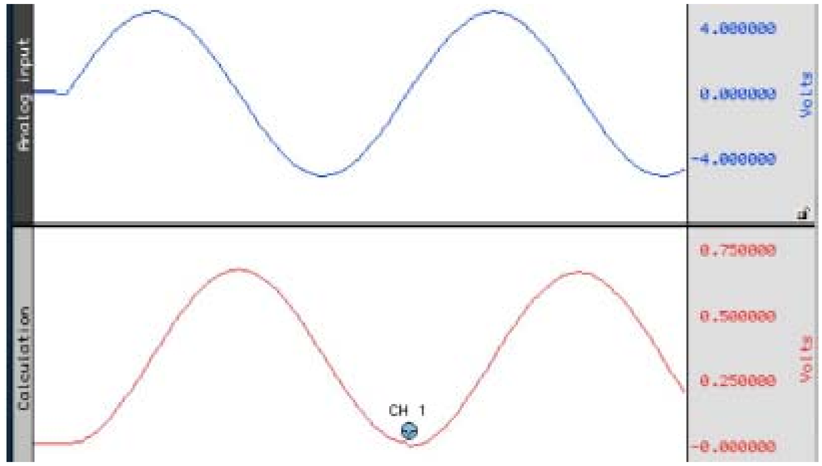
The Max cycle period should be longer than the maximum time expected from trigger event to trigger event in the Control Channel. Typically, the default scale settings for cyclic integrated data will be fine. However, the units may need to be changed (i.e., liters/sec to liters) via the Scaling option.

<u>Output reset events</u>—*not available for metachannels*

Add Events markers to show where Reset occurred and distinguish why the channel reached zero.

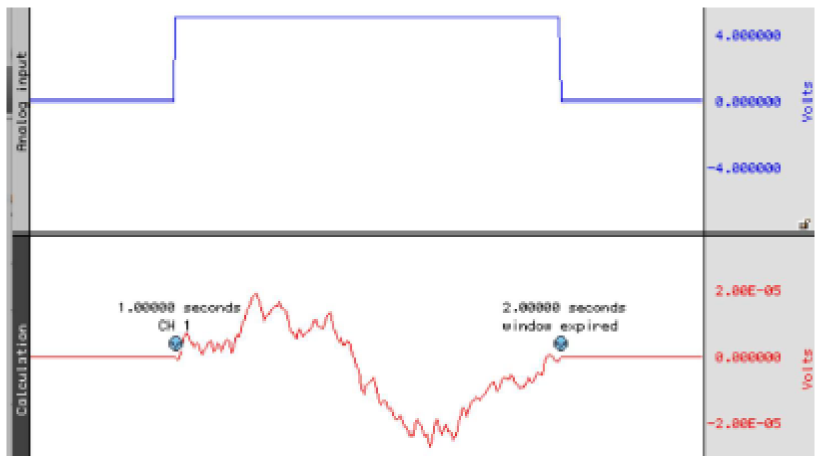
- Threshold crossing on the control channel

  For example: Calculation channel resetting on positive crossings of 0V on CH 1.



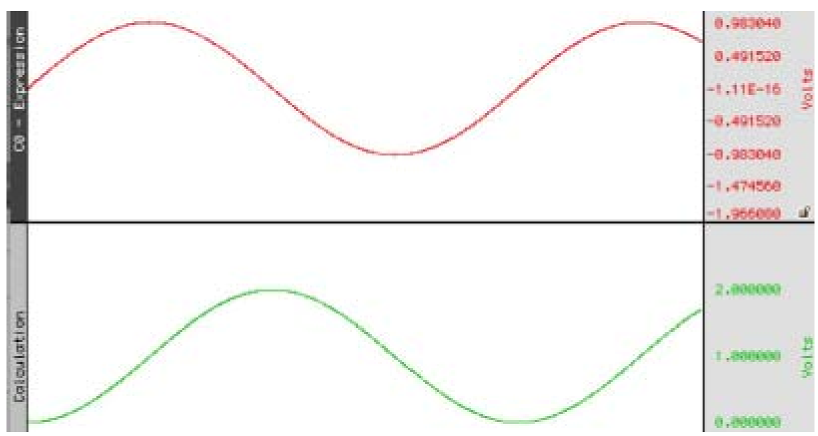
- Window expiry when mean removal is enabled

  For example: No threshold crossing within "mean cycle width" as specified in calc channel setup. Settings of calc channel: threshold crossings positive, 3V, Mean cycle subtraction, 1 second period width. First reset is due to threshold crossing; second reset is due to window expiry.



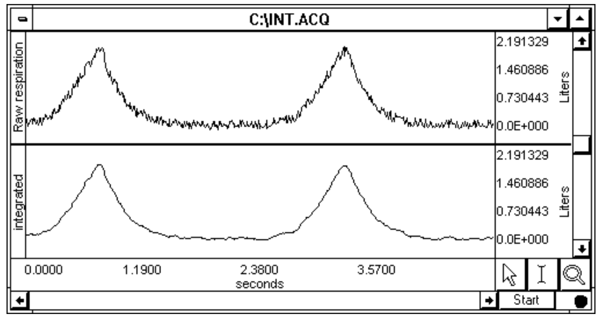
- Zero value due to "true" zero being achieved due to mathematical results

  For example: Mathematical Source is sine wave, integral is cosine. Input (10V) never crosses threshold levels. Signal reaches zero mathematically; no reset events appear on output.



Average over samples (Integrate operation)

Online sample averaging can be useful when there is a high degree of noise present in the data. At least some of this noise can be "averaged out" by pooling some number of adjacent data points together, taking the average of these points, and replacing the original values with the new averaged values. This process creates a "window" of moving averages that moves across the waveform smoothing the data.



Integration used to smooth noisy data

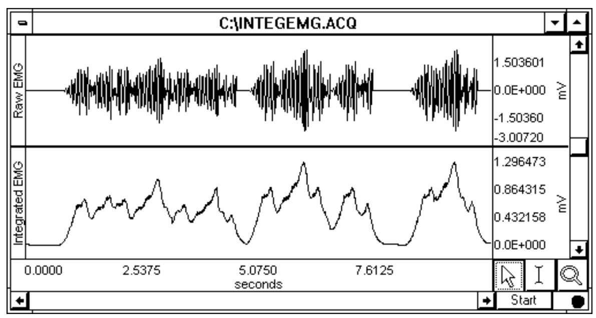
Since an average represents the sum of a series of data points divided by the number of data points present, you can use the Average over samples calculation to provide the information needed to create a moving average.

<u>Samples</u>

To specify the number of data points to average across, enter a value in the Samples box. The number you select will depend in large part on the sampling rate you select and the type of noise present. All things being equal, for slower sampling rates you will probably want to mean average across a smaller number of samples. As you increase the sampling rate, you will probably want to integrate across more and more samples. As the number of samples specified in the samples box increases, the amount of high frequency information contained in the data will decrease.

<u>Parameters</u>

Rectify —The Average over samples calculation can also be used for producing an envelope of modulated data. For instance, EMG waveforms frequently contain high frequency information, which is often of little interest compared to the low frequency information also contained in the data. When the Rectify option is checked, Acq*Knowledge* will take the absolute value of the input data prior to summing and a plot of the waveform's mean envelope over a specified number of samples will be obtained.



Online "Average over samples" feature used as an envelope detector

Typically, this option is only used for processing raw EMG and similar types of applications. The signal for Rectify is normalized by a factor of (# samples averaged)/(Channel sampling rate).

Root mean square—provides the exact root mean square (RMS) of the input data (typically EMG) over the specified number of samples.

Remove baseline—provides the exact standard deviation of the input data (typically EMG) over the specified number of samples. When the mean of the input data equals 0-0, the standard deviation and the RMS will be equivalent.

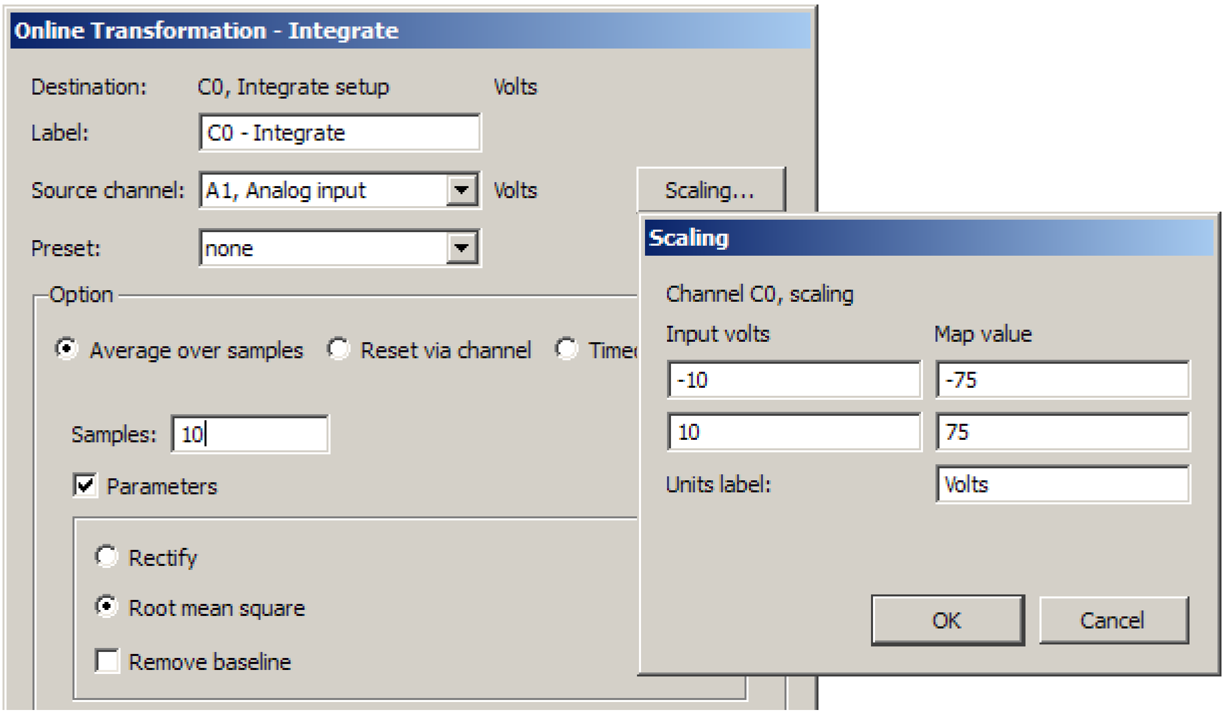
Scaling… button—Since the integration values are going to be on a different scale than the original units, you need to change the scale of the integration channel to reflect the new units. When you click the Scaling… button, a Change Scaling Parameters dialog will be generated.

The rescaling involves multiplying the "Input units" values by a factor determined by the sampling rate and number of samples mean averaged across.

$$\text{Map or Scale value} = \text{Input units } x \; \frac{\text{Sampling rate}}{\text{Number of samples to be mean averaged}}$$

As an example, if data was being acquired at 75 samples per second, and you wanted to integrate across an interval of 10 samples, you would set the Integration Setup Scaling parameters so that +10 Volts corresponded to a Map (Scale) value of 75 and a Map (Scale) value entry of –75 reflected an Input value of –10 Volts.

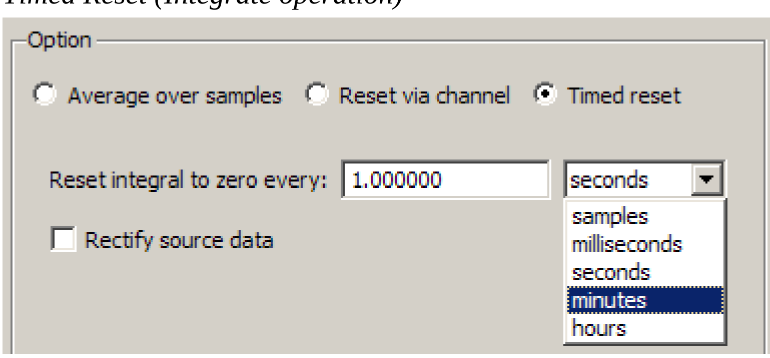
- ➢ It is important to note that this rescaling should be performed independent of any rescaling performed on analog channels themselves. Even if an analog channel is being rescaled to some other units, the input values in the integration scaling should be set to +10 Volts (next to Cal 1) and –10 Volts (next to Cal 2).



Integrate Calculation and Scaling dialoges for 10 point averaging

When data is averaged in this way, a portion of the data at the beginning of the record (equivalent to the number of samples being integrated) should be ignored, as they will reflect a number of zero values being averaged in with the first few samples of data.

Timed Reset (Integrate operation)



Timed Reset is a new option for the Integrate operation in Acq*Knowledge* 4.1. This operation computes a straight sum of the source data points and resets this sum after a fixed amount of time has elapsed. This periodic integral is used in several types of analysis, such as EMG analysis where it can generate an iEMG signal or estimate the power in fixed time intervals.

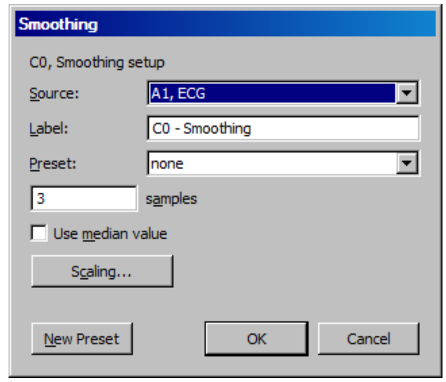
The time interval at which the integral resets to zero may be specified in seconds or in samples.

Timed reset functionality may also be used in calculation channel presets and by the Mac OS X Integrate automator action.

Smoothing Calculation

The Smoothing Calculation functions online in real time and is very useful if you are trying to remove noise of varying types from a data set.

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Smoothing.



5. Click the Setup button in the Input Channels dialog to generate the Smoothing dialog.

(Off-line Smoothing is available under Transform > Smoothing.)

Source	Source is a pull-down menu of the available channels.
Smoothing factor	enter the number of samples to use as a smoothing factor.
Smoothing method	This calculation channel provides real-time Mean (default) or Median smoothing.
Mean value	The default is mean value smoothing. Use Mean value smoothing when noise appears in a Gaussian distribution around the mean of the signal.
Use Median value	Click in the box to activate Median value smoothing if some data points appear completely aberrant and seem to be "wild flyers" in the data set.

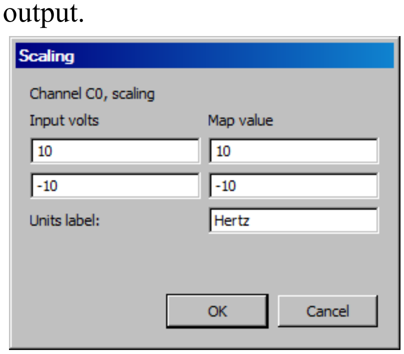
For a given sequence of wave data, $x = \{x_1, x_2,...,x_n\}$, Median value smoothing will sort the sequence and extract the median equivalent to the recommended NIST (National Institute of Standards and Technology) formula:

- *n* is odd: median is the center element of the sorted list of *n* items.
- *n* is even: median is the mean of the center pair of elements of the sorted list of *n* items.

The smoothing calculation channel is the primary method of computing real-time median values using the definition of median as given above. The smoothing output at a sample position is the median of the window of source channel samples including the current sample and the previous samples in the window.

The size of the window is 1 at the start of acquisition and increases incrementally until the final window size is reached. The median extraction method shifts between even and odd definitions as the window size is incremented.

Scaling	Click the Scaling button for access to options that allow you to modify the units or linearly scale the output.



Difference Calculation

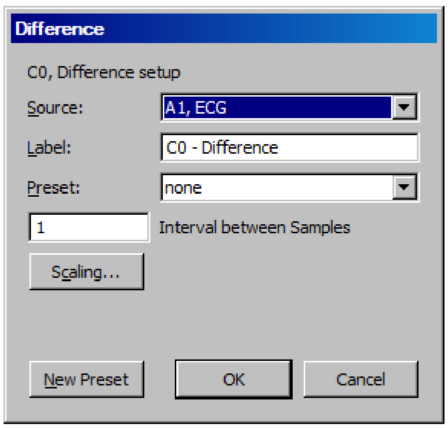
The Difference calculation returns the difference between two data samples over a specified number of intervals and divides the Difference by the time interval spanned by the data values. The Difference Calculation is useful for calculating an approximation of the derivative of a data set in real time.

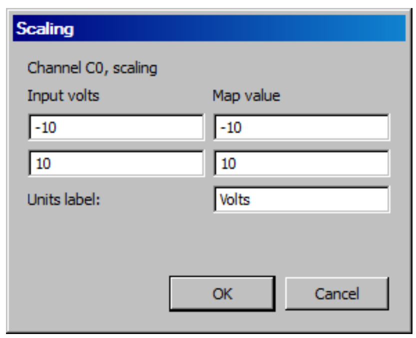
To have Acq*Knowledge* perform a Difference calculation in real time:

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Difference.
5. Click the Setup button in the Input Channels dialog to generate the Difference dialog.

The Difference Calculation dialog allows you to specify the source channel and the number of intervals between samples over which the difference is to be taken, and also includes the option of rescaling the channel to reflect different units.

Click the Setup button in the Input Channels dialog to generate the Difference dialog:





Source — When the Source channel contains relatively high frequency data, the Difference Calculation may result in a very noisy response, so it’s best to use Difference on relatively smooth data.

Sample rate — This line provides the sample rate for the selected channel (may be different than the acquisition sample rate).

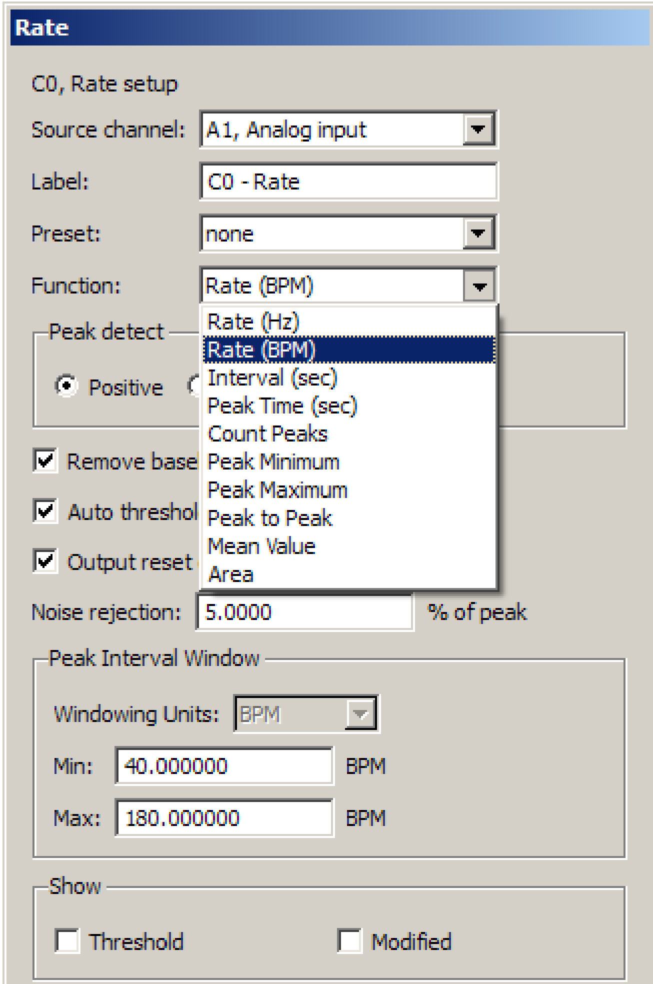
Intervals — Difference is calculated with respect to the number of intervals between points (rather than the number of sample points). For instance, two sample intervals span three sample points:

POINT<interval > POINT<interval > POINT

A 1-interval difference transformation applied to a blood pressure (or similar) waveform will result in the widely used “dP/dT” waveform.

✓ See page 291 for a complete description of the online Difference function.

Rate Calculation



The Rate Calculation is used to extract information about the interval between a series of peaks in a waveform. This interval can be scaled in terms of BPM (the default), frequency (Hz), or time interval between peaks.

- The BPM (or beats-per-minute) Rate function is used as a measure of peaks or events that occur in a sixty-second period.
- The frequency rate function is commonly used to describe the periodicity of data, or the amount of time it takes for data to complete a full cycle (from one peak to the next peak).
- The Interval Rate function returns the raw time interval between each adjacent pair of peaks, which is essentially the inter-beat interval (IBI), frequently used in cardiology research.

These three functions essentially provide the same information in different formats, since a frequency of 2Hz is equal to an inter-peak interval of 0.5 seconds, both of which are equivalent to a BPM of 120. Other options allow you to record the maximum or minimum value of all peaks (the peak max/min option), or to count the aggregate number of peaks (the count peaks option).

In order to calculate Rate information, you have the option of specifying the threshold manually or having Acq*Knowledge* automatically compute the threshold value (which is the default). This section describes the basic parameter settings for typical online Rate Calculations.

> NOTE: Parallel functions can be performed after data has been acquired. A detailed description of the Rate Calculation options can be found in the Find Rate section on page 324.

To perform a Rate Calculation in real time:

1. Choose MP150 > Set Up Channels.

2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Rate.
5. Click the Setup button in the Input Channels dialog to generate the Rate dialog.

Destination—determined by the Calculation channel that was selected when the “Setup” button was pressed.

Source—selected from the Source popup menu at the top of the dialog.

Sample rate—provides the sample rate for the selected channel (may be different than the acquisition sample rate).

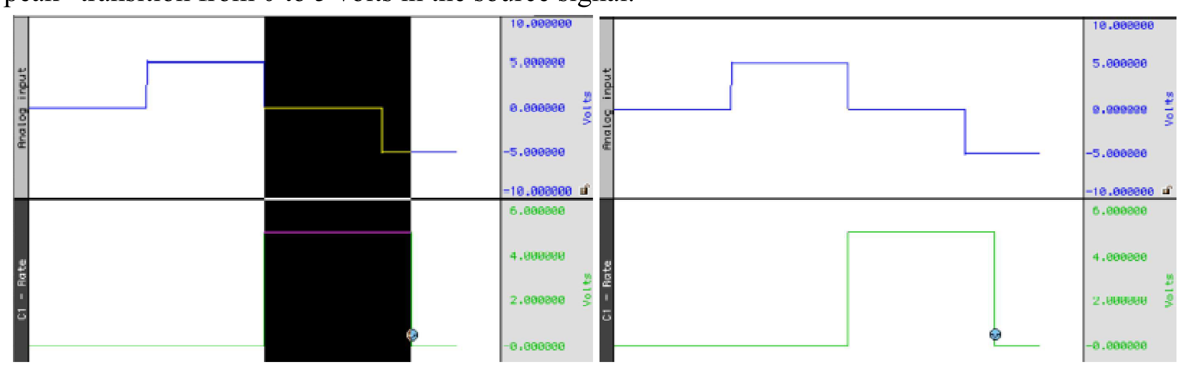
Function —The popup menu includes options to scale the rate in terms of Hz, BPM, Interval, Peak Time, Count Peaks, Peak Minimum/Maximum, Peak-to-Peak, Mean Value, or Area.

- For more information on each of these functions, see the Calculation Channels section beginning on page 115.
- Calculate systolic using the peak maximum Function, diastolic using the peak minimum Function, and mean blood pressure using the mean value Function.
- NOTE: All of these Function options are available in the post-acquisition mode through the Analysis > Find rate function

Remove baseline—provides the exact standard deviation of the input data (typically EMG) over the specified number of samples. When the mean of the input data equals 0-0, the standard deviation and the RMS will be equivalent.

Auto Threshold detect—The most convenient way to calculate a Rate channel online is to have Acq*Knowledge* automatically compute the threshold value (the “cutoff” value used to discern peaks from the baseline). This is done by checking the Auto Threshold detect box.

Output reset events (not available for metachannels)—When auto threshold detection is being used, the minimum and maximum rates of the signal are specified in the Windowing controls. If the input signal falls out of this range, the value of the rate function and automatic threshold level will be reset. By enabling “Output reset events” a reset event will be placed on the output at the location of these window expirations. Rate detector is set to “Peak function, default window of 40 BPM to 180 BPM, auto threshold detect for positive peaks. The reset event occurs after the window expiration, approximately a full 40 BPM interval after the “peak” transition from 0 to 5 volts in the source signal.



Polarity—For Rate Calculations involving data with positive peaks (such as the R-wave in ECG data), click the button next to “Positive” in the Polarity section of the dialog.

Noise rejection—Acq*Knowledge* constructs an interval around the threshold level when Noise rejection is checked. The size of the interval is equal to the value in the noise rejection text box, which by default is equal to 5% of the peak-to-peak range. Check this option to help prevent noise “spikes” from being counted as peaks.

Peak Interval Window—When "automatic" Rate Calculations are set, specify a minimum rate and a maximum rate. These parameters define the range of expected values for the Rate Calculation. By default, these are set to 40 BPM on the low end and 180 BPM on the high end. The Windowing units option is only activated when the selected function can have variable units (i.e., count peaks, mean value, area).

The Rate Calculation will use these values to find and track the signal of interest, assuming the input BPM range is reasonably well bracketed by these values. Depending on the shape of the input cycle waveform, the Rate window settings may be closer or further from the expected rates.

- For ECG-type data (where the waveform peak is narrow with respect to the waveform period), the Rate window values will closely bracket the expected values.
- For more sinusoidal data, with the waveform energy distributed over the waveform period (as with blood pressure or respiration), the Rate window will closely bracket the expected rate on the high-end, but can be up to twice the actual measured rate at the low-end.

One of the most frequent applications of the Rate Calculation is to compute BPM online for ECG, pulse, or respiration data. For more information on optimizing ECG amplifiers for online calculation of heart rate, see the ECG100C section of the *MP Hardware Guide*.

Show Threshold—Plots the threshold used by the Rate calculation function. This feature is useful to help the rate detector performance on any given data.

Show Modified—Plots the modified data as processed by the Rate Detector. Typically, the modified data is a differential version of the original input data. The data will be modified if the "remove baseline" feature is checked in the Rate Detector Setup dialog.

Math Calculation

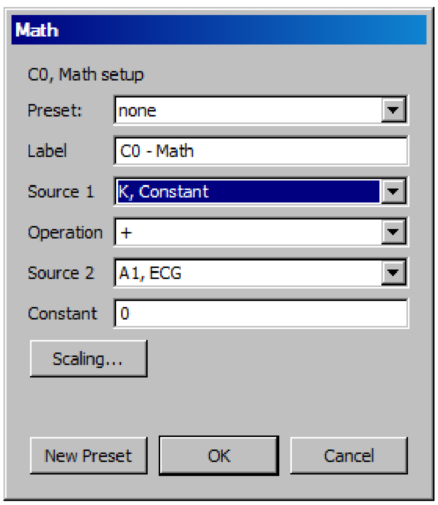
The Math Calculation performs standard arithmetic calculations using two waveforms or one waveform and a constant. It is also possible to use other Calculation channels (such as a Rate Calculation channel) as an input channel for a Math Calculation channel, as long as the Calculation channel used as a source channel has a lower channel number than the Math Calculation channel.

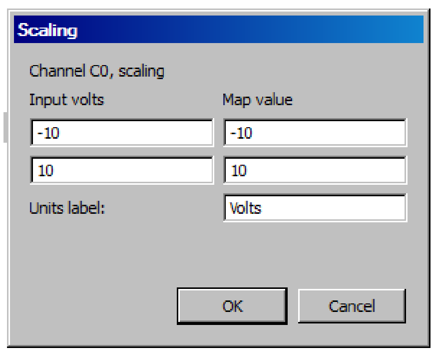
1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Math.
5. Click the Setup button in the Input Channels dialog to generate the Math dialog.

Use the pull-down Source menus to select the source channels (Source 1 and Source 2).

The Sample rate line provides the sample rate for the channel selected as Source; the channel sample rate may be different than the acquisition sample rate.

Use the pull-down Operand menu to select a function. In the example below, analog channel 1 (Source: A1) is added to analog channel 2 (Source: A2). To use this summed waveform as an input for another Math Calculation channel. One useful application would be to divide this waveform (C0) by K, where K=2, thus producing an arithmetic average of source channels A1 and A2.





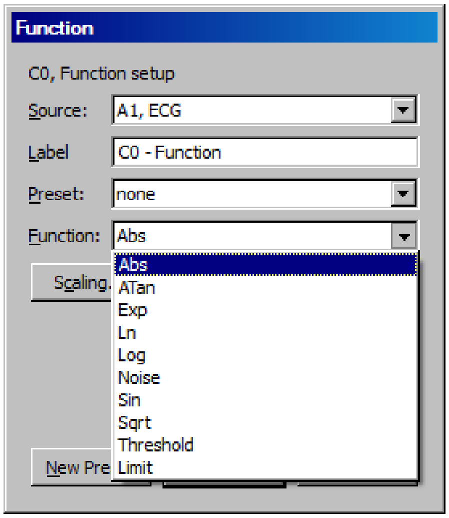
The “Constant” entry is activated when “K” is selected as a Source.

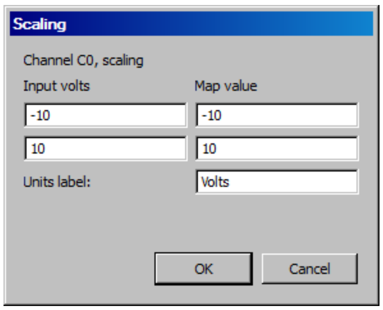
As an alternative to creating an additional Calculation channel for dividing the summed waveform, you can use the scaling function to perform the same task. To do this, click Scaling… button and then set the Map (Scale) value for the summed waveform equal to +5 and –5 (to correspond to Input Volts values of +10 and –10 respectively). This will effectively plot the sum of channels A1 and A2 as the arithmetic mean of the two waveforms.

For additional libraries of online Calculation options, consult the sections on Function Calculation channels and the online Equation Generator (Expression, page 133). These types of Calculation channels can be used to perform more complex operations on waveforms. Although Calculation channels can be “chained” together (so that the output from one serves as the input for another) to form more complex calculations, a separate channel must be used for each function. Since only sixteen Calculation channels are available, not all calculations can be performed. Additionally, chaining more than three or four channels together can require considerable system resources.

For complex calculations (such as squaring a waveform then adding it to the average of two other waveforms) the Equation Generator (Expression) is a more efficient solution. All of the features available online in the Math Calculation channels can also be computed after an acquisition using the Waveform Math option (see page 294), which will eliminate the problem of system overload.

Function Calculation





The Function calculation can be used to perform a variety of mathematical functions using two waveforms or a waveform and a constant. Function Calculation channels compute new waveforms in a manner similar to the math Calculation functions, but provide access to higher order functions. Like math Calculation channels, function Calculations can be chained together to produce complex functions (such as taking the absolute value of a waveform on one channel and Calculating the square root of the transformed waveform on another channel). These same functions are also available under the transform menu in Acq*Knowledge* for *post-hoc* operations. Many of these functions can also found in the online Equation Generator (see Expression on page 133 for details).

To have Acq*Knowledge* perform a Function Calculation in real time:

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Filter.
5. Click the Setup button in the Input Channels dialog to generate the Function dialog.

Other Functions are available in the online Equation Generator (see Expression on page 133). Function Calculations can be chained together to produce more complex Calculations, although it is more efficient to program complex functions using the Equation Generator (Expression).

The Sample rate line provides the sample rate for the selected channel (may be different than the acquisition sample rate).

<u>Function</u>

Abs	Returns the absolute value of each data point
Atan	Computes the arc tangent of each data point
Exp	Takes the e^X power of each data point
Limit	Limits or “clips” data values that fall outside specified boundaries
Ln	Computes the base e logarithm for each data point
Log	Returns the base 10 logarithm of each value
Noise	Creates a channel of random noise with a range of ± 1 Volt
Sin	Calculates the sine (in radians) of each data point
Sqrt	Takes the square root of each data point.
Threshold	Converts above an upper threshold to +1 while converting data below a lower threshold to 0.

Thresholding Algorithm Assume a domain variable $t \in \{t_{start}, t_{start}+1, t_{start}+2, \ldots\}$

with t_{start} being an integer, a real-valued signal y(t) defined for all t, and two real valued levels y_{low} and y_{high} satisfying the relation $y_{low} \le y_{high}$.

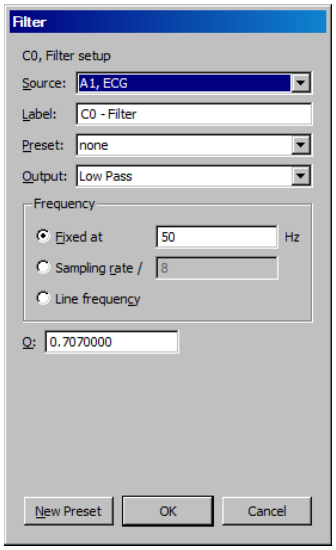
Define the Threshold function thresh(t) function such that:

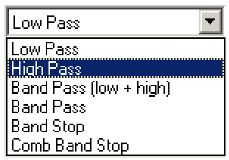
$$thresh(t_{start}) = \begin{cases} 1 & y(t_{start}) \ge y_{low} \\ 0 & y(t_{start}) < y_{low} \end{cases} \qquad thresh(t) = \begin{cases} 0 & y(t) < y_{low} \\ 1 & y(t) > y_{high} \\ thresh(t-1) & y_{low} \le y(t) \le y_{high} \end{cases}$$

Filter Calculation

The Filter Calculation channel allows you to perform real time digital filtering on analog, digital, or calculation channels. To have Acq*Knowledge* apply a digital Filter Calculation in real time:

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Filter.
5. Click the Setup button in the Input Channels dialog to generate the Filter dialog.





Filter Setup & Output Options

In the dialog above, the signal on analog channel one (A1) is run through a low-pass filter that attenuates data above 50 Hz. The "Q" for this filter is 0.707, which is the default.

> One possible application of the online filtering option is in conjunction with the Show Input Values option (see page 221). Raw EEG data, for instance, can be filtered into distinct bandwidths (alpha, theta, and so forth) using one source channel and multiple filter Calculation channels. The filtered data can then be displayed in a bar chart format during the acquisition using the Show Input Values option.

Source	Set the source channel.
Sample rate	provides the sample rate for the selected channel (may be different than the acquisition sample rate).
Type (Output)	Lists the filter options: low pass, high pass, band pass, band pass (low + high), band stop, and comb band stop. See *About Filters* in this section for more details on filter types.
Frequency	Fixed value—Type a value in the entry box.
	Sampling rate—Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.
	Line frequency—Uses the line frequency at which the data was recorded.
Q coefficient	The online filters are implemented as IIR (Infinite Impulse Response) filters, which have a variable Q coefficient. The Q value entered in the filter setup box determines the frequency response patterns of the filter. This value ranges from zero to infinity, and the "optimal" (critically damped) value is 0.707 for the Low pass and High pass filters, and 5.000 for the Band pass and Band stop filters. If you wish, you may change the Q. A more detailed explanation of this parameter, and digital filters in general, can be found in Appendix B.

About Filters

While the technical aspects of digital filtering can be quite complex, the principle behind these types of filters is relatively simple. Each of these filters allows you to set a cutoff point (for the low and high pass filters) or a range of frequencies (for the band pass and band stop filters).

- A Low Pass filter allows you to specify a frequency cutoff that will "pass" or retain all frequencies below this point, while attenuating data with frequencies above the cutoff point.
- High Pass filters perform the opposite function, by retaining only data with frequencies above the cutoff, and removing data that has a frequency below the specified cutoff.
- Each type of Band Pass filter is optimized for a slightly different type of task.

  The Band Pass (low + high) filter is designed to allow a variable range of data to pass through the filter. For this filter, you need to specify a low frequency cutoff as well as a high frequency cutoff. This defines a range or "band" of data that will pass through the filter. Frequencies outside this range are attenuated. The Band pass (low + high) is actually a combination of a low pass and a high pass filter, which emulate the behavior of a band pass filter. This type of filter is best suited for applications where a fairly broad range of data is to be passed through the filter. For example, this filter can be applied to EEG data in order to retain only a particular band of data, such as alpha wave activity.

  The alternative Band Pass filter requires only a single frequency setting, which specifies the center frequency of the band to be passed through the filter. When this type of filter is selected, the "width" of the band is determined by the Q setting of the filter (discussed in detail below). Larger values for q result in narrower bandwidths, whereas smaller Q values are associated with a wider band of data that will be passed through the filter. This filter has a bandwidth equal to Fo/Q, so the bandwidth of this filter centered on 50 Hz (with the default Q=5) would be 10 Hz. This type of filter, although functionally equivalent to the band pass (low + high) filter, is most effective when passing a single frequency or narrow band of data, and to attenuate data around this center frequency.
- The Band Stop performs the opposite function of a band pass. A Band stop filter defines a range (or band) of data and attenuates data within that band. In this case, the Band stop filter is implemented in much the same way as the standard Band pass, whereby a center frequency is defined and the Q value determines the width of the band of frequencies that will be attenuated.
- The Comb Band Stop removes interfering harmonics; resonance, aliasing, and other effects may generate interference at multiples of a base frequency. It combines all the required filters instead of requiring a separate filter for each interfering overharmonic. For setup details, see page 272.

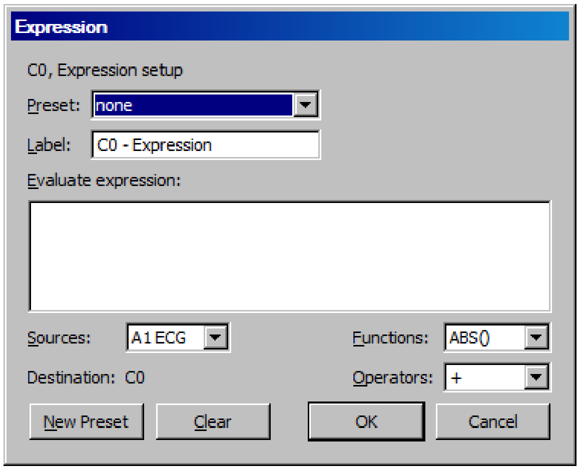
Off-line filtering

Apart from these online filter options, similar filters can be applied after an acquisition is terminated. Many of the biopotential amplifiers available from BIOPAC have selectable filters, which allow you to filter certain frequencies (including 50 Hz or 60 Hz electrical noise) and possibly reduce the need for online filters.

Digital filtering can also be performed after an acquisition using the same types of filters. You can choose from the different filter types by selecting Digital filters from the Transform menu. The filters available after the acquisition use a different algorithm but operate in essentially the same way.

For more information on digital filters and filters that can be applied after an acquisition, turn to the Digital Filtering section on page 266 or Appendix B.

Equation Generator (Expression)



The online Equation Generator (Expression calculation channel) is available for performing computations more complex than possible in the Math and Function calculations. The Equation Generator (Expression calculation) will symbolically evaluate complex equations involving multiple channels and multiple operations. Acq*Knowledge* can perform conditional evaluation, data extraction, logical operations, expressions requiring a range of samples or the results of the previous expression, and evaluation of generic formulas that can be expressed in a closed, recursive form.

Unlike the Math and Function calculations—which can only operate on one or two channels at a time—the Equation Generator (Expression calculation) can combine data from multiple analog channels, and allows you to specify other Calculation channels as input channels for Equation channels. Also, computations performed by the Equation Generator (Expression calculation) eliminate the need for "chaining" multiple channels together to produce a single output channel.

While the Equation Generator (Expression calculation) is more powerful than other Calculation channels, each Expression calculation requires more system resources than other Calculations. This essentially means that acquisitions that utilize Equation calculations are limited to a lower maximum sampling rate than acquisitions without online Expression functions. When an expression is evaluated, it is actually evaluated multiple times. The expression is computed starting at the first sample acquired, and is then evaluated once for each successive acquired sample.

Acq*Knowledge* can accept the notations `SC`, `MC`, and `CH`*n* to reference the sample at the current evaluation position or `SC(`*x*`)`, `MC(`*x*`)`, and `CH`*n*`(`*x*) for values at locations prior to the present evaluation location using an offset expressed in sample intervals. For example, CH1(-1) will give the previous sample of Channel 1.

The same features that are available in online Calculation channels are also available under the Transform menu for evaluation of complex equations after acquisition. Thus, simple Calculations such as summing two channels or dividing one channel by another (and so forth) are best performed in either the Math calculation channels or the Function calculation channels.

On the other hand, for complex Calculation channels, such as squaring one channel, multiplying it by the sum of two other channels, and dividing the product by the absolute value of another waveform, a single Expression calculation channel is more efficient than chaining five Math and Function calculation channels.

<u>Save to Calculation Channel</u>

To evaluate an expression and save the result to a Calculation channel in real time:

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Expression.
5. Click the Setup button in the Input Channels dialog. This will produce a dialog, where you can enter the expression to be evaluated.

The different components of each expression can be entered either by double-clicking buttons from the button rows (sources, functions, and operators) in the setup expression dialog, or by typing commands directly into the Equation box. The Equation Generator (Expression) uses standard mathematical notation.

For each expression, you need to specify at least one source, the function(s) to be performed, and any operators to be used. Sources are typically analog channels, although you may also select Time from the source button row and Acq*Knowledge* will return the value of the horizontal axis (usually time) for each sample point. When the horizontal axis is set to frequency (in the Display > Horizontal axis dialog), the “time” item in the source button row will switch to “frequency.”

When using the online Equation Generator (Expression calculation channel), it is important to keep in mind that while different channels, functions, and operators can be referenced, the Calculation cannot reference future sample points. That is, data from waveform one can be transformed or combined in some way with data from waveform two at the same point in time, although data from one point in time (on any channel) cannot be combined with data from another point in time (on any channel). See the section on post-acquisition expression commands (beginning on page 293) for ways around this limitation.

Functions — The arguments to each function are represented in the Functions table in italics and may be replaced by any valid expression. Each argument is separated from its next argument by a comma. Expressions can only contain commas within balanced parenthesis pairs. An ellipsis (“...”) at the end of a function description indicates that any number of arguments may be present provided they are in a comma separated list. When a function is added to an Expression, the cursor is placed between the parentheses.

Conditionals — Change output based upon a condition test. All of the conditionals treat the value zero as false and any non-zero value as true. Expressions can only contain commas within balanced parenthesis pairs.

Offset Notation — Offset notations take integer offsets in terms of the number of samples using the formation CH#(P) *where* CH# is the channel number and P is the number of points. For example, an offset of -1 will return the data point immediately to the left of the selected point and an offset of +1 will return the data point immediately to the right of the selected point.

To refer to previously acquired data, offsets must be negative. For notational convenience, offsets that result in an invalid negative sample position (e.g. no data is defined prior to the first sample in the graph) evaluate to zero. Any attempt to access a sample beyond the end of the data will result in an error. Any attempt to use a positive offset for an online Equation Generator (Expression calculation channel) will result in an error.

- `CH`*`n`*`(`*`x`*`)` Returns the value of channel with index n *x* samples away from the current evaluation position.
- `SC(`*`x`*`)` Returns the value of the selected channel *x* samples away from the current evaluation position. Only allowed for Transformations and Measurements; not allowed for Calculations.
- `MC(`*`x`*`)` When *x* is zero or positive, returns the value of the measurement channel *x* samples away from the current evaluation position. When x is negative, returns the result of the expression evaluation that occurred *x* steps previous to the current evaluation position. Only allowed for Measurement Expressions (see below); not allowed for Calculations or Transformations.

Recursive notation — Since transformations and calculation channels replace the source data of the channel with the result of the expression evaluation in sequence, negative offsets are equivalent to returning the final result of the expression that was evaluated a certain number of steps in the past. The channel where the expression results are stored can be thought of as a storage record of the previous evaluation steps. Negative sample offsets, therefore, can be used to compute any formula that can be expressed in closed recursive form. For example, the recursive definition of the Fibonacci sequence is:

$$F_n = F_{n-1} + F_{n-2}$$

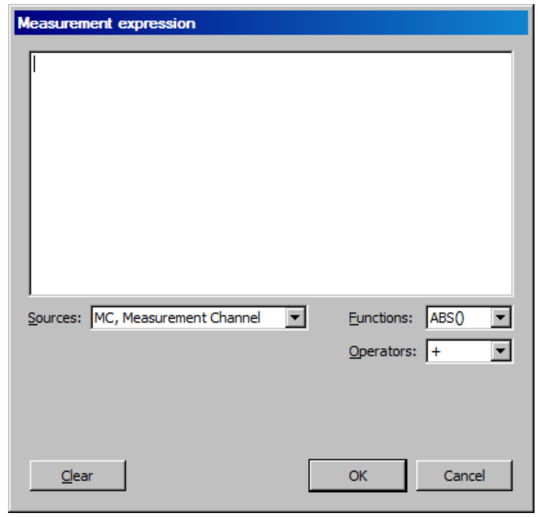
To evaluate this as an expression transformation, use the expression:

SC(-1)+SC(-2)

Note that to actually get the Fibonacci sequence, the selected channel would need to have a constant value of one prior to the transformation.

Expression Measurement

Measurements are powerful tools for quick manual analysis and also for advanced automated analysis when combined with the Cycle/Peak detector. Expression measurements extend measurements to evaluate simple formulas or complex data reduction. Each Expression measurement has an expression associated with it and the measurement result is derived from computing the Expression(s) on the selected data.



Measurement expression dialog is generated the first time a measurement is set to Expression or when the measurement "info" button is clicked.

OK invokes a syntax check. If there is an error, the user will be prompted to correct the error and the error will be selected (highlighted) in the Expression edit field.

Cancel discards any changes to the Expression measurement and reverts back to the previous Expression.

Clear erases the current contents of the expression edit field.

Measurement Channel

Expression measurements can reference the "measurement channel" (MC), which refers to either the selected channel or a specific channel as set in the measurement channel selection box within the graph window.

Negative sample offsets to MC are interpreted as returning the result of the Expression from a prior step. Transformations and calculation channels achieve this as they replace the contents of their destination channels sequentially. Measurements, however, do not actually replace the data of their source channels. Expression measurements are actually executed on a temporary copy of the channel data in memory. This implies that negative indicies to the measurement channel are interpreted exactly the same for measurements as for transformations and calculation channels even though the "transformed" data of the measurement is not visible. Negative sample offsets to MC that refer to the sample position prior to the leftmost sample of the selected area will always return zero.

Evaluation Rules

When a new selection is made, the first step in evaluation searches through the Expression measurement for any MMT() invocations. Any measurement whose value is needed by MMT() is computed at this time prior to the Expression evaluation. This behavior is similar to calculation channels and successfully allows measurements to the right and bottom of the Expression measurement to be used in the expression.

The expression is subsequently evaluated from the leftmost sample in the selection to the rightmost sample. It is evaluated at the waveform sampling rate of its source channel, with one expression evaluation per sample contained within the selected area. Interpolation is not used at the boundaries to maintain a consistent sample interval for the expression. After each expression evaluation, the result is cached in memory for potential negative MC result references.

The value of the final expression, the rightmost sample, becomes the result of the measurement.

Circularity Detection

Expression measurements may reference other expression measurements or calculation measurements by using the MMT() function in the expression. This raises the possibility of circular dependencies being formed by the user if a measurement expression either directly or indirectly needs its own value to compute a MMT() invocation. Circular dependency checking will be in place at execution time and will result in an error.

To refer an Expression measurement to its own value, use the MC notation.

Error Reporting

The Expression measurement result will display the text "Error" if there are syntax errors in the Expression measurement, errors computing measurements referenced by MMT(), or a circularity.

Validation Tip

To function correctly, Acq*Knowledge* requires real-valued data. You are encouraged to ensure that your expression results are real-valued. To test if a floating point number *x* is a real-valued number, use the expression:

NOT(OR(ISINF(*x*), ISNAN(*x*)))

Note for variable sample rate processing:

The Equation Generator (Expression) and Waveform Math functions will constrain operations between waves of different rates as follows:

If an equation is operating on two or more waves of different sample rates, the result of the operation will always be output at the lowest sampling rate from the waves (F low). If the destination channel for the result has an assigned rate other than (F low), the operation will not be permitted. If the destination channel is set to a new channel, the operation will always be permitted.

In Acq*Knowledge* 4 and higher, all sources for Expressions and Waveform Math operations must be sampled at the same waveform sampling rate.

VSR data padding—If the channels are of unequal length (as a result of variable sampling rate or waveform editing), they will be padded for Append acquisition. Digital and Analog channels are stored as short integers by default; a waveform paste into a digital or analog channel, however, will result in its underlying data being converted to floating point. This will generate the "Abort/Replace" warning for pastes to Digital or Analog channels since the data format has changed since the last acquisition.

Additionally, if an Analog or Digital channel is used as the source waveform for a Copy, it will also be converted to floating point and will result in the "Abort/Replace" warning being generated.

Since Calculation channels are already floating point, pasting into them or copying from them will not change their data format. The channels will be padded with their last value and the append will commence.

Waveform Cut operations do not change the underlying data format for Analog, Calculation, or Digital channels. If only Waveform Cut is used, no data format conversion will occur and channels will be padded with their last value and subsequent appends are allowed.

Source	Description
ACQLENGTH	*Calculation only* Acquisition length from Set Up Acquisition; keeps Appended segments the same whereas "Sample" would increase with each segment.
CH	Value of the designated channel (CH*n*) at the current evaluation step.
Primary Source Channel *metachannels only*	Appears as PSC in the dialog. Refers to the data of the primary source channel of a metachannel.
Time	Time (in sec) of current evaluation step
Sample	Sample index of evaluation step; the first sample in the graph will always be reported as a value of zero.
MC	*Measurements only* Value of the channel in the measurement menu—either the explicit channel or "SC"—at the current evaluation step.
Pi	Value of pi (3.141592654…) to double-precision accuracy.
SC	*Transformation and measurement only* Value of the selected channel at the current evaluation step; can still back-reference samples points.
True	Evaluates to the value 1 (non-zero values are interpreted as True)
False	Evaluates to the value 0
Segment Timer	Used as a source for the onscreen Stopwatch gauge view.
Random	Generates random white noise.
Gaussian Random*****	Generates Gaussian white noise for startle responses. Returns a random value from a Gaussian distribution.

*****Standard Gaussian model; useful for peak fitting.

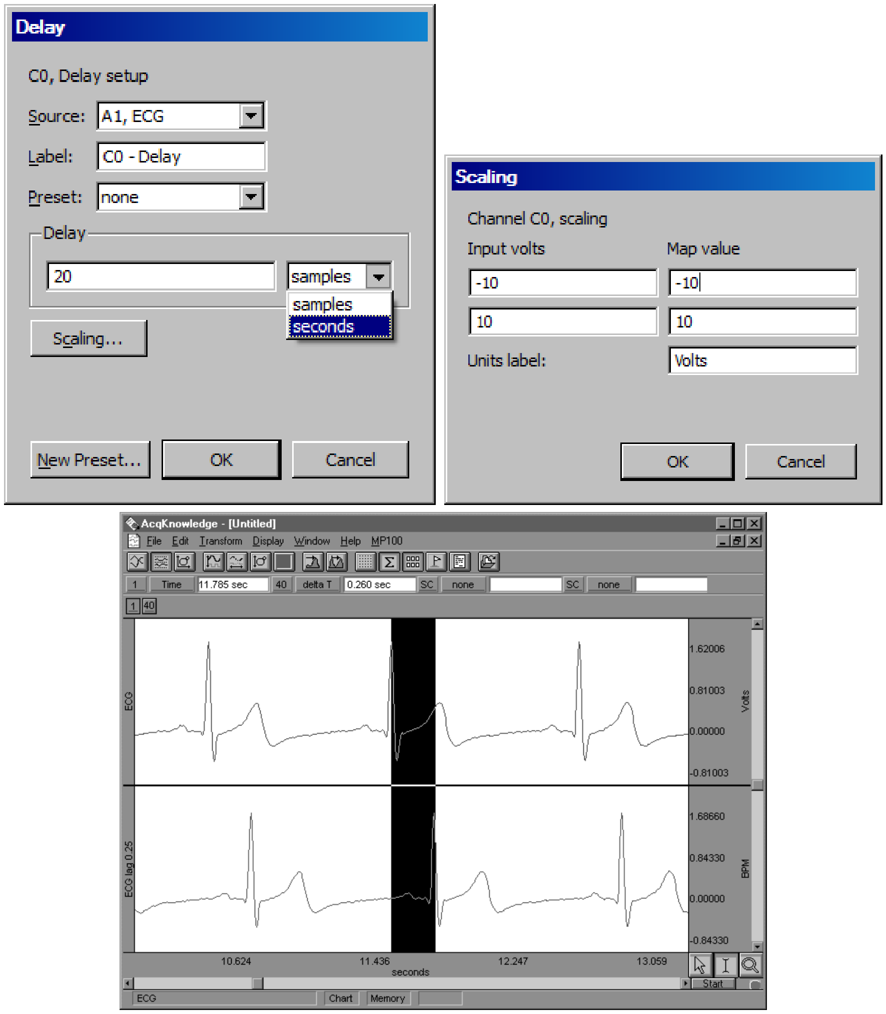
param(0)*EXP(-((TIME-param(1))/param(2))^2

Operator	Operation
+	Addition
-	Subtraction
*	Multiplication
/	Division
^	Power
(	Open parentheses
)	Close parentheses

FUNCTION	RESULT
ABS	Returns the absolute value of each data point.
ACOS	Computes the arc cosine of each data point in radians.
AND(*x, y, …*)	Computes a logical "and" operation for its arguments. Accepts up to eight (8) arguments and evaluates to 1 if all of its arguments are non-zero values. 0 if one of its arguments is zero.
ASIN	Calculates the arc sine of each value in radians.
ATAN	Computes the arc tangent of each sample point.
CEIL(*x*)	Computes the ceiling function (the closest integer larger than the value x).
COND(T, A, B, C)	Three-way conditional takes four arguments: COND(*test_expr*, *neg_test_value*, *zero_test_value*, *pos_test_value*) Evaluates test_expr and if < 0, returns neg_test_value = 0, returns zero_test_value > 0, returns pos_test_value
COS	Returns the cosine of each data point.
COSH	Computes the hyperbolic cosine of each selected value
EQUAL(*x, y, …*)	Performs a Logical equal (numerical comparison) of its arguments. Accepts up to eight (8) arguments and evaluates to 1 if all of its arguments are equal. 0 if one of its arguments is not equal to the others.
EXP	Takes the e^x power of each data point..
FLOOR(*x*)	Computes the floor function (the closest integer less than the value x).
IF(T, A, B)	Two-way conditional takes three arguments: IF(*test_expr*, *true_value_expr*, *false_value_expr*) The conditional evaluates test_expr and if non-zero, returns true_value_expr 0, returns false_value_expr
ISINF(*x*)	Filters out infinities and unrepresentable numbers from data; important because such values can cause erratic behavior in autoscaling and other operations. Use to test whether any expressions have resulted in floating point overflow and have generated numbers too large to be represented in the computer. Evaluates to 1 if x is inf, the floating point representation of infinity. 0 if x is NaN or a real-valued floating point number.
ISNAN(*x*)	"Is not a number" can be used to test whether any expressions have resulted in floating point errors such as division by zero. Use to ensure that the output of transformations and equations does not produce numbers that Acq*Knowledge* cannot display. Evalutes to 1 if x is NaN, the invalid floating point number. 0 if x is inf or a real-valued floating point number.
LESS(*x, y*)	Performs a numerical comparison of its arguments and evaluates to 1 if x is less than y. 0 if x is greater than or equal to y.
LOG	Computes the natural logarithm of each value
LOG10	Returns the base 10 logarithm of each value

FUNCTION	RESULT
MMT(*row,col*)	*Transformation and measurement only* Evaluates to the result of a measurement being displayed in the graph, as specified by row and column. Use to scale by a result without having to manually enter the result. Row and Column for a measurement start as 0,0 for the top left measurement box; the fourth argument on the first row is accessed by MMT(0,3). For this function, the required measurement box must be displayed in the graph. Since the values of measurements may change during the course of an acquisition, calculation channel expressions cannot use this function. If a Model Expression (page 298) uses MMT() syntax to reference a measurement and that referenced measurement is linearly interpolated, the results of the NLM measurement will also be displayed as being linearly interpolated.
MOD(*x,y*)	Computes the floating point modulus; returns integer portion of modulus. Example: MOD(5,2) evaluates to “1”
NOT(*x*)	Computes a logical negation of its argument. Evaluates to 1 if x is zero. 0 if x is non-zero.
OR(*x, y, …*)	Evaluates multiple variables; true if any are true. Computes a logical “or” operation for its arguments. Accepts up to eight (8) arguments and evaluates to 1 if any one of its arguments is non-zero. 0 if all of its arguments are zero.
ROUND(*x*)	Returns an integer closest in value to the argument. For example: round (2.4) = 2 round(2.5) = 3 round(-1.5) = -1 round(-1.6) = -2
SIN	Calculates the sine (in radians) of each data point.
SINH	Computes the hyperbolic sine for each sample point.
SQR	Squares each data point.
SQRT	Takes the square root of each data point.
TAN	Computes the tangent of each sample point.
TANH	Calculates the hyperbolic tangent of each sample point.
TRUNC(*x*)	Removes the fractional part of the number and returns an integer. For example: TRUNC(2.4)= 2 TRUNC(2.5)= 2 TRUNC(-1.5)= -1 TRUNC(-1.6)= -1 *Note* When used with scientific notation, TRUNC(x) applies only to the fractional portion after the exponential factor is taken into account: TRUNC(2.93E+4) = TRUNC(29300) = “29300”. Since 2.93e+4 (29,300) has no fractional portion, the number is returned unchanged. Similarly, TRUNC(2.931245E+4) = TRUNC(29312.45) = “29312”.
XOR(*x, y, …*)	Logical exclusive OR; true if an odd number is true. Computes a logical “exclusive or” for its arguments (e.g. “one or the other, but not both”). Accepts up to eight (8) arguments and evaluates to 1 if an odd number of its arguments are non-zero. 0 if an even number of its arguments are non-zero or if none of its arguments are non-zero.

Delay Calculation



Delay setup dialog and resulting graph showing 20 sample delay

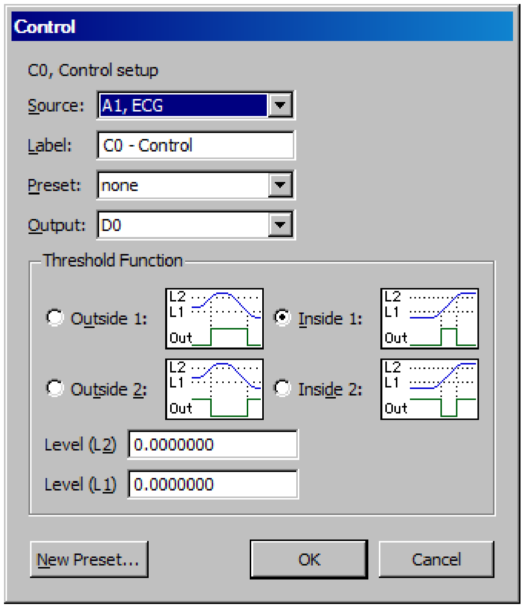
This option allows you to use a Calculation channel to plot another channel lagged (delayed) by an arbitrary interval. To have Acq*Knowledge* apply a Delay Calculation in real time:

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Delay.
5. Click the Setup button in the Input Channels dialog to generate the Delay dialog.

The delay interval can be specified either in terms of samples or seconds. These types of plots are useful for producing non-linear ("chaos") plots in Acq*Knowledge*'s X/Y display mode (see page 39 for a description).

When a delay channel is recorded, there is a segment at the beginning of the Calculation channel (equal to the value of the delay) that will read as 0 Volts. This is normal and occurs because the delay channel is waiting to "catch up" with the original signal. Acq*Knowledge* fills this buffer with zeros until the delay channel begins to plot actual data. In the example below, the delay channel contains a 0.25-second interval of zeros at the beginning of data file.

Control Calculation



The Control function is used to output a digital pulse when the value for a specified input channel exceeds a certain level, falls inside a given range, or falls outside a given range. This feature is unique in that the output is on a digital channel (which ranges from I/O 0 through I/O 15) rather than a Calculation channel. Also, unlike other Calculation channels, this Control Calculation can only be performed in real time (i.e., while data is being acquired) and cannot be performed in post acquisition mode.

In addition to outputting a signal on a digital channel, the Control Calculation will also plot an analog version of the digital signal on the Calculation channel you specify. For instance, in the example below, Calculation channel C0 is used to perform a control function using analog channel 1 (A1) as an input and digital channel 0 (D0) as an output. In addition to outputting a pulse on D0, the setup below will also produce a plot on channel 40 (the first Calculation channel) that emulates the signal being output on digital channel 0. Since Calculations are analog channels, the Calculation channel does not contain a "true" digital signal, but is a reasonably good approximation. To retain the physical output generated by a Control channel, the output digital channel should be looped back to another digital input channel of the MP150 unit and acquired as well as being connected to any external devices. The calculation channel values are not guaranteed to precisely match the actual digital output.

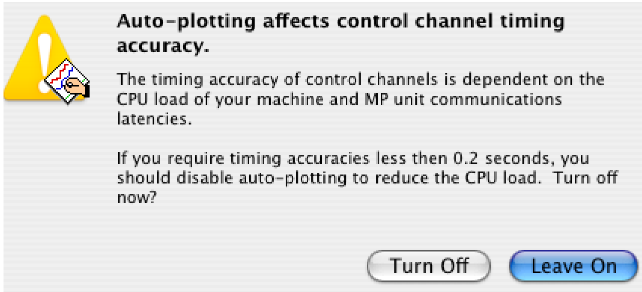
To have Acq*Knowledge* apply a Control Calculation in real time:

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Control.
5. Click the Setup button in the Input Channels dialog to generate the Control dialog.

There are four parameters that need to be specified for each Control channel:

a) Source channel
b) Output channel
c) Type of threshold function
d) Threshold level values

"Source" refers to the input channel to be used for the Control function. As with other Calculation channels, the Control function can use either an analog channel or another (lower) Calculation channel as an input. In the previous example, analog channel 1 (A1) is used as the input channel. It is not possible to use a digital channel as an input channel for a Control Calculation.



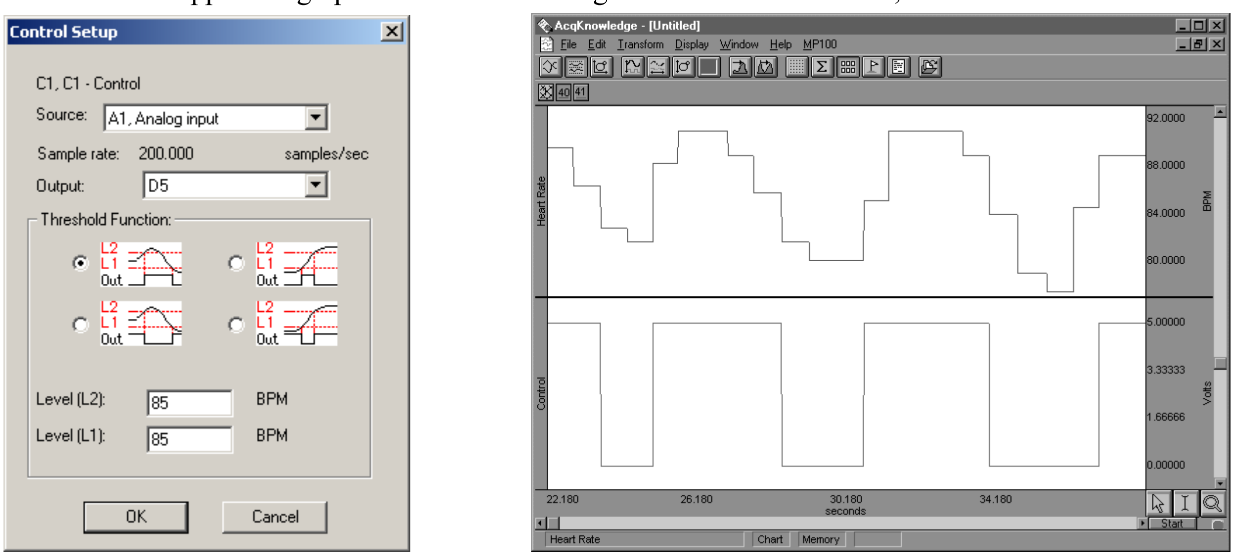
The channel selected in the Output Channel section determines which digital channel the pulse will be sent to. The digital channels range from 0 to 15 (D0 through D15) and external devices can be connected as described in the section on UIM100C connections in the *MP System Hardware Guide*. In the sample dialog shown, the digital pulse is sent over I/O line D0.

Digital channels have two levels, 0 Volts and +5 Volts. When the signal transits from 0 Volts to 5 Volts, an "edge" is created and since the signal is going from low to high, this is referred to as a positive edge. Similarly, as the signal transits back from 5 Volts to 0, a negative edge is created. These transitions or edges can be used to trigger external devices when an analog signal level meets certain threshold criteria.

The Threshold Function option sets the criteria for the Control channel. You can specify threshold conditions such that the digital I/O line goes to +5 Volts when the conditions are met, or you can program the digital line to go to 0 Volts when the threshold conditions are met. Threshold conditions can be set so that either (a) the digital line is switched when the value of an analog channel exceeds a specified value or (b) the digital line is switched when an analog channel falls within a given range. Acq*Knowledge* also allows you to create a single level threshold or a "wide" threshold.

Tip To use test conditions more complicated than simple thresholding, combine the conditional tests of Expression calculations with the Control channel to change digital output based on the Expression result.

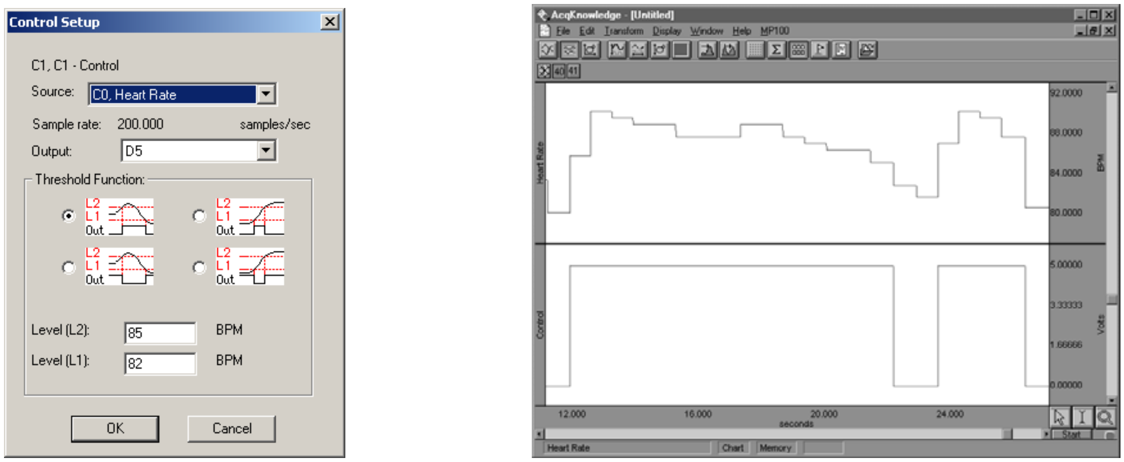
For example, suppose you want to set a Control channel to switch digital line 5 from low to high whenever the signal for Calculation channel one (C0) exceeds 85 BPM. Set the source channel to C0 and the output to D5. Select the upper left graph in the control dialog and set L2 and L1 to 85, as shown:



Control dialog and graph showing result of BPM control example

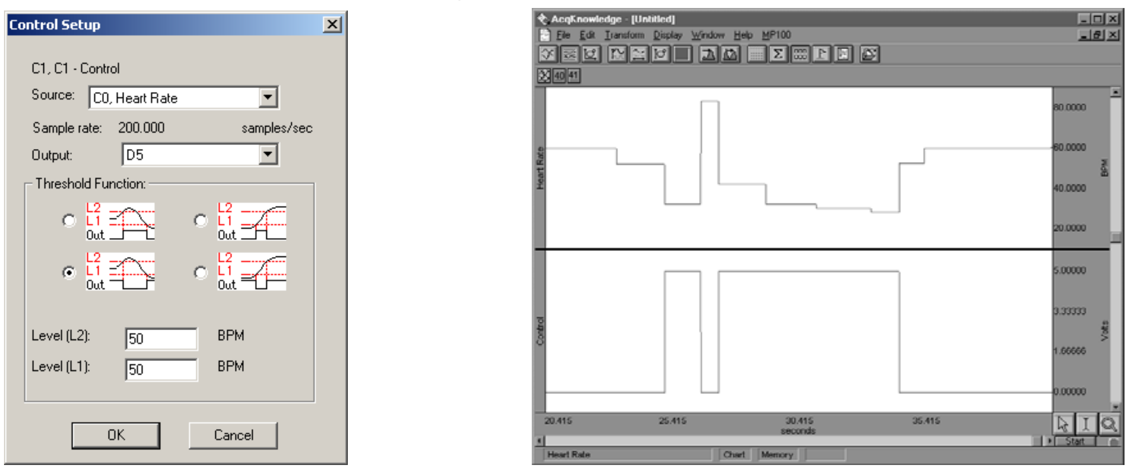
As you can tell from the preceding graph, there are a number of instances where C0 (heart rate) exceeds 85, usually for a short period of time. When it does drop below 85, it appears to return to a value greater than 85 within a second or two. In instances such as this, it might be useful to "widen" the threshold so that the digital line is triggered whenever the input value is greater than 85, but the signal must drop significantly below the threshold value before the threshold is reset.

As another example, the upper threshold value (L2) is set to 85 and the lower threshold (L1) is set to 83, which means that the threshold will not reset until the signal from the source channel drops below 83. In the following example, the digital line is switched from low to high (from zero to +5 Volts) when the heart rate channel exceeds 85, and stays at +5 Volts for several seconds even though the source channel drops below 85 (but above 83). The digital line does not switch back to zero until the heart rate channel drops below 83 (toward the end of the record). Once this occurs, the threshold is reset and the digital line will switch again the next time the source channel exceeds 85 BPM.



Control dialog and graph showing control channel with "wide" threshold

It is also possible to have the digital line switch when the source channel drops below a certain value. In the example below, a simple threshold is used to switch the digital line high each time the source channel drops below 50 BPM. Since L2 and L1 are set to the same value, this is not a "wide" threshold (as above) and the threshold resets each time the source channel goes above 50 BPM.

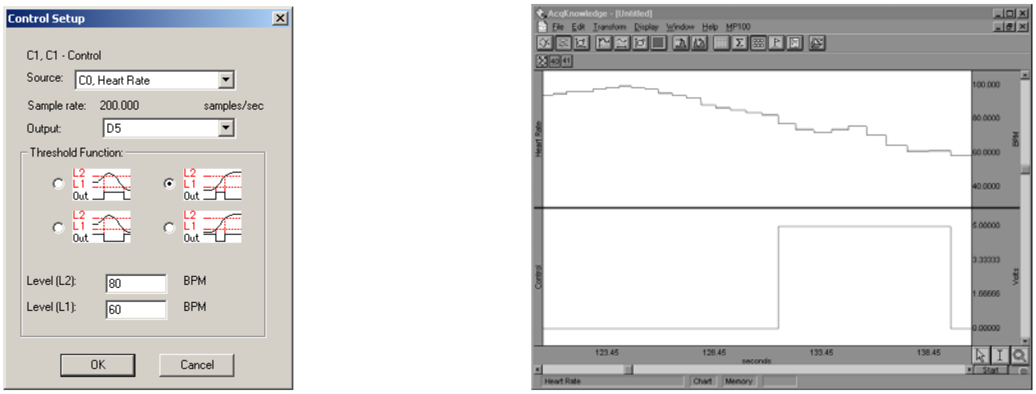


Control dialog and graph showing control channel detecting source channel levels less than 50 BPM

These examples are only a few of the possible applications of the control channel using the two threshold icons on the left-hand side of the Control Setup dialog. You can construct variations of these (i.e., switching the digital line from low to high using a wide threshold whenever the source channel drops below a given channel) that are not discussed above. Moreover, each of the options can be construed somewhat differently than they have been presented here. For example, the previous example switches the digital line from low to high each time the signal on the source channel drops below 50 BPM. Conversely, it also switches from high to low each time the source channel value is greater than 50 BPM. This allows you to vary the default setting for the digital channels (whether the default is zero or +5 Volts) depending on what types of devices are connected.

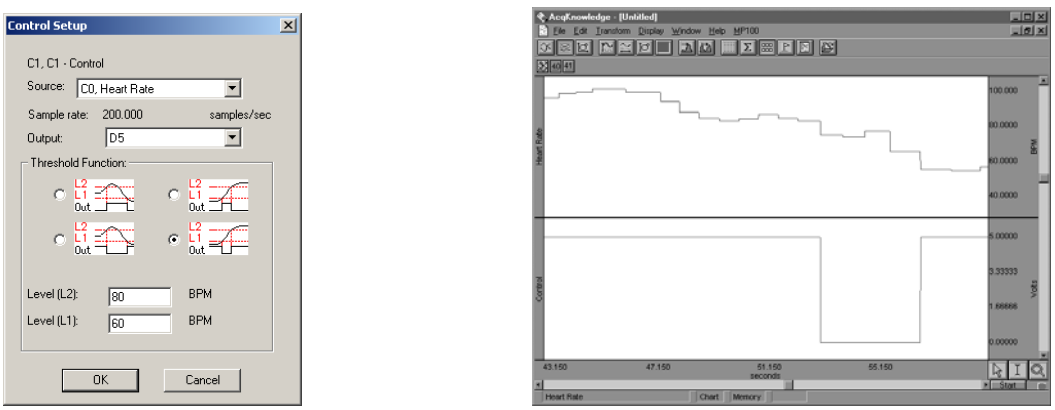
(For a description of how to connect various digital devices, see the section on UIM100C connections in the *MP System) Hardware Guide*.)

In addition to setting “above and below” type thresholds, you can program the Control channel such that the digital line is switched whenever the source channel falls within a given range or outside a specified range. In the example that follows, digital line 15 is set to switch from zero to +5 Volts whenever the source channel signal falls between the values entered in the L1 and L2 boxes. In this case, I/O is switched to +5 Volts whenever the heart rate is greater than 60 BPM but less than 80 BPM.



Control dialog and graph showing control channel switching from low to high when source channel is between 60 BPM and 80 BPM

You can also program the digital line to switch from high to low when the signal on the source channel falls *within* a given range. This is equivalent to setting the digital line to shift from low to high when the source channel values fall outside a given range (as shown below).



Control dialog and graph showing control channel switching from high to low when source channel is between 60 BPM and 80 BPM

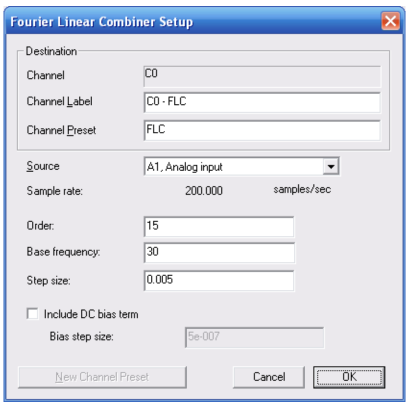
Fourier Linear Combiners: FLC, WFLC, CWFLC Calculations

Fourier Linear Combiners are linear combinations of adaptable sinusoidal functions that are particularly well suited to processing cyclic data. Sine and cosine are harmonics that are multiples of a *base frequency* that are summed together, and the *order* is the fixed number of harmonics used in the model. *Step size* provides mu, the gain factor used to adjust the weights of the harmonics at each processing step. Step sizes must be much less than 1 for the system to converge. As step sizes decrease, relaxation time lengthens. The FLC model is adjusted based on the source data using least means square (LMS) feedback and the *bias* compensates for DC offset.

To have Acq*Knowledge* apply an FLC Calculation in real time:

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select FLC, WFLC, or CWFLC.
5. Click the Setup button in the Input Channels dialog to generate the appropriate dialog.

➲ See FLC Transform options, including *Scaled FLC*, on page 275.



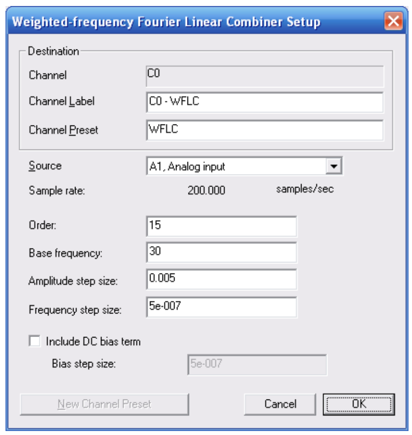
Basic FLC

Simple summation of fixed numbers of sines and cosines; uses harmonics of a fixed frequency and adjusts weighting coeffiicients of the mixture.

Operates on a single channel at a time.

Well suited for extracting data of a known frequency band from a signal with a stable frequency.

- Use as an adaptive noise filter to remove non-periodic and semi-periodic noise uncorrelated to the base harmonic frequency.



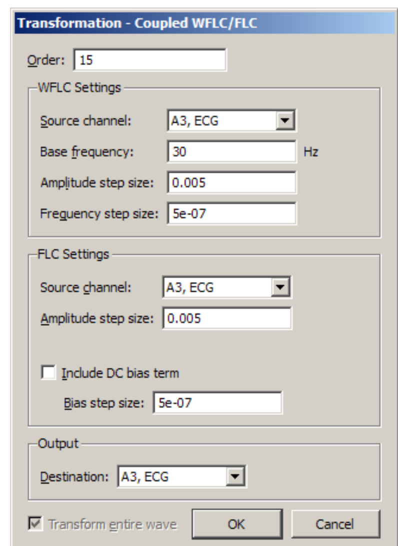
Weighted-Frequency FLC

Base frequency of the harmonics is variable; adapts the frequency in response to the input signal using LMS feedback; the frequencies are similarly adjusted to the amplitudes.

Operates on a single channel at a time.

Well suited for modeling periodic signals of an unknown and potentially varying frequency and/or amplitude.

- No cycle boundaries or frequencies need to be pre-determined.



Coupled WFLC/FLC

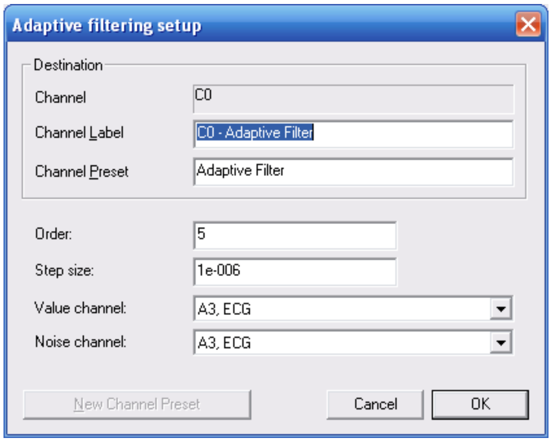
Runs a WFLC on the signal to determine the harmonic frequency and then runs the result through an FLC using the computed harmonic.

The second FLC can be run on the same or a different channel.

Well suited for real-time extraction of information from one signal based upon the frequencies contained in another signal.

- Use to remove movement noise from ECG.
- Unique configurations can be established with two input signals, one for frequency and one for amplitude.

Adaptive Filtering Calculation



➲ See the Adaptive Filtering transform on page 272.

Adaptive filtering is a signal processing technique that processes two different signals in relation to one another and can be used for noise estimation, noise reduction, general-purpose filtering, and signal separation. Adaptive filtering creates efficient high-quality filters with a minimal number of terms, which can be very useful in blocking mains interferences or other known periodic disturbances.

- Useful for noise filtering where it is possible to acquire a signal that is correlated to the noise (similar to the way noise-cancelling headphones detect and remove outside noise). Applications include removing EMG from ECG or EOG from EEG.

To have Acq*Knowledge* apply an Adaptive Filtering Calculation in real time:

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Adaptive Filtering.
5. Click the Setup button in the Input Channels dialog to generate the Adaptive Filtering dialog.

The weights within an adaptive filter are modified on a step-by-step basis. Acq*Knowledge* uses the N-tap FIR adaptive filter, with coefficients updated using least means squares (gradient) feedback.

Order	Specify a positive integer for the number of terms to be used in the internal FIR filter.
Step size	Provides *mu*, the rate of adaptation of the coefficients within the FIR filter.
Source channel	The source channel will be replaced by the adaptive filter results.
Noise channel	The noise channel is the signal that is correlated with the noise to be eliminated from the Source; it is not modified by adaptive filtering.

Source and Noise channels must have the same channel sampling rate (under Channel Set Up).

Comb Band Stop Filter Calculation

To have Acq*Knowledge* apply a Control Calculation in real time:

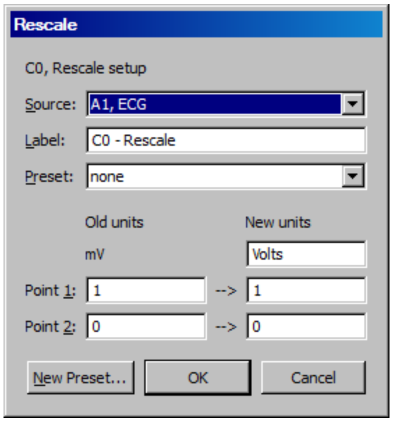
1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Comb Band Stop.
5. Click the Setup button in the Input Channels dialog to generate the Comb Band Stop dialog.

See page 131 for details.

Metachannel

See Metchannel details on page 116.

Rescale Calculation



Rescale applies two-point linear mapping and allows users to change the measurement units (for example, to change temperature from Celcius to Farenheit). The text corresponding to the new units can be manually entered.

To have Acq*Knowledge* apply a Rescale Calculation in real time:

1. Choose MP150 > Set Up Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Rescale.
5. Click the Setup button in the Input Channels dialog to generate the Rescale dialog.

- Use the Rescale transformation (after acquisition) to adjust forgotten calibration of analog channels or reverse incorrect calibrations.
- A "Rescale" Automator action has been added to allow rescaling to be performed in workflows.

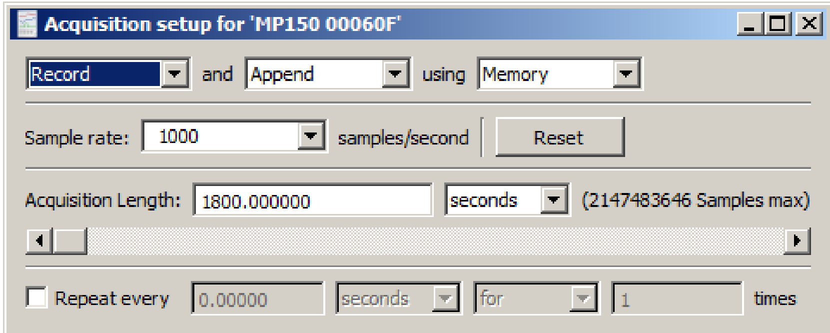
The rescale formula is:

$$v_{new} = \frac{y_{new} - y_{old}}{x_{new} - x_{old}} v_{old} + \left(y_{new} - \frac{y_{new} - y_{old}}{x_{new} - x_{old}} x_{new} \right)$$

Rescale Source	Displays the label and number of the selected channel.
Old Units	Displays the values of the current vertical units of the channel
New Units	Allows for manual entry of the new units to be used. The new units will be displayed in the vertical units of the channel

Note When rescaling only a selected area of the waveform, the manual entry of new units is not available unless “Transform entire wave” is checked since it is not possible to display different units for different time ranges in the same channel.

Chapter 7 Set Up Acquisition



Set Up Acquisition—The Basics

Once you have selected the channels to be acquired, the next step is to Set Up Acquisition. These options control the data collection rate, where data will be stored during an acquisition, and the duration of each acquisition. Choose MP150 > Set Up Acquisition to generate the dialog to set these options.

Storage Mode

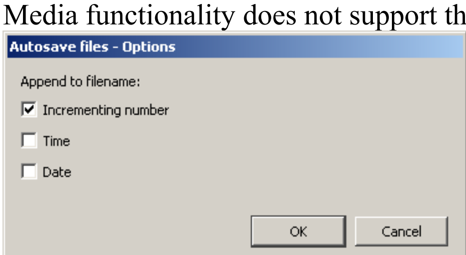
At the top of the dialog are three popup menus that allow you to control a number of aspects for storing the data from each acquisition.

Record/Record last allows you to control whether the software saves all the data or only the most recent segment of the data.

- **Record**—the MP System (MP150 or MP36R) will store data for the amount of time that is specified in the acquisition length box. This is the default and is appropriate for almost all types of acquisitions.
- **Record last**—only available when acquisitions are set to 'Save Once' or 'Memory'—the MP System (MP150 or MP36R) will acquire data continuously, but will only store the most recent segment of data equivalent to the duration in the acquisition length dialog. That is, if the value in the acquisition length box is 30 seconds and record last is selected, the MP System (MP150 or MP36R) will acquire data ad infinitum, but will only store the most recent 30 seconds of the data.

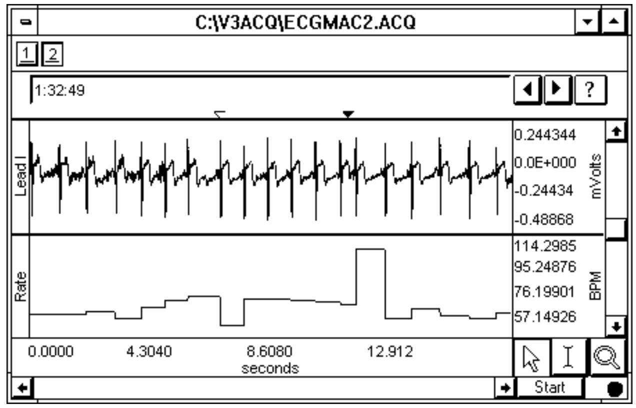
Save once/Autosave file/Append allows you to vary how the data is saved to a file. By default, Acq*Knowledge* will save the data to a single continuous file.

- **Save once—**Acq*Knowledge* will begin an acquisition when the mouse is clicked on the start button, and will stop either when the acquisition length has been reached or when the stop button is clicked with the mouse.
- **Autosave file** —allows you to perform several acquisitions one after another, and save the data from each acquisition in a separate file. When the Autosave option is selected, a File button will appear to the left of the sample rate dialog. Click File to generate a standard Save dialog to enter the root file name for the data from each acquisition. After you click Save in this dialog, another dialog is generated with options to append an incrementing number, time (system clock), or date (system clock) to the filename: Media functionality does not support the *Autosave file* acquisition mode.



- **Append** —similar to 'Save Once', except that Append allows you stop and restart acquisitions at arbitrary intervals. Append mode is unique in that clicking on the Stop button only pauses the acquisition, which can then be restarted by clicking on the Start button.

In Append mode, each time an acquisition is restarted, a marker is inserted into the record showing the time (hh:mm:ss) at which the MP System (MP150 or MP36R) started acquiring data. Although you can pause for any period of time, the MP System (MP150 or MP36R) will only acquire data for the amount of time indicated in the Acquisition Length box. Data can be acquired in Append mode while being saved to memory, disk, or the MP data acquisition unit (but not in Averaging mode).

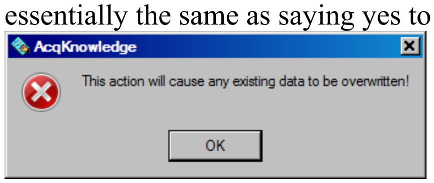


Sample data Acquired in "Append" mode.
Markers indicate where Acquisition was paused.

Appended segments can be stored to disk, memory, or MP150.

- ➢ **Append to Disk**: In this mode, it is usually best to record all channels at the same rate. If the user stops the acquisition, the length will be the same for all channels—so the next segment of appended data will neatly link onto the end of the existing record. If channels are sampled at different rates, append to disk operation will cause the software to rewrite all data files in the graph and add "extra" data to the "uneven" waves. This extra data will be a continuation of the same data point at the end of each uneven wave. This operation may take some time to complete for very long data files.
  - ▪ You can append to existing files—just open them, change the storage mode to "Append to Disk" and Start the acquisition.
  - ▪ Append to disk requires Acq*Knowledge* 4 format files. If you open any other file format, you will be prompted to translate the file.
- ➢ **Append to Memory**: In this mode, data is appended to the "uneven" waves in the same manner as described for Append to Disk. When channels are sampled at different rates, this mode will respond faster than Append to Disk because the data files are already in memory so the software does not have to rewrite all the data files in the graph.

A **Reset** button is generated in the Set Up Acquisition dialog when Append is selected. Click the Reset button to erase the acquired data file and start a fresh acquisition file (this is essentially the same as saying yes to an "Overwrite existing data?" prompt).



The Rewind button on the toolbar will delete the last recorded segment. Ctrl-Rewind (Windows) or Option-Rewind (Mac OS X) will delete all recorded segments (similar to the Reset button).

Append plus **external trigger**

An acquisition that takes place over a long period of time with brief events which are few and far between can be Set Up in the following manner: the researcher watches for these event, triggers the acquisition to start, and then lets the pre-defined acquisition length run out. When another event of interest occurs, the researcher triggers the next acquisition. This acquisition will be "appended" onto the end of the first acquisition. Memory is the only limit as to how many "appendages" can be added.

Append plus **Variable Sampling Rates**

If the mode is started and stopped manually, it is statistically possible that, prior to the next pass of the Append, extra data points may be inserted in various data channels to "line up" the data (see sample on page 107). These extra data points simply replicate the last sample in any affected channel. To minimize the impact of the extra data points, make sure the lowest sampling rate is on the order of 10 Hz or higher, or don't use VSR.

Disk/Memory/MP/Averaging determines where to store data during an acquisition. Once data has been acquired and is stored in a file, it is stored on a hard disk or other similar device. There are a number of options for storing data *during* an acquisition. The best choice as to where data should be stored during an acquisition depends in large part on the nature of the acquisition itself, and the type of computer being used.

- Memory stores data in computer memory (RAM) during an acquisition. After the acquisition is finished you will have to select Save As... from the File menu to permanently save this to your computer's hard disk. This usually allows for faster acquisition rates, although most computers have less available RAM than disk space.
- Disk saves data directly to the computer's hard disk during an acquisition. Disk mode is fast enough (in terms of maximum sampling rate) for many applications, especially when only a few channels are being acquired. Saving data to Disk also allows for longer acquisitions, since most computers have more hard disk space free than free RAM. A final advantage of saving data directly to Disk is that if there is a system failure (including power outage), all the data collected up to that point is saved on disk and can be recovered, whereas the data is deleted if it is being saved to computer memory.

  IMPORTANT—When saving files to Disk, always be sure to save your files under a different name BEFORE you start each acquisition. Otherwise, any previous data in that file will be overwritten. In Memory mode, simply save the file after the acquisition.
- MP stores a small amount of data on the MP data acquisition unit itself. The MP150 is limited only by internal memory, with storage estimated at 4 MB and 400 kHz aggregate sampling rate.

  Obviously, data cannot be sampled this fast for a very long period of time if it is to be stored in the MP data acquisition unit. Also, as more and more channels are acquired, the duration of acquisition to the MP data acquisition unit will shorten. Another drawback of storing data to the MP data acquisition unit is that the data is not plotted on the screen as it is being acquired, but will automatically be plotted on the screen as soon as the acquisition is terminated.
- Averaging is used exclusively for acquisitions involving repeated trials; see page 154.

Acquisition Sample Rate

The value in the box labeled "Sample rate" indicates how many samples the MP System (MP150 or MP36R) should take per channel during each second of data acquisition. The sample rate can be changed by clicking on the pull-down menu. To allow for variable sample rates, the rate options are constrained so that channel sample rates are equal to or a specific power of 2 less than the acquisition rate. Sample rates can be chosen at the selected increments only; custom rates are not accepted.

Depending on the nature of the data being acquired, the "best" choice in terms of sampling rate will vary. Technically speaking, the minimum sampling rate should be at least twice the highest frequency component of interest. This means that if the phenomenon you are interested in observing has frequency components (which are of interest) of 100 Hz, you should sample at least 200 times per second. Fourier analysis (FFT) can be used to determine what frequency components are present in the data (see page 301 for a more detailed description of the FFT function).

TIP: A good rule of thumb is to set the sampling rate to at least three to four times the highest frequency component of interest.

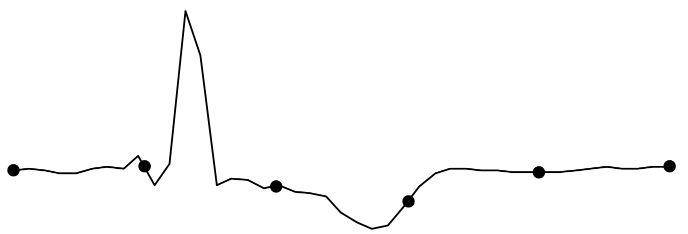
In less technical terms, lower sampling rates can be used for data with slowly changing values (e.g. respiration, EDA, GSR), whereas higher sampling rates should be set for data where values change markedly in magnitude or direction (e.g. ECG, EEG, evoked response).

The maximum allowable sampling rate will automatically adjust itself according to the storage mode, how many channels are being acquired in the channel setup window and the type of computer being used. You can try this by entering a large value (say 99, 999) in the sample rate box. Now click the mouse button or press return and Acq*Knowledge* will automatically return the maximum allowable sample rate given the computer's throughput and the acquisition parameters.

If data is being stored to disk or computer memory (RAM) during an acquisition, To set a sample rate that is too high. The acquisition will begin normally, but Acq*Knowledge* will stop the acquisition and display a message indicating that the acquisition buffer has overflowed. The data up to this point has been saved, and the sample rate must be set to a smaller value if you wish to complete an entire acquisition.

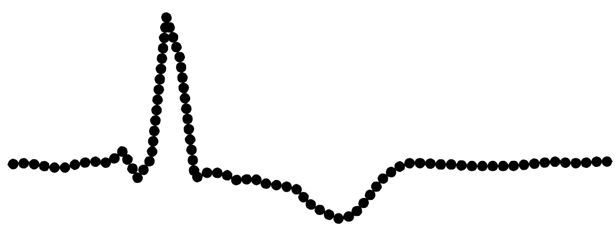
The sample ECG waveforms below illustrate the effect of different sampling rates on obtaining varying levels of fidelity when reproducing the data.

- Top waveform: data is sampled relatively slowly; difficult to make out the shape of the waveform.
- Middle waveform: sampled at the faster rate; more samples are taken in the same period of time, which results in higher resolution for some components of the waveform.
- Bottom waveform: sampled at a relatively high rate; increased resolution of the waveform. Waveform components that were obscured at slow sampling rates are now well defined, and measurements taken on this waveform would be able to better establish the maximum amplitude, time between different ECG complexes, etc.



Representation of ECG waveform sampled with relatively few samples per second "True" ECG wave is superimposed over dots that indicate sample points.

Preceding waveform as it would look if plotted in Acq*Knowledge* (with data points superimposed).



Representation of same ECG waveform sampled at a relatively higher sampling rate.

As shown, under-sampling completely misses the QRS complex of this waveform, although it might detect components of the QRS in subsequent beats. Although this is an extreme example of how under-sampling can affect digitally processed data, it is important to note that the rate at which data is sampled has important implications for the interpretation and analysis of data.

The disadvantage of acquiring data at high sampling rates is that each sample point takes up memory, whether it is RAM , disk space or memory. Moreover, once the file is saved, it will require more disk space than a file of similar duration sampled at a slower rate.

<u>Note for variable sample rate processing</u>:

The Equation Generator (Expression) and Waveform Math functions will constrain operations between waves of different rates as follows:

If an equation is operating on two or more waves of different sample rates, the result of the operation will always be output at the lowest sampling rate from the waves (F low). If the destination channel for the result has an assigned rate other than (F low), the operation will not be permitted. If the destination channel is set to a new channel, the operation will always be permitted.

VSR data padding—If the channels are of unequal length (as a result of variable sampling rate or waveform editing), they will be padded for Append acquisition. Digital and Analog channels are stored as short integers by default; a waveform paste into a digital or analog channel, however, will result in its underlying data being converted to floating point. This will generate the “Abort/Replace” warning for pastes to Digital or Analog channels since the data format has changed since the last acquisition.

Additionally, if an Analog or Digital channel is used as the source waveform for a Copy, it will also be converted to floating point and will result in the “Abort/Replace” warning being generated.

Since Calculation channels are already floating point, pasting into them or copying from them will not change their data format. The channels will be padded with their last value and the append will commence.

Waveform Cut operations do not change the underlying data format for Analog, Calculation, or Digital channels. If only Waveform Cut is used, no data format conversion will occur and channels will be padded with their last value and subsequent appends are allowed.

Acquisition length

To set the duration of an acquisition, enter a number in the acquisition length box. By default, 30 seconds of data will be recorded. The popup menu right of the length box allows you to scale the duration of the acquisition in terms of milliseconds, seconds, minutes, hours, or samples. Changing this option will not change the length of the acquisition, only the units used to describe it. Thus you can describe the same acquisition as lasting 30 seconds, or 0.5 minutes, or 30, 000 milliseconds. Scaling the duration of an acquisition in terms of samples is essentially the same as the time scaling options, except the length of the acquisition will be expressed in the total number of samples to be collected on one channel.

Regardless of what scale you use to determine the length of acquisition, Acq*Knowledge* will end an acquisition when the value in the total length box is reached. You may also stop the acquisition at any time by clicking on the stop button in the lower right hand corner of the graph window.

The MP150 will automatically limit the maximum recording length to the amount of available memory on the target storage device (memory, disk, or MP150). The default is to record one acquisition of the duration specified in the acquisition length box. The acquisition length parameter has a somewhat different interpretation in the *Record Last* and *Averaging* modes. See pages 148 and 154 (respectively) for more information on these features.

Multiple Hardware

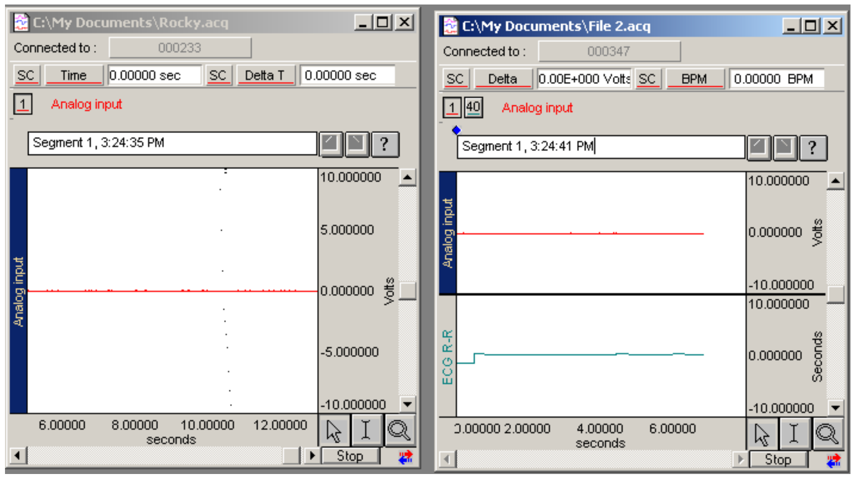
Acq*Knowledge* can be used with multiple MP150 data acquisition units to

- control multiple, independent experiments on one computer
- increase the total number of channels used for a single experiment (e.g., 32-channel EEG)

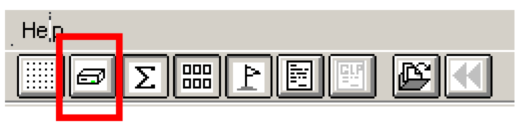
To synchronize the Start of multiple units, use the External Trigger function.

To combine up to 60 channels of data into one file, use the Merge Graphs feature (see page 261).

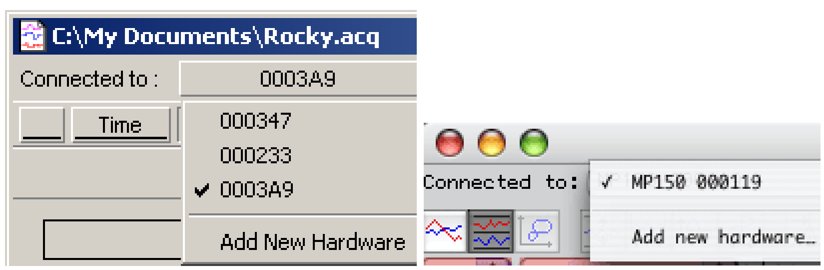
Each graph window can support a different MP150 unit. To add an MP150 unit for acquisition, open a New Graph (not a Data View).



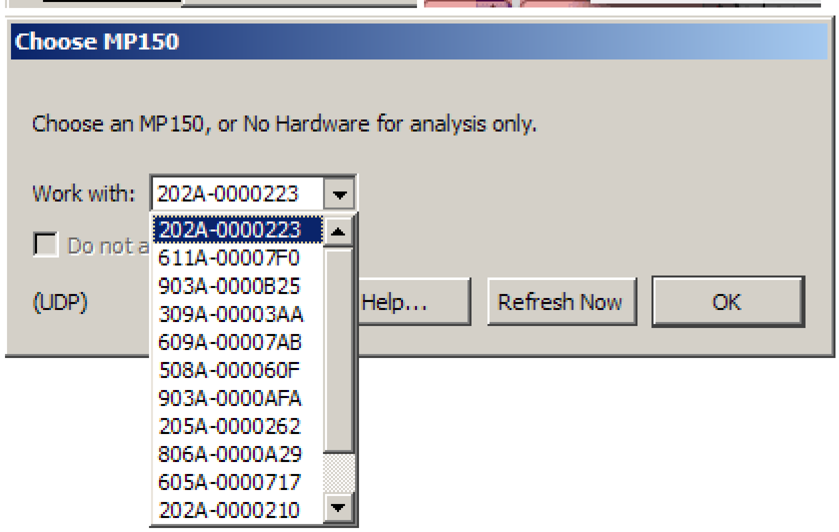
To show/hide the "Connected to:" information, toggle the Show/Hide Hardware icon in the Toolbar.



To switch the MP150 unit associated with a graph window, click the "Connected to" box and select an available unit or Add new hardware.



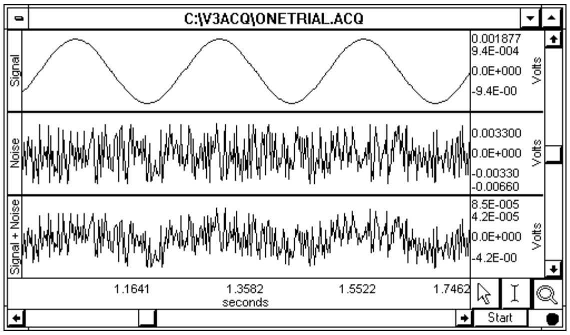
Click the **Help…** button to open a troubleshooting guide (PDF) with support tips to try if an MP150 is not communicating with the computer.



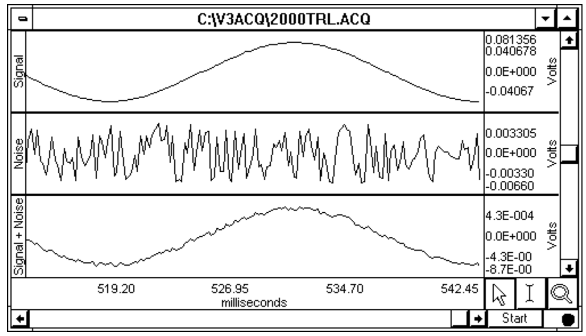
Averaging

Overview

In some instances, the signal of interest does not stand out against the background or ambient noise (the level of ambient noise exceeds the signal produced by the object of interest), and the only way to detect the signal of interest is to perform repeated trials as part of one acquisition, and average the trials together. Since the "noise" associated with the signal is assumed to be random, and the "signal" is assumed to be systematic, the noise should approach zero as the individual trials are averaged together.



Signal (top) measured in the presence of noise (middle), which results in the bottom waveform when measured in standard Acquisition mode



Same signal averaged in the presence of noise over 2,000 trials to produce the lower waveform.

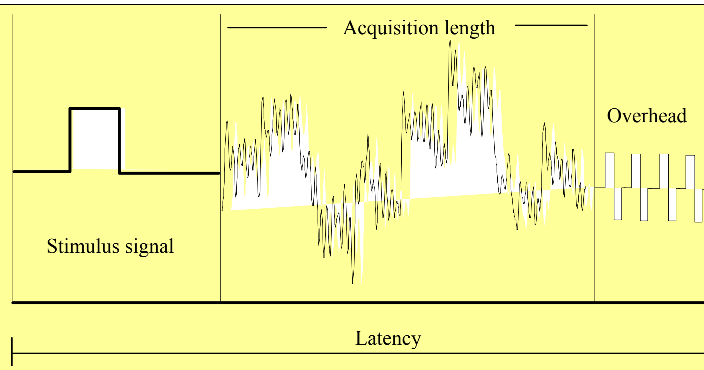
Any averaging acquisition consists of three general components:

(a) the stimulus signal

(b) the duration of the acquired data, and

(c) a small amount of processing time (or overhead) that takes place between acquisitions.

The duration of the stimulus signal and the duration of data to be acquired can be set by the user. The amount of overhead required is a function of the acquisition length, the sampling rate, and the number of channels being averaged.



Stimulus signal	usually some sort of pure tone or pulse; occurs at the beginning of each trial.
Acquisition length	refers to the amount of data to be acquired during each trial.
Overhead	refers to a period of time after data has been acquired that is needed to perform the mathematical averaging.
Latency	refers to the total time elapsed between the start of one trial and the start of the subsequent trial.

Important usage notes

- **The maximum length of a single averaging pass is restricted to 2 seconds**; if longer averaging passes are required, use regular data acquisition and use the Ensemble Average offline analysis option to generate averages in post-processing.
- **The preferred hardware setup for on-line averaging mode is direct connection to the MP150** via cross-over cable. To improve stability, avoid interruptions during acquisition:
  - Do not access top-level menus (File, Edit, Transform, etc.) or generate popup dialogs (Setup…).

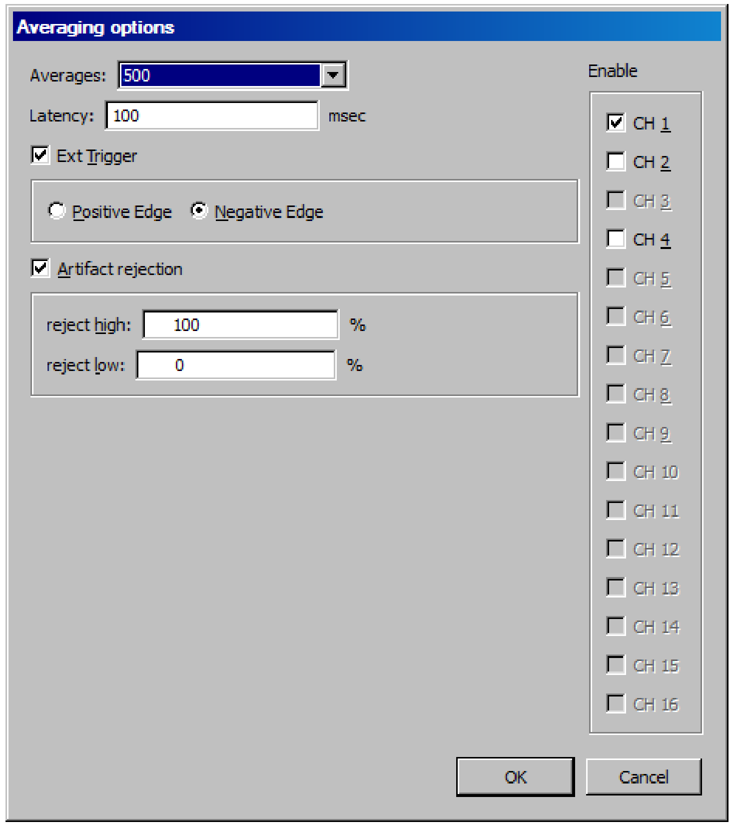
- Avoid running other programs—helps ensure that required system resources (processor time, memory, and network throughput) remain available.
- If the MP150 is connected over a network, avoid running applications that consume network traffic (Internet Explorer, mail client, media player)—these may interrupt/delay communication to the MP150.

Averaging Setup

For Advanced Averaging, see page 157

To set up Averaging:

1. Choose MP150 > Set Up Acquisition and select "using Averaging" option.
2. Click the Setup button to generate the Averaging options dialog.
3. Set the Averaging options as detailed below.
4. Click OK to close out of the dialog.
5. Set the Stimulus (see page 170).
6. Use the buttons in the graph window to Start, Stop, and save the averaging acquisition.



Online averaging progress bar

An online averaging progress bar is a toolbar that is added to graph windows in Acq*Knowledge* 4.1 when online averaging acquisitions are in progress. The toolbar displays the number of averaging passes that have been completed and the number of passes that have been rejected by the MP150 firmware. This is similar to the text displayed in the status area of Windows Acq*Knowledge* 3.9.1 and earlier.

<u>Averaging Options</u>

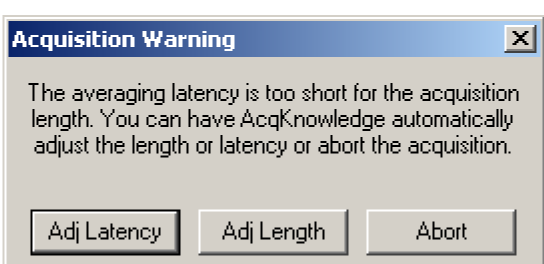
Averages

Select the number of averages to perform from the pull-down menu, to a maximum of 10,000.

Latency

The individual components of stimulus signal, acquisition length, and overhead are, in sum, equal to the latency of the acquisition. As a rule, you should set the latency to at least three times the acquisition length. In some cases—such as when you want to allow a subject to return to a baseline state or condition—you may want to set the latency to a value much larger than this. By default, each trial is initiated when the latency value is reached (in the sample dialog shown, a new trial is initiated every 100 msec).

If the latency is set to a value too short to allow for averaging to take place, an Acquisition Warning will be generated:



- Adj Latency: automatically adjust the latency to the shortest possible value that still allows for data to be acquired and processed.
- Adj Length: reduce the amount of data acquired without changing the latency.
- Abort: return to the graph window without any data being collected.

Averaging Options continued

External trigger

To initiate a trial on a signal from an External Trigger, enable this option and select positive or negative edge. When this option is checked, a new trial will be acquired each time a trigger circuit is closed. For more information on triggers, see page 166.

Artifact rejection

Occasionally during an acquisition, extreme levels of artifact will be present for one reason or another. Checking artifact rejection allows you to determine what signal levels constitute artifact, and have the MP System (MP150 or MP36R) reject these trials. When artifact rejection is enabled, the MP System (MP150 or MP36R) will ignore any trials that contain signals exceeding the artifact rejection thresholds, keep track of how many trials have been rejected, and add that number of trials to the total number of trials to be acquired. This allows you to “re-try” a trial that was rejected due to the presence of artifact.

To set these parameters, you need to set a high threshold and a low threshold. Both thresholds refer to the scale limits (normally ±10 Volts). If the high and low artifact rejection thresholds are set to 80% and 30% (respectively), the MP System (MP150 or MP36R) will reject any trial where the signal exceeds +8 Volts or –3 Volts.

When the channel scaling feature is used to change the range of Map (Scale) values to something other than ±10 Volts, the artifact rejection formula for symmetrical limits is: $y = ((2 \cdot PV)/100) \cdot x - PV$

where y = voltage threshold
PV = Peak Value
x = percent threshold (whole number)

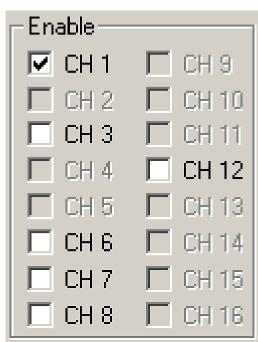
If non-symmetrical limits are used, the following equation is used: $y = ((V1-V2)/100) \cdot x + V2$

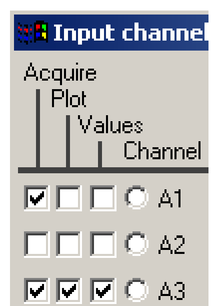
where y = voltage threshold
$V1$ = Higher Peak Value
$V2$ = Lower Peak Value
x = percent threshold (whole number)

Enable Channels

To add analog channels to the average, check additional channels in the Enable list.

- Channels must be set to “Acquire” under MP150 > Set Up Channels to be selectable here; otherwise the channel box will be grayed out.





Stimulus Signal

Although Acq*Knowledge* does not require a stimulus signal to be output for Averaging trials, most applications that use signal averaging make use of a stimulus signal. Digital stimuli (i.e., clicks) or analog stimuli (i.e., tones, pulses, and arbitrary waveforms) may be output.

In almost all cases, the most convenient way to output a stimulus signal is to output a predefined wave on analog output channel A0 and/or A1. You can create pulse waveforms, tone waveforms, ramp waveforms, and arbitrarily shaped analog waveforms. Use MP150 menu > Stimulator Setup to set all of the stimulus output functions (see page 170).

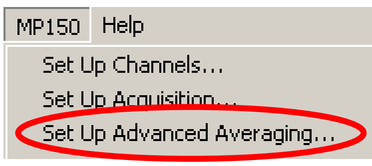
When you start Averaging, the Start button turns to Averaging status and the green dot turns to “A” to indicate that Averaging is in process.

Advanced Averaging—P300

Advanced averaging can be used to set up P300 protocols. A sample P300 setup is included in the Samples folder.

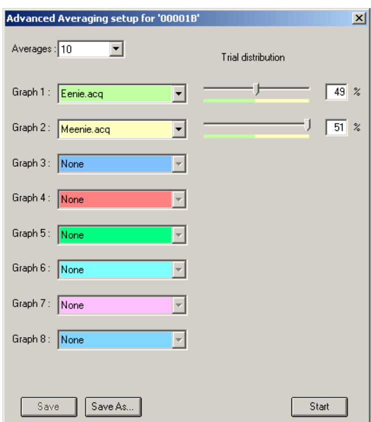
To set up Advanced Averaging:

1. Open two or more graph files.
2. Use Set up Acquisition to set each graph file for Averaging (see page 154).
3. Click the Averaging Setup button and set Averaging Options as desired for each graph file.
   - Advanced Averaging will use the defaults if you choose not to set Averaging Options for Latency, Artifact Rejection, or Enabled channels.
4. Use Setup Stimulator to establish the desired stimulus output for each graph file (see page 170).
   - Set the Output channel to the same channel (A1 or A0) for all graph files.
   - Set the Stimulator Output to During Averaging Pass (recommended).
5. Save each graph file with an appropriate name.
6. Choose MP150 > Set Up Advanced Averaging.



This menu option is only enabled if two or more open graphs are set to Averaging.

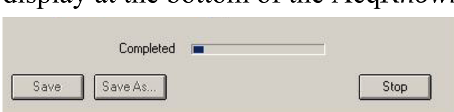
7. Set the Advanced Averaging options:



   a. Averages: Select the number of averages from the pull-down menu (max 10,000).
   b. Graph: Assign a Graph from the pull-down menu of open graph files. Up to eight graph files can be used in Advanced Averaging.
   c. Trial distribution: Use the slider to assign a percentage for each graph; the total will adjust to 100%

   Note The software counts 0 as 1, so the percentage of the active graph should be entered as one less than the desired output (for 50% enter 49%).

8. Click the Start button in the Advanced Averaging setup dialog to begin acquisition.
9. Review the status in the "Completed" bar that is activated when Start is pressed and/or in the status display at the bottom of the Acq*Knowledge* software window.

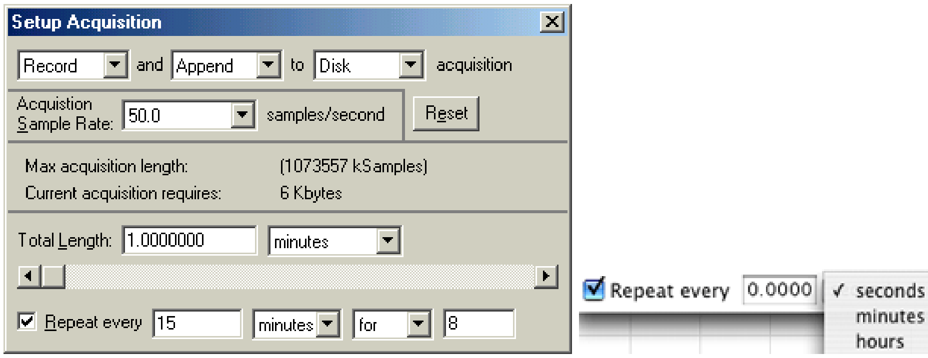


10. Save each graph file.

11. Make sure that the Graph names are correct in the Advanced Averaging setup dialog, and then use Save or Save As to save the setup as an AVG file.

Repeating

The Repeat mode allows you to acquire data from repeated trials using the same parameters for each trial. Checking the Repeat every box at the bottom of the acquisition setup dialog enables a series of dialoges and popup menus at the bottom of the dialog. These allow you to control how many times an acquisition will repeat as well as the interval between trials. When this is unchecked, the acquisitions will repeat as soon as possible (usually instantaneously, but slightly longer if data must be saved to a file between trials).



Interval The entry to the right of the “Repeat every” checkbox tells Acq*Knowledge* how long to pause between the start of one acquisition and the beginning of the next acquisition. This can be scaled in terms of seconds, minutes, or hours using the second popup menu.

It is important to note that this value measures the interval between the start of two adjacent trials, rather than the interval between the end of one trial and the start of the subsequent trial. If the repeat interval is set for 15 minutes and the acquisition length is set to 60 seconds, then there will be a 14-minute pause between the end of the one trial and the beginning of the next.

Trials Set how many trials to acquire:

for perform a finite number of trials; enter the number of trials to acquire

forever perform an infinite number of trials. Trials will be repeated at the specified interval until the acquisition is stopped either by clicking on the stop button in the graph window or if there is not enough free memory on the target storage device.

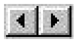
Regardless of which options are checked, data for each trial is acquired according to the acquisition parameters specified in the dialog. In the above example, each trial of data will be sampled at 50 Hz and will last 1 minute; the trials will be repeated every 15 minutes for a total of 8 trials.

By default, each acquisition will delete the data from the previous acquisition. You can change this by selecting the Autosave file option from the Save once/Autosave file/Append option at the top of the acquisition setup dialog. When the repeating option is checked and Autosave is selected, Acq*Knowledge* will save the data from each trial using the file name and extension indicated by the autosave feature. See page 148 for a more detailed description of Autosave.

Setup Channel Options

Channel

The **Channel** column contains the alpha-numeric channel numbers. "**Analog**" (or continuous) input channels begin with "**CH**" and run from CH1-CH4. "**Digital**" input channels begin with "**D**" and run from D1-D8. "**Calculation**" channels begin with "**C"** and run from C1-C12.

Display is limited to four channels of each type. Use the scroll button  to set up additional Digital or Calculation channels.

Acquire

When the **Acquire Data** box is checked for a given channel, data will be collected on that channel.

Plot

If **Plot on Screen** is also checked, data will be plotted on screen in real-time during the acquisition. If the plot box is unchecked, data will still be recorded for that channel, but the waveform display will be disabled. To display the waveform plot after the acquisition is over, show the channel.

Enable Value Display

Checking the **Enable Value Display** box means that you can choose to display (numerically and/or graphically) the values for each channel in real time. To display the values, you must also select **Show Input Values** (via the MP36 menu). Input values are displayed in a separate window from the main graph window.

Default

The default is to collect one channel of data on analog channel 1 (CH1), and to plot and enable value display for this channel

TIP

Usually, you will want to check all three boxes for each channel you acquire data on

Label

The **Label** entry for each channel allows you to type in up to 38 characters to identify the channel.

Presets

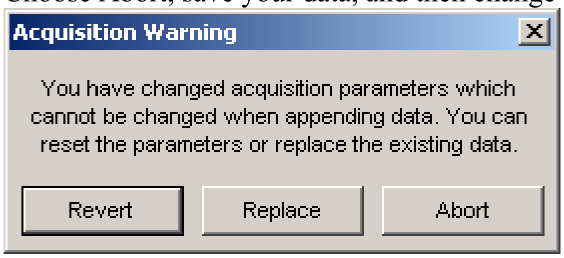
Clicking on the **Presets** button will generate a menu of available presets for the channel. Presets for common applications configure the hardware gain, filters, etc.

- For a detailed summary of **Analog Input channel, Digital Input channel,** and **Calculation channel** options see the **Presets** section beginning on page 115.

View/Change

To **View/Change Parameters** for a Preset, click the wrench icon. If you change the parameters, you have the option of creating a **New Channel Preset** to make the established parameters available to other channels.

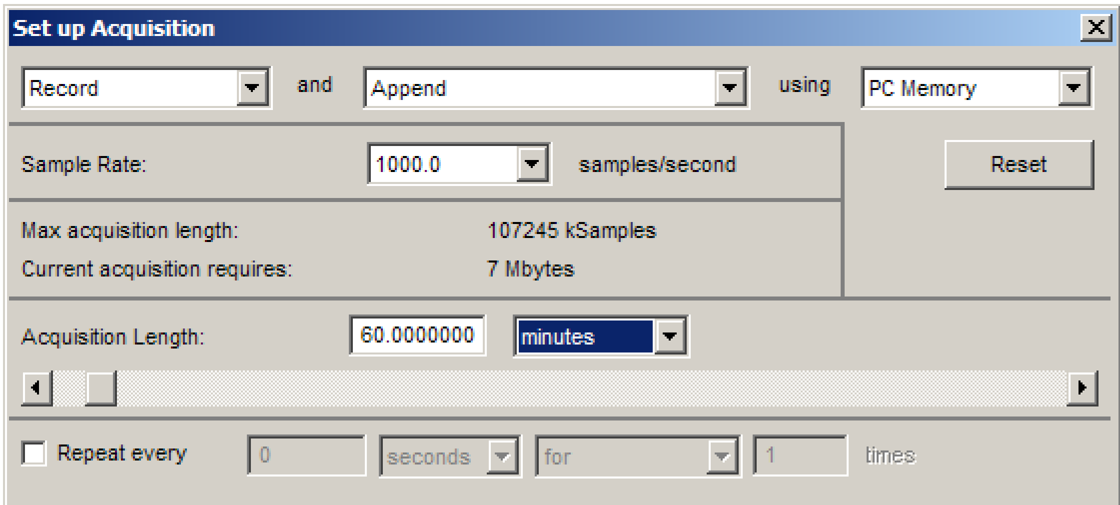
If you make a change to a preset and start recording in the Append mode, you will be prompted as follows. Choose Abort, save your data, and then change the presets to aquire as a new data file.



Setup Acquisitions

Once you have set up the channel parameters, the next step is to specify the acquisition settings. You can do this by choosing **Set Up Acquisition** from the **MP** menu. This generates a dialog that will describe the type of acquisition about to be performed.

There are a number of options here, but the basic parameters involve specifying: where data should be stored as it is being acquired, the sample (data collection) rate, and the acquisition length.



Data storage At the top of the Acquisition Setup dialog, you should see a display that reads **Record** and **Append** using **PC Memory**. This is the default option for collecting data and tells the BIOPAC software to automatically record data into single continuous file, and to store the data in computer memory (RAM) during the acquisition. The third pop-up menu (which defaults to **PC Memory**) allows you to specify where the data should be stored during the acquisition. You will need to choose **PC Memory** or **Hard Disk** storage. Computer memory (RAM) is usually faster (but less abundant) than disk space. If your system uses any virtual memory, the BIOPAC software will use as much as possible.

Sample rate This is analogous to "mm/sec" on a chart recorder, and refers to how many samples the MP unit should take each second. As the sample rate increases, the representation of the signal becomes more accurate — however, so does the demand for system resources memory, disk space, etc.). The sampling rate has a lower bound of 1 sample per second, and an upper bound of 100,000 samples per second (2 kHz). Choose the best sample rate from the pull-down menu generated when you click the Sample Rate entry.

A good rule of thumb is to select a sampling rate at least four times the highest frequency of interest for the signal.

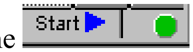
Triggering from an analog channel requires oversampling by a factor of 4, which ensures that the trigger signal will not be missed. For example, an initial sampling rate of 1,000 samples/second should be increased to 4,000. The trigger can be established in the Set up Triggering dialog

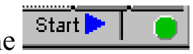
Acquisition Length This entry controls how long an acquisition will last (duration). This can be scaled in seconds, minutes, hours, milliseconds or number of samples, as selected from the pull-down menu. Set this value by entering a number in the Acquisition Length box or by moving the scroll box left (to decrease) or right (to increase).

Repeat The **Repeat** function is an advanced operation and is discussed on page 159.

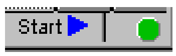
Starting an acquisition

After you have setup the channels to contain data and defined the channel parameters, you are ready to start the acquisition. If a file window is not already open, choose **File** > **New** to generate a graph window.

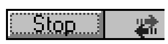
In the lower right corner of the screen, next to the  button, you should see a button with a circle next to it. The circle indicates the status of the communication link between your computer and the MP data acquisition unit (MP150 or MP36R). If the MP unit is properly connected to the computer and is turned on, the circle should be solid and green. If the MP unit is not properly connected, a solid gray circle will appear (on monochrome displays, the circle will appear solid when the MP unit is connected properly, and unfilled when the MP unit is not communicating with the computer).

You can start the acquisition by positioning the cursor over the  button and clicking the mouse button or by selecting "**Alt + Spacebar**." If there are no input devices (e.g., electrodes or transducers) connected to the MP150/MP36R, it will collect a small value of random signal "noise" with a mean of about 0.0 Volts.

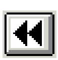
- For information on how to connect measurement devices to the MP36R, see the *BSL Hardware Guide*.
- You may also start an acquisition using a variety of "triggers," which are discussed on page 166.

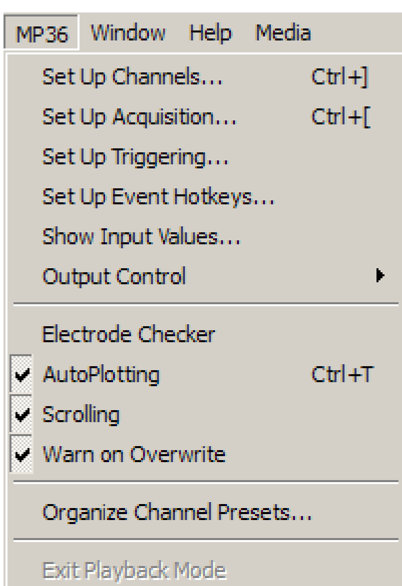
Once acquisition starts, the  button in the acquisition window changes to . The two opposing arrows to the right of the button indicate that data is being collected. Also, the "Busy" status indicator light on the front of the MP150/MP36R will illuminate, showing that data is being collected.

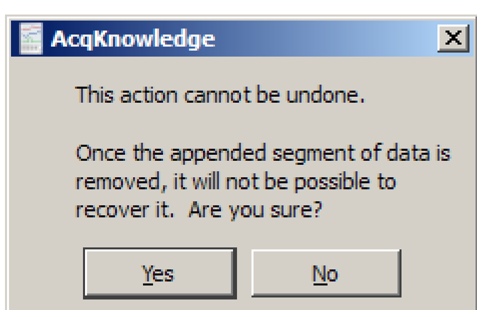
Stopping an Acquisition

To stop an acquisition at any time, click the  button in the lower right corner of the screen or select "**Alt + Spacebar**." An acquisition will stop automatically when it has recorded an amount of data equal to the **Acquisition Length** entry.

Rewind

 The Rewind button on the Toolbar allows you to erase the last recorded data segment and continue to Append data to the existing data file. This function will erase the last segment along with the Append Marker  for that segment; the application will keep track of Append Marker labels, so that the label always matches the segment number.



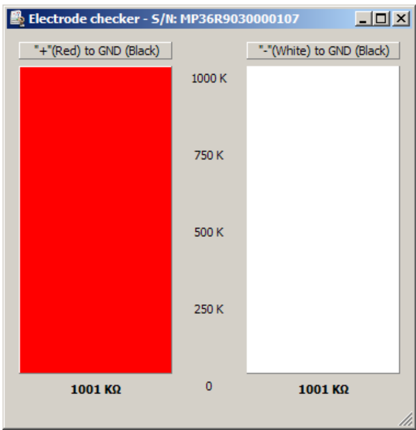


If the "Warn on Overwrite" option is active, a warning dialog will be generated before the segment is deleted.

Saving acquisition data

To save a data file, pull-down the File menu and choose the Save command.

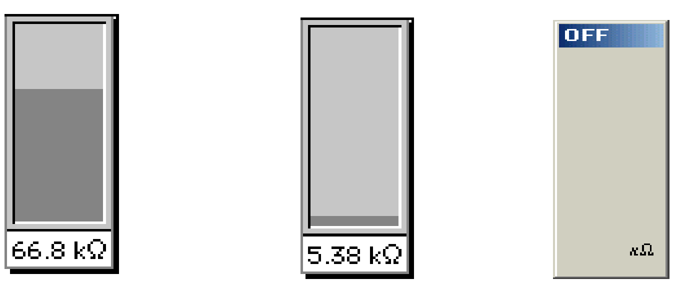
Electrode Checker



The **Electrode Checker**, in conjunction with the MP36R unit, measures how well electrodes are making contact with the surface of the skin. To use this feature:

1) Attach the electrodes as you normally would.
2) Connect the electrodes to an electrode lead set (such as the SS2LB).
3) Instead of connecting the electrodes to one of the four analog inputs, connect the Simple Sensor end of the electrode lead to the **Electrode Check** port on the front of the MP36R acquisition unit.
4) Click the **MP36** menu and scroll down to select **Electrode Checker**.

This will generate a small "thermometer-like" display. At the bottom of the display you should see a number with kΩ after it. This value describes the impedance of the electrode/skin contact, with lower numbers being associated with better conductivity. The better the conductivity, the "cleaner" the signal displayed on the screen. If the MP36R is off or no nothing is connected to the "Electrode Checker" on the MP36R unit, the Electrode Checker display will say "OFF."



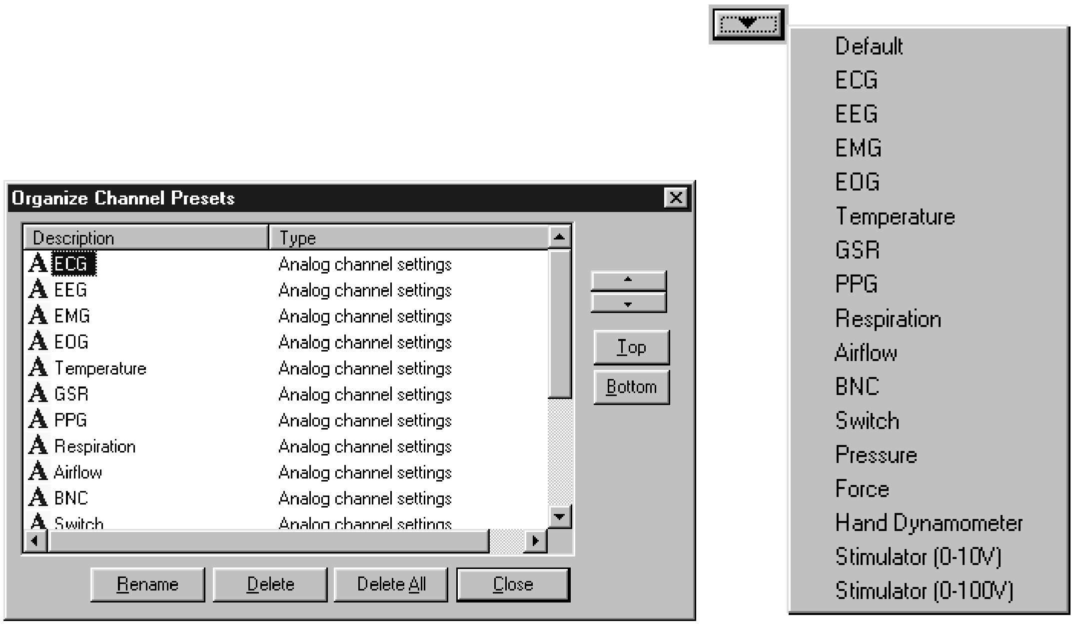
Poor contact Good contact Off

TIP While there are few absolutes as to what constitutes "good" contact, one rule of thumb is that this number should be below 10 kΩ, and the lower the better.

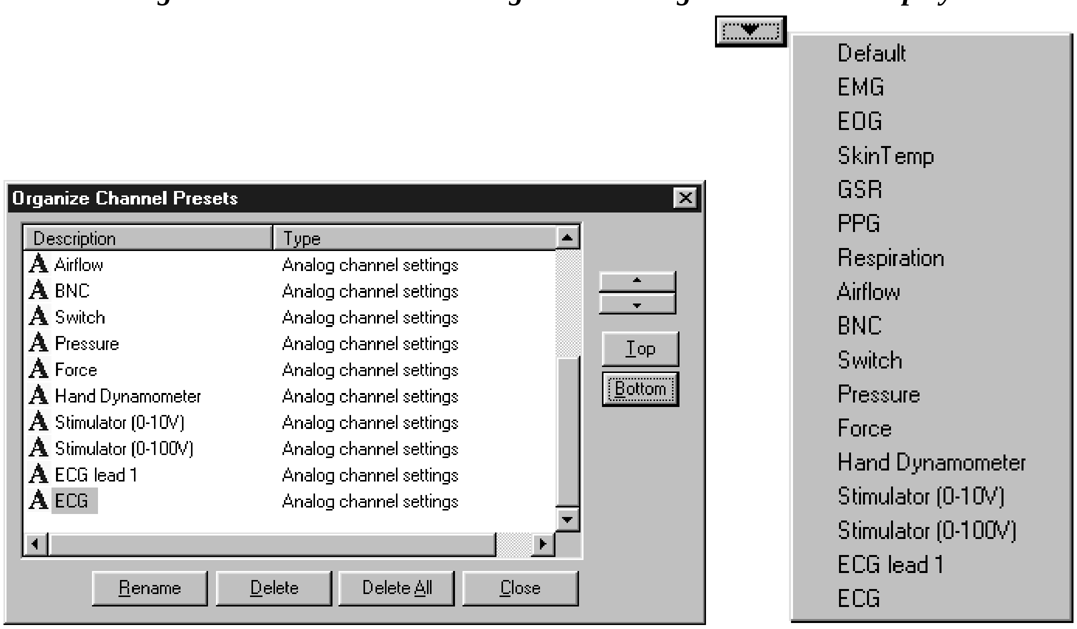
TIP To decrease the impedance of an electrode connection, you may want to "abrade" the surface of the skin with an abrasive pad (such as ELPAD). This removes a thin layer of dead skin cells and should result in a signal that has relatively little noise.

Organize Channel Presets

The **Organize Channel Presets** option of the **MP36** menu is related to the channel presets in the **Set up Channels** dialog. You can organize the Presets (established or new) to place the most frequently selected at the top of the menu or to group related Presets, such as the established ECG Presets with any new channel Presets you create. Click a Preset description to select it, and then use the buttons to organize the Presets. The up and down arrows will move your selection one space at a time, and the **Top** and **Bottom** buttons will jump to the start or end of the list.

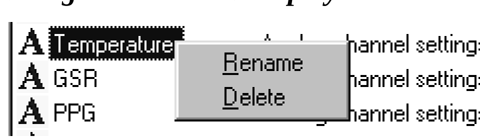


Organize Channel Presets dialog and resulting Presets menu display

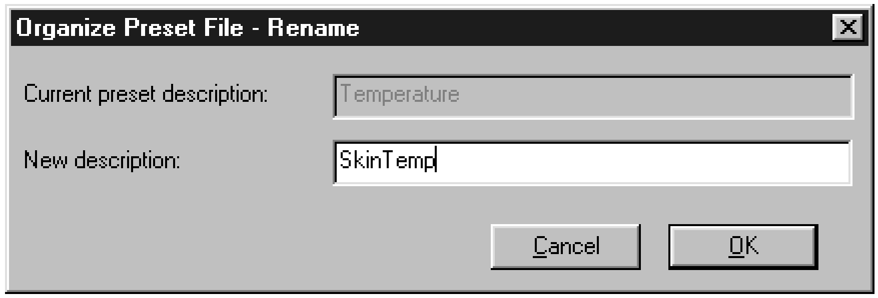


Revised Organize Channel Presets dialog and resulting Presets menu display

To delete or rename a Preset, select the Preset name from the listing and click the **Delete** or **Rename** button. Or, click the right mouse button to select the Preset from the listing and scroll to the desired option.



Rename a Preset by typing in a new description and clicking OK.

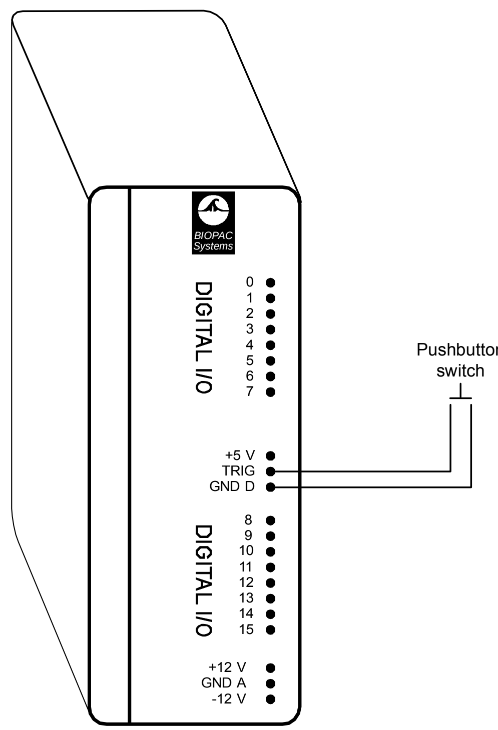


Delete a Preset by selecting that option. You cannot delete the Default Analog Input preset. When you delete a Preset, you will be asked to confirm the request because it is an irreversible action.

Chapter 8 Set Up Triggering

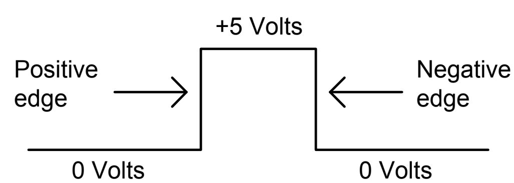
During a normal acquisition, the MP System (MP150 or MP36R) will begin collecting data following a mouse click the start button. It is also possible to begin acquisition using a trigger. Using a trigger allows you to start an acquisition "on cue" from a variety of different trigger sources. All trigger options are set in the Set Up Triggering dialog, which can be selected from the MP150 menu. By default, the trigger is Off, and acquisitions are started by clicking on the Start button in the graph window. Other options can be selected from the popup menu in the Triggering Setup dialog. To begin an acquisition with a trigger, first choose the trigger options most appropriate for your application and then click the Start button. After the Start button has been pressed, data will be acquired as soon as the trigger is activated. There are two general types of trigger sources: digital channels and analog channels.

Digital Triggers



Digital channels are channels that contain binary (either/or) data as typified by a switch being either open or closed. This type of data can be acquired from a push-button switch or other device that produces an on/off pulse. For instance, it is sometimes useful to have an acquisition begin when a subject presses a button or when a signal generator sends out a pulse. These are typical digital signals and the trigger devices that emit these signals can be connected via the UIM100C. Most stimulus generators are equipped to output a digital pulse simultaneously with the stimulus signal.

In a simple trigger design, an external switch is connected to the TRIG and GND D input as shown above. Since this switch will be either open or closed, the data will be digital and have two levels, +5 Volts and 0 Volts. A value of +5 Volts is interpreted as a binary 1, and a level of 0 Volts is interpreted as a binary 0. In the setup above, when the switch is closed (i.e., the button is pressed) the signal changed from +5 Volts to 0 Volts, creating a transition or "edge."

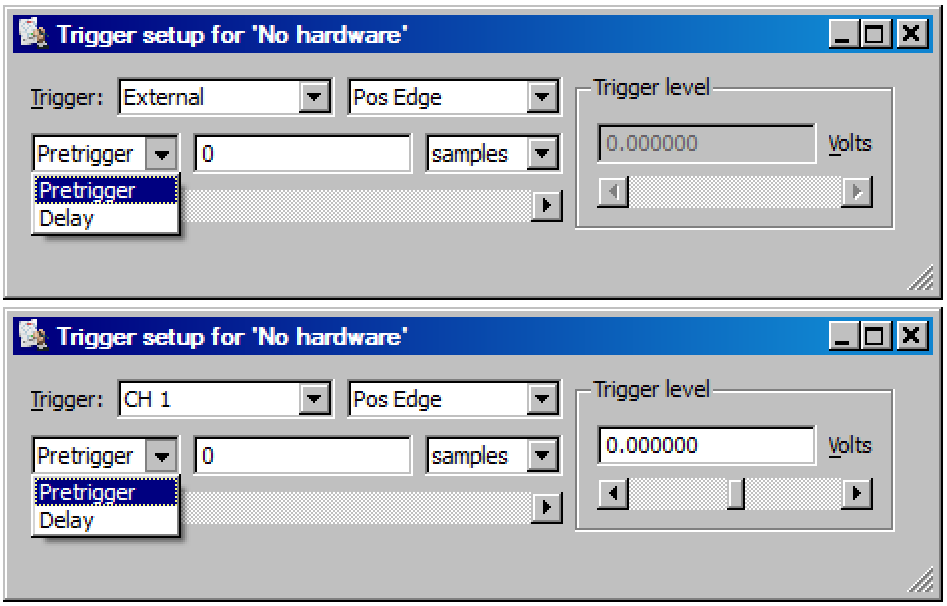


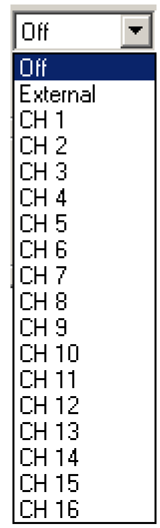
If the trigger is set to external, and the edge is set to positive, the acquisition will begin as soon as the push-button is pressed anytime after the start button in the graph window is pressed. Once the button is pressed, the acquisition will proceed according to the acquisition parameters you have set (acquisition length, sampling rate, and the like).

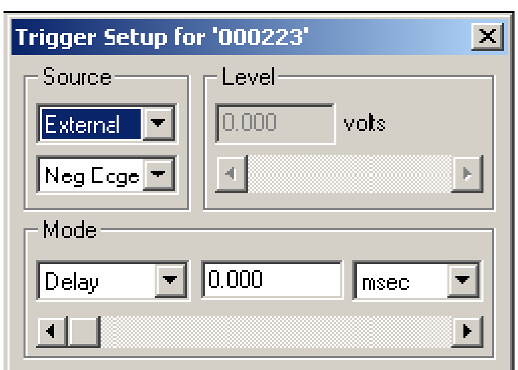
Analog Triggers

Initiate an acquisition when an analog channel reaches a certain level. To enable the analog trigger feature, data must be acquired to either memory (RAM) or disk, and a value must be entered in the Delay box (although the delay may be set to zero). The channel containing the data to be used as a trigger does not require the acquire/plot/values boxes to be checked in the Set Up Channels dialog. Leaving these boxes unchecked will allow the incoming data to trigger an acquisition but will not cause the trigger channel to be acquired or plotted.

Select MP150 > Set Up Trigger to generate the Trigger dialog:







Source Off: Disables Triggering while maintaining the established setup.

External: Select for Digital Trigger.

CH #: Select for Analog Trigger; must be acquiring to Memory or Disk. Specify the analog channel that contains the trigger data and then specify a voltage Level to initiate the trigger. Acquisition will begin when the data on the specified channel reaches the specified Level.

- To trigger an acquisition when an ECG wave on analog channel 1 reaches a certain voltage or value, you would set "Source" to CH 1 and then set the Level when the entry box is enabled.
- Triggering from an analog channel requires oversampling by a factor of 4, which ensures that the trigger signal will not be missed. The sampling rate can be adjusted in the Set up Acquisition dialog.
  - o For example, an initial sampling rate of 1,000 samples/second should be increased to 4,000.

Level The Level option is activated when a Source CH is selected. Set a level to initiate the trigger (e.g., if the ECG wave peaks at 3 V, set the trigger level just under 3 V).

Edge Triggers can have a positive or negative edge, defined as follows:

Edge	Digital	Analog
Pos	signal changes from 0 to 1	signal crosses from a baseline to a peak
Neg	signal changes from 1 to 0	signal crosses from a peak to a baseline

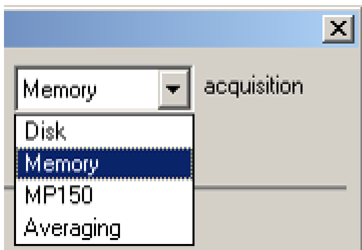
- For ECG data (and other types of data with peaks of relatively short duration) there will be only minor differences between the two edges, although the positive and negative edges can be widely separated in time for data with slowly changing values (such as GSR or skin temperature data).

Mode — Once the trigger channel and level have been specified, the final parameter is the delay. Delay can be measured in terms of samples, milliseconds, seconds, or minutes, and may be set to zero if desired. The delay option instructs the MP System (MP150 or MP36R) to wait a specified period after the trigger level is reached before beginning the acquisition.

Delay — When using a trigger, the default setting is for the acquisition to begin immediately after the trigger pulse or level occurs. You can change the default by using the Delay option in the Trigger Setup dialog. This feature allows an acquisition to begin a specified period after the trigger level is reached. If you want to start an acquisition one second after a switch closes, set the trigger to external and enter 1.00 in the box next to Delay. The default scale for Delay is seconds, meaning that the acquisition will begin a specified number of seconds after the trigger has been initiated. The scale of the delay can be changed from seconds to samples, milliseconds, or minutes.

Pretrigger — During normal triggered acquisitions, data is collected only after the trigger has been activated (or after some delay). For some applications, it is useful to collect data on events that occur just prior to the trigger event. As an example, if an acquisition was set to begin when a device (such as a tone generator or flash) sends an output pulse, it might also be important to collect information on the subject’s state just before the stimulus.

Pretrigger functionality is not supported in all acquisition modes (MP150 > Set Up Acquisition):



Mode	Source: EXTERNAL	Source: CH #
Disk	Pretrigger supported	Pretrigger supported
Memory	Pretrigger supported	Pretrigger supported
MP150	Pretrigger supported	not available
Averaging	not available	not available

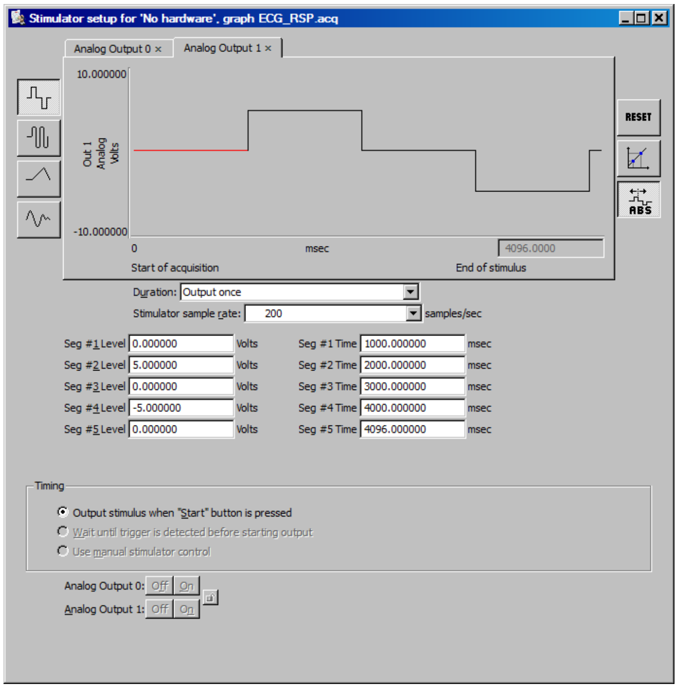
When the Pretrigger function is enabled, start an acquisition by clicking the Start button. When the internal memory in the MP data acquisition unit is full, the MP System (MP150 or MP36R) will start replacing the oldest data with the newest data (similar to the record last feature). This process continues until the trigger event occurs. Following the trigger, the MP System (MP150 or MP36R) will collect data until the total length is reached. The acquisition now contains data from both before and after the trigger.

The amount of data collected before the trigger event is determined by the value in the box next to the Pretrigger popup menu. As with Delay, scaling can be set in terms of samples, milliseconds, seconds, or minutes. The duration of the Pretrigger may also be adjusted using the scroll box to the right of the Pretrigger dialog.

When Pretrigger is selected, it is important to note…

- The total length of the acquisition includes the duration of the Pretrigger. If the acquisition length is set to 120 seconds and the Pretrigger is set to 20 seconds, only 100 seconds of data will be collected after the trigger event occurs.
- Since the total length of the acquisition includes the duration of the Pretrigger, the duration of the Pretrigger may not exceed the length of the acquisition.

Chapter 9 Set Up Stimulator



Although data acquisition is the primary function of the MP System, you may also output a signal through one or two analog channels while data is being acquired. This is handled through a window similar to the standard Acq*Knowledge* graph window.

Four types of signals can be output:

1. Square waveforms—page 177
2. Tone waveforms—177
3. Ramp waveforms—178
4. Arbitrary waveforms—179

Each of these waveform types can be set to repeat signal output either Once or Continuously, and parameters can be set to either Relative or Absolute time scales.

To set the type of waveform to be output, select Setup stimulator from the MP150 menu. This generates a window that allows you to control the type of signal output by the MP System. Like the standard graph window, this plots time on the horizontal axis and amplitude on the vertical axis.

You can use this window to create and shape waveforms to be output. Adjust the Stimulator Sample Rate (described below) to further control the parameters of the Stimulator Output design.

For any waveform (or stimulus) to be output, you need to specify the type of stimulus, the “shape” of the signal, the output channel to be used, and how many times the stimulus should be output.

All of these parameters can be set from within the Stimulator Setup dialog. Regardless of the type of waveform you select, stimulus signals will normally be output when an acquisition is initiated, either as a result of clicking on the start button or a trigger being activated.

Stimulator Sample Rate

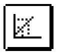
A very powerful feature intrinsic to the MP150 unit is the ability to set a stimulation signal output rate that is different than the acquisition rate, thus permitting considerable flexibility for a variety of physiological applications.

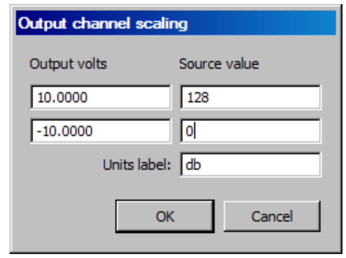
Use the pull-down menu to select a unique sample rate for the stimulator.

➡ *See also*: Application Note AH162 - Using the Stimulation Features of the MP System.

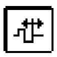
Parameters

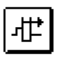
Reset Refresh the display; use after the time scale has been adjusted.

Scaling  Scaling button—Rescale stimulus signals to units other than Volts according to the Change Scaling Parameters.

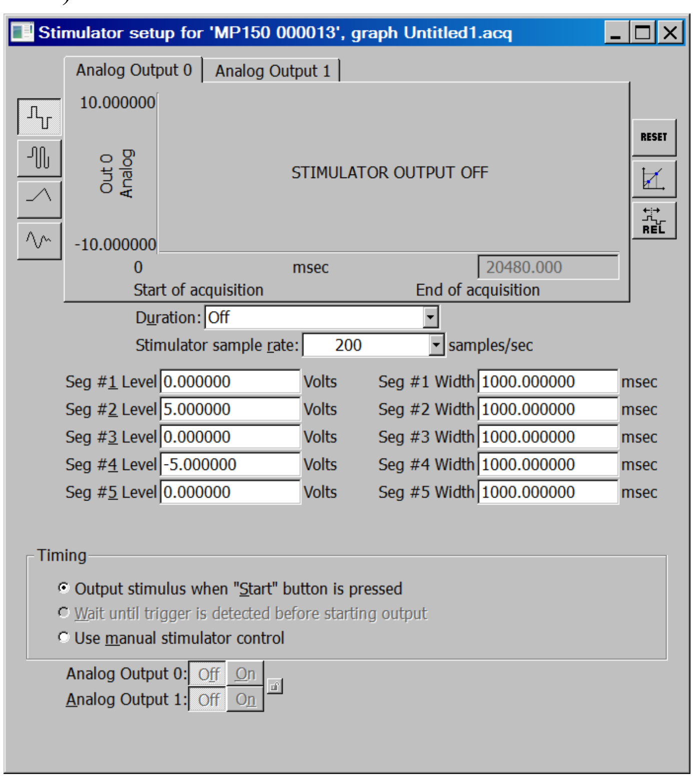


This type of rescaling does not change the amplification of the signal, it is useful for recalibrating the output signal to more meaningful units. In the example shown here, an output signal of +10 Volts is rescaled to +128 dB, while an output signal of –10 Volts is rescaled to reflect 0 dB.

Relative  Set the duration of each segment of the output waveform in Seg # Width. In the sample dialog shown below left, a 5000 msec output is created by entering individual segment widths: 500 + 400 + 250 +200 + 3650 = 5000 msec

Absolute 

As an alternative, you can enter an exact Seg # Time for each segment of the output waveform. This mode can make it easier to control the overall timeline of the stimulus output because you can review the setup as the total time. Enter the precise Time for each segment change. To create the same 5000 msec output as used in the Relative example, you would enter Seg # 2 Time as 900 (to mimic 500 + 400 in Relative mode) , and end the last segment at 5000 (the Seg # Time reflects the time associated with the last sample point of each segment, rather than the duration of the segment itself).



Output

A# Analog Output You can output on one or two analog output channels. The output channels are listed as A0 and A1 and correspond to Analog Output 0 and Analog Output 1 the UIM100C.

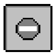
- For dual stimulation and independent control, connect an output device to A0 and A1.
- See *Analog Output for MP150 Users* notes on page 174.

The maximum resolution of a stimulus signal output through an analog channel is 22 µsec; this means that the shortest segment in the stimulus signal must be at least 22 long.

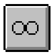
PW Pulse Width Acq*Knowledge* allows you to output a single digital pulse through digital channel I/O 15, with a resolution of 1 µsec. Since this is a true digital channel, pulse output has only two levels (0 Volts and +5 Volts), which cannot be edited. The segment that can be edited is the pulse width (duration), which can be set to any value greater than 1 µsec.

Repeats

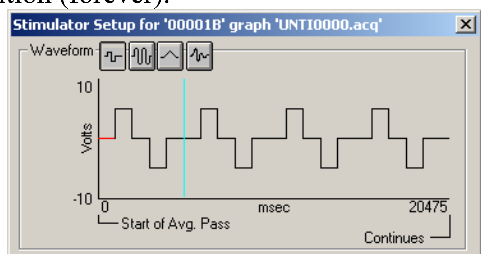
Set independently for A0 and A1.

 Turn Output OFF (no stimulus signal output).

Output the stimulus signal once.

 Output the stimulus signal for the duration of the acquisition (forever).

When output continuously is selected, a vertical line is generated at the end of the first section of the waveform in the stimulator window to indicate where the first output signal ends and the second begins. The line can be dragged left or right like a vertical segment in a stimulus waveform to control the duration of the waveform as it is continuously output.



Trigger

When a trigger option is selected (in the Trigger Setup window), Acq*Knowledge* allows you to select from additional menu items with respect to when the signal is output. By default, the stimulus signal will be output when you click the start button. When a trigger is enabled, however, you have the option of either outputting the signal when the start button is pressed or when the trigger is initiated. The trigger option is added to the stimulator window when a trigger is enabled in the Setup Trigger box (described on page 166).

Manual Stimulator Control

- Only available when a stimulator is connected and with MP150 units running firmware 1.1.14 or higher

When an MP150 unit is being used, the manual stimulator controls at the bottom of the Stimulator Setup dialog can be used to start and stop stimulators independently of the acquisition. If changes are made to the stimulus wave while a stimulator is running, the stimulator will need to be turned off and then back on to apply the changes to the settings.

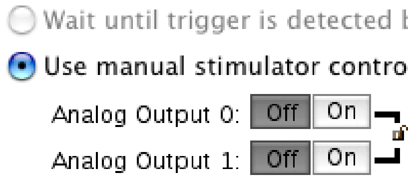
The manual stimulator controls can not be used if the MP150 is set to acquire in averaging mode.

- Acquisition will start the stimulator when the acquisition starts.
- On/Off button will start the stimulator when the Start button in the Stimulator Setup window is engaged. The Start button toggles to a Stop button.

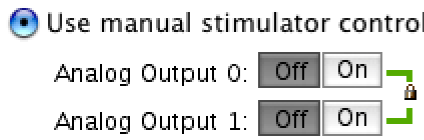
If Dual Stimulator settings are active, “Start with” applies to both stimulators.

A "lock" between the two sets of controls can be used to turn both stimulators on or off at the same time. This lock is useful for two-channel stimuli delivery, such as stereo sound.

UNLOCKED



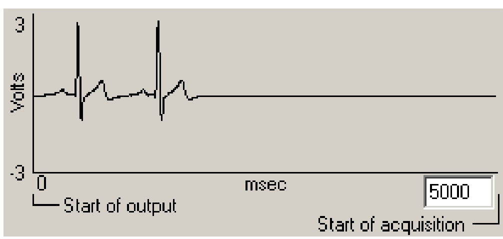
LOCKED—Both channels Start/Stop together



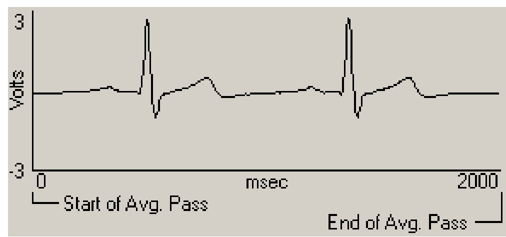
Stimulator Output

You can set "Stimulator Output" to start before or during an averaging pass.

- For Averaging details, see page 154.



Before Averaging Pass



During Averaging Pass

Analog Output for MP150 Users

The two MP150 Analog Output channels can independently output static or dynamic values:

- Static output: Use "Manual Control" (page 222) to set the output level for each channel in the range -10V to +10V.
- Dynamic output: Use "Stimulator Setup" (page 170) to define the output level and pattern.

The MP150 will automatically use the "Manual Control" value if:

- No acquisition is in progress OR
- Acquisition is in progress but the Stimulator is disabled via the "Setup Stimulator" dialog.

The MP150 will only use the "Stimulator Setup" value if:

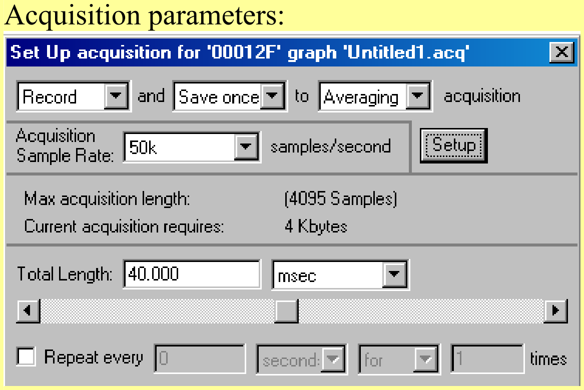
- Acquisition is in progress (or before Averaging pass) AND
- Stimulator is enabled via the "Stimulator Setup" dialog.

When the stimulator is in use:

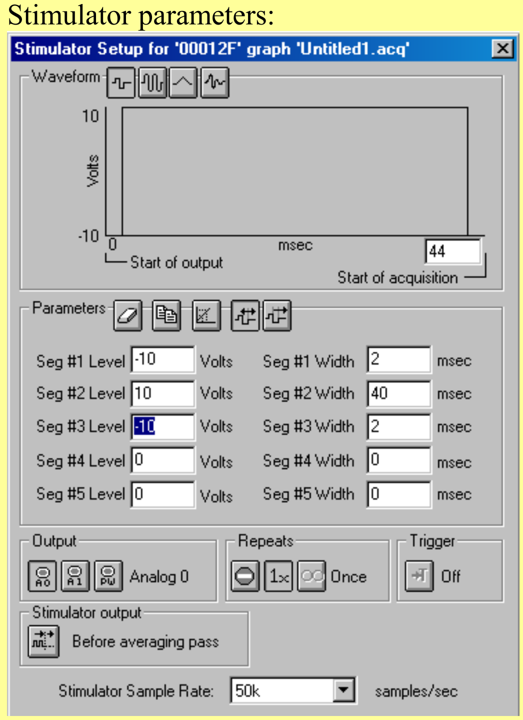
1. Any Stimulator Output starts (from before Time = 0) with the value established for "Manual Control".
2. If Segment # Width = 0 the stimulator ignores the associated Segment # Level.
3. If the stimulator is in 1x mode, after the output waveform is sent, the value of the last segment is fixed until acquisition stops.
4. When acquisition stops, the stimulator resets to the "Manual Control" value.

The following dialogs and output illustrations demonstrate how the "Manual Control" value influences Analog Output for the Stimulator when an MP150 is used:

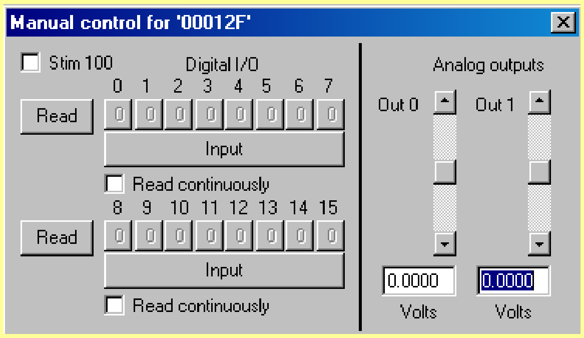
Acquisition parameters:



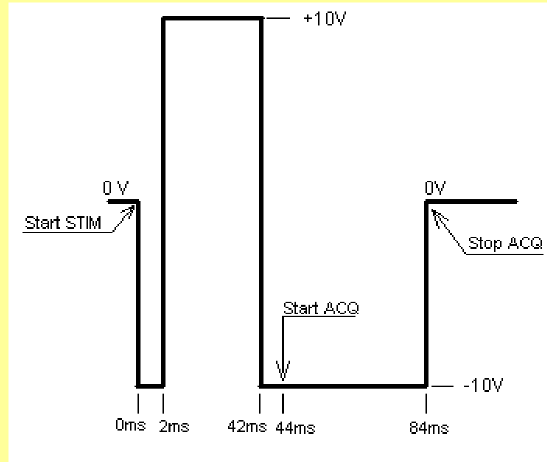
Stimulator parameters:

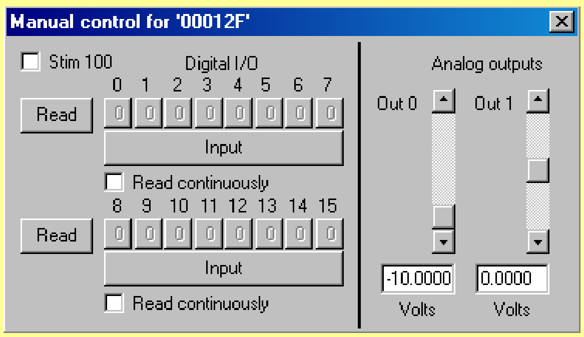


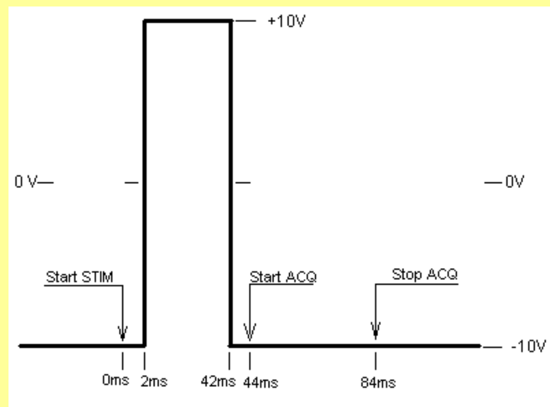
Manual Control list box:



Stimulator Output pattern (using MP150):

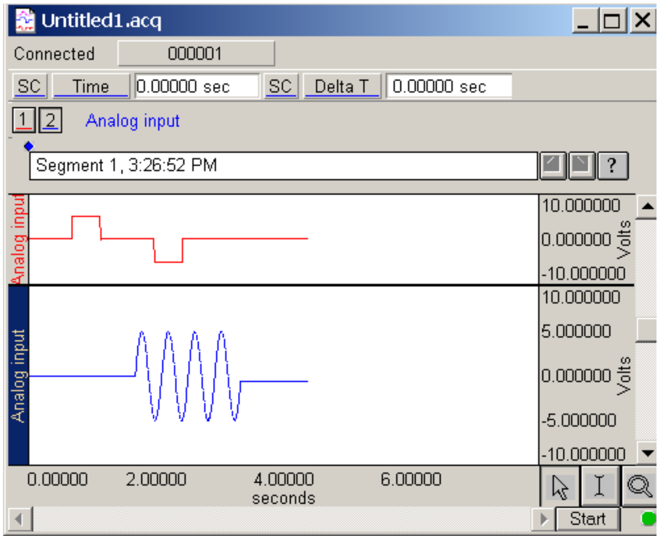






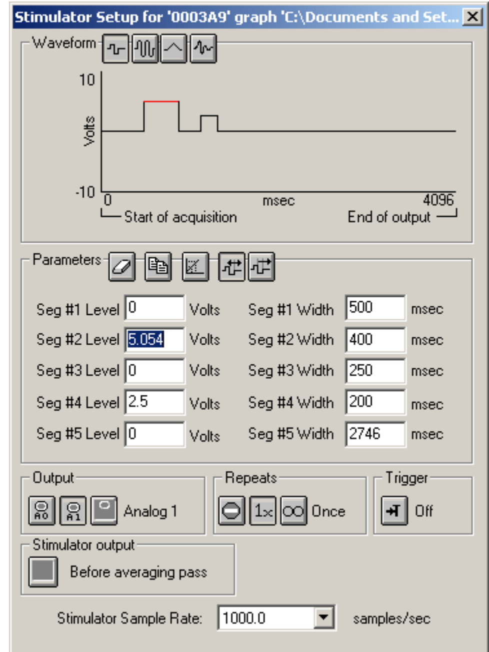
Dual Stimulation

For independent control of two stimuli (such as sound and electrical output), set stimulator functions for Output to A0 and A1 for each MP150 unit. Click the tab for each output at the top of the Stimulator Setup dialog and complete independent settings.



- For additional stimulus paradigms, add MP150 units (see Multiple Hardware, page 153).

Square waves



Square waveforms are useful for generating pulse waveforms, which can be used as stimuli or to trigger a stimulus-generating device (such as a flash device or a tone generator).

To output a square wave, choose the 1x icon in the "Repeats" section. You should see a rectangular wave appear in the window. You can control the shape of the wave by manipulating the various segments of the wave. A square wave has five segments, and Acq*Knowledge* allows you to set the level (amplitude) and width (duration) of each segment.

In a square wave, each of the editable segments is oriented horizontally, with vertical segments connecting the adjacent sections of the wave. The first segment of a pulse waveform is the segment that appears at the far left of the waveform section. By positioning the cursor on this segment of the waveform, you can tell from the box at the bottom of the screen that the level (vertical offset) of the first segment is 0 Volts, and the width of the first segment is 500 msec.

To adjust the level of a segment, either:

a) enter the desired level in the box that says Seg # Level; or

b) position the cursor on the first segment of the waveform and drag it up or down using the mouse (segment 2 is selected in the preceding dialog, and appears in red).

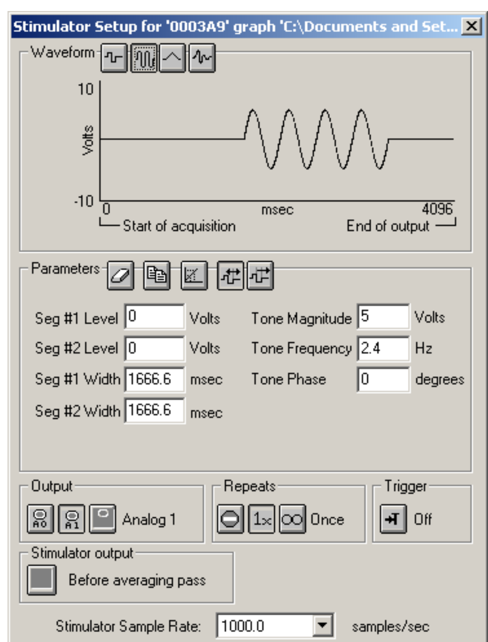
To change the duration of a segment, either:

a) Enter a value in the Seg # Width box at the bottom of the Stimulator Setup dialog; or

b) Position the cursor on the first *vertical* segment in the setup dialog, click the mouse button, and drag the vertical segment left or right. Moving the first vertical segment left shortens the duration of the first segment, whereas moving the first vertical segment right lengthens it.

Each of the segments in the pulse wave can be "edited" in this way.

Tone Stimuli



Tone waveforms allow you to create pure tone signals of any duration, magnitude, and frequency. This option outputs a pure sine wave, which is useful for audiological and stimulus response testing.

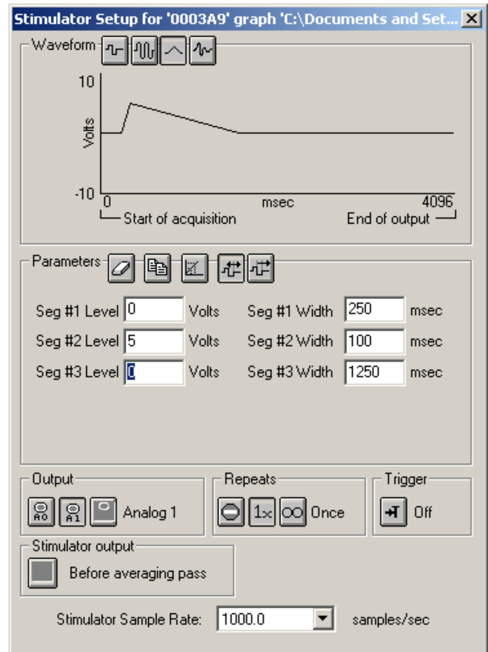
A tone waveform is comprised of two segments, with only the second segment being the actual tone itself. This allows you to include a pre-signal delay (by setting the level for Segment #1 to 0 Volts and the duration to a desired value).

To set the duration of the tone, adjust the length of segment #2 (by changing the Seg #2 Width value box or by clicking and dragging the segments within the window). As shown, there is an additional (uneditable) section of the waveform *after* the second section. This segment returns the last value from segment two, and continues to output that signal level until the acquisition is terminated (if the stimulator is set to output once) or until another signal is output (if the MP System is set to output continuously).

There are three additional parameters for Tone waveforms: frequency; magnitude; and tone phase.

- Tone frequency refers to the frequency of the second segment of the waveform. This can be set to any value, although the most common settings are between 20 Hz and 20,000 Hz.

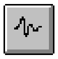
- Magnitude refers to the peak-to-peak range of the signal, which can range from ± 0 to ± 10 Volts.
- Phase of the stimulus signal can be any value equal to or greater than 0 degrees. Phase settings of more than 359 degrees will be rescaled to fit the 0°-359° range. In other words, setting the phase to 360° or 720° has the same effect as setting the phase to zero degrees.

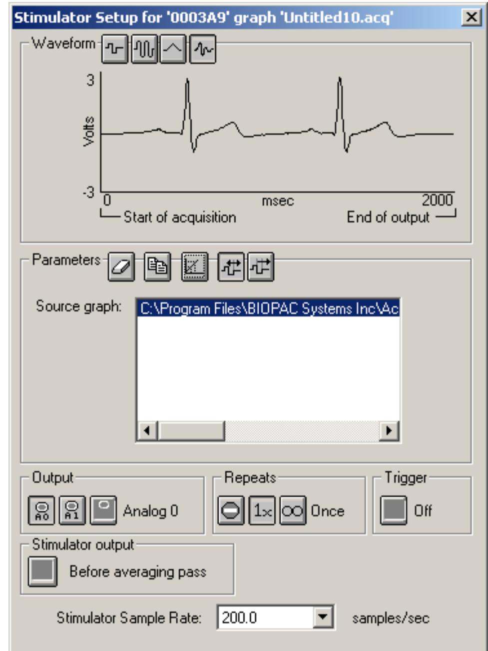


Ramp Waves

 Ramp waveforms are useful when you need to construct a monotonically increasing or decreasing stimulus signal. Ramp waves are comprised of three segments and the amplitude and duration can be set for all three sections.

Arbitrary Waveform





The Arbitrary waveform option allows you to set a waveform's shape and length using standard Acq*Knowledge* editing functions.

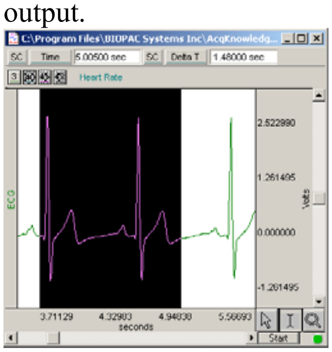
- See Application Note #AH162 for performance specifications.
- The length of an arbitrary waveform is only limited by the available memory (if recording in Memory/Disk mode; it will be limited to 4096 samples if recording in MP150 mode).

Unlike the other types of waveforms, Arbitrary waveforms have no segments, so the "shape" of the waveform is determined by selecting an existing waveform and the only parameters that can be set are Scaling, Repeats, and Trigger.

There are two methods to create an arbitrary waveform:

A. Copy waveform segment

1. Open a waveform in a standard graph window.
2. Select the section of the waveform you wish to output.



3. Return to the Stimulator Setup dialog—the selected area will automatically be pasted into the dialog.

B. Create waveform

You can also construct an Arbitrary waveform by copying and pasting predefined stimulus waveforms (e.g., square waves or ramp waves) into a standard graph window. This is useful when a pure signal needs to be modified by adding noise or modifying waveform parameters such as rise time or decay. It also allows you to combine complex sequences of existing stimulus waveforms, such as a pulse followed by a tone.

1. Create a waveform in the Stimulator setup (as described above) of the desired duration and shape.
2. Choose Edit > Copy.
3. Switch to an empty graph window.
4. Choose either Insert waveform or Paste from the Edit menu.
5. Modify the waveform characteristics as desired.
6. Choose Edit > Copy.
7. Switch to the original graph window and paste into the Stimulator Setup window.
8. Output as an arbitrary waveform.

Stimulator Icons

Waveforms:
- Square wave
- Tone (sine) wave
- Ramp wave
- Arbitrary wave

Parameters:
- Reset the display (use after adjusting the time scale)
- Copy a stimulus waveform from the Stimulator Setup window to the Graph window
- Scaling (rescale Stimulus signals to different units)
- Set time base to relative
- Set time base to absolute

Output:
- Output to Analog Output channel 0 (default)
- Output to Analog Output channel 1
- Pulse Width outputs a true digital signal: 0 Volts and +5 Volts

Repeats:
- Toggle the selected Stimulator Output ON and OFF
  For dual stimulator setup, Output is independent for A0 and A1
- Output stimulus signal once
- Output stimulus signal for duration of acquisition

Trigger:
- Toggles between “Off” and “Wait for” if MP150 > Set Up Triggering is active
  Off—Output stimulus signal when Start button is pressed
  Wait for—Output stimulus signal when trigger is initiated

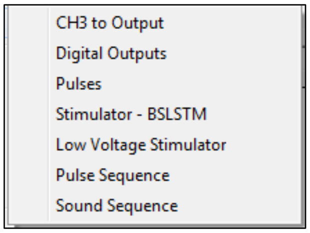
Stimulator output:
Toggles between “Before” and “During” Averaging Pass if Set Up Acquisition is set to Averaging.

Before


During


Chapter 10 Output Control

Note: Output Contol chapter refers to MP36R hardware only.
For MP150 and MP100, see the previous chapter, 'Set Up Stimulator'.



The MP UNIT can output pulses or analog voltages via the **Analog Out** port; this port is also used to connect to BIOPAC's external stimulators. The MP36R has an additional **I/O Port** which is used to output digital (TTL Level) signals.

Parameters for output signals are set via **Output Control**. Access to a specific Output Control is via the **MP36R** > **Output Control** submenu.

There are seven Output Controls for the MP36R:

Output Control	See…	**MP36R** Functionality
CH# to Output	page 183	Direct analog CH1-4 to output listen to signals
Digital Outputs	page 185	Control 8 digital outputs
Pulses	page 186	Use with third-party devices; software can control pulse width and repetition.
Stimulator - BSLSTM	page 186	Use with BSL Stimulator
Low Voltage Stimulator	page 186	MP36R: Use OUT3 adapter for MP36R built-in low voltage stimulator. Software can control pulse amplitude, width and repetition (-10 to +10 V)
Pulse Sequence	Page 188	Direct analog CH1-4 output. Allows for output of customized pulse trains.
Sound Sequence	Page 191	Outputs customized sounds assignable to a user configurable pulse train.

To open an Output Control, select it from the **MP UNIT** > **Output Control** submenu. A checkmark appears next to the submenu selection and an **Output Control** panel is displayed, bordered in red in the active data window. To close an Output Control, select from the menu again (toggles between display and hide) or right-click in the open control panel and choose **Close**.

Only one Output Control panel may be open at any time. Switching between different data files can change the display and operation of the control panel.

Because some output devices can be used for stimulation on humans and can achieve voltages up to 100 Volts, built-in software logic makes output control as safe as possible.
See page 205 for safety notes regarding human subjects.

The following applies to all Output Controls.

The output will not operate unless its software control panel is open.

When an Output Control panel is closed, or the Acq*Knowledge* application is closed, MP36R output goes to 0 Volts, preventing the output device from sending pulses.

When an Output Control panel is opened, output is always OFF until activated by a click of the ON/OFF switch in the control panel or, if parameters allow, a click of the Start button in the data acquisition window. (Exceptions are the Voltage Output Control, which outputs immediately, and the Digital Outputs Control when set to the preference "Set each output immediately.")

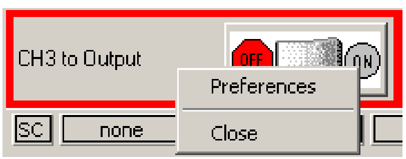
Output preference parameters are local and are saved with the data file or a graph template file. The data or template file holds the output parameters as established when the file was saved. (See "Save as Graph Template," page 240.) Switching between other open graphs can change the display and operation of the control panel since the settings in each graph are independent entities.

CH to Output

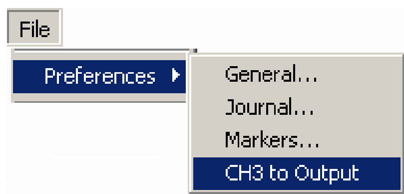
Use both the Output Control panel and its respective Preferences dialog to control the output signal. Output Control **Preferences** dialogs establish the parameters for output. Preferences dialogs are only available when the corresponding Output Control panel is open and active.

To generate the **Preferences** dialog, either:

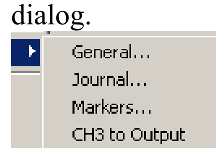
Open an Output Control panel and then right-click anywhere in it to generate a pop-up menu. Choose **Preferences** to open the dialog (**Close** will close the control panel).



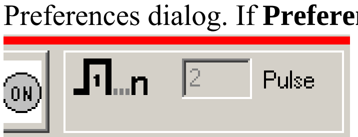
or

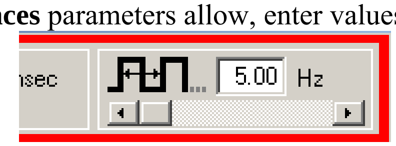


Open an Output Control panel and then choose **File** > **Preferences** and select from the submenu to open the dialog.



If a control panel entry box is grayed or disabled, its values may be established, or limited, by settings in the Preferences dialog. If **Preferences** parameters allow, enter values directly in the **Output Control** panel.



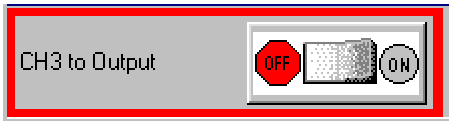


Key into the entry boxes and then enter the value by pressing the **Enter** key.
Use the **Tab** key or mouse to move to another entry box.
Click the **OK** button if in the preference dialog.
Values entered into a control panel or its Preferences dialog that are outside the specifications of the output device, or outside the limits defined by the Preferences dialog, may change automatically to reflect either the closest value to that requested that the the hardware can achieve, or the closest increment defined by the limits in Preferences. (The system will not check while you type, it checks and may make changes after the value is entered.)
For example, if a Pulse width of 5 ms is entered into the Pulses Output Control panel entry box, but Preferences defines a range limit of .5 to 2 ms for Pulse width, the system will automatically change the new entry to 2 ms.

Saving Panel settings:

Output Control panel settings will be retained until a file is closed or saved. If a file is closed but not saved, settings will be lost (defaults established); if a file is saved, panel settings will be saved.

CH# to Output Output Control



The CH# to Output Output Control redirects an analog input signal to the **Analog Out** port on the back of the MP UNIT. The signal from the assigned channel will continue to be recorded and plotted as it normally would. This Output Control is used mainly when attaching headphones to the MP UNIT to listen to signals coming in on an analog input channel. One common use is listening to the EMG (muscle) signal, a clinical procedure physicians use to actually hear certain problems with muscles.

To display this control panel:

Choose MP UNIT > Output Control > CH# to Output to open the control panel.

MP36R users may use analog input CH1-CH4. Channel 3 is the default setting. If another channel N has been designated, the menu will read “CH<N > .”

Use the control panel **ON/OFF Switch** to start and stop output. OFF grounds the output so no signal (or sound) should be present.

Preferences

Set **Preferences** to designate which channel to redirect to output.

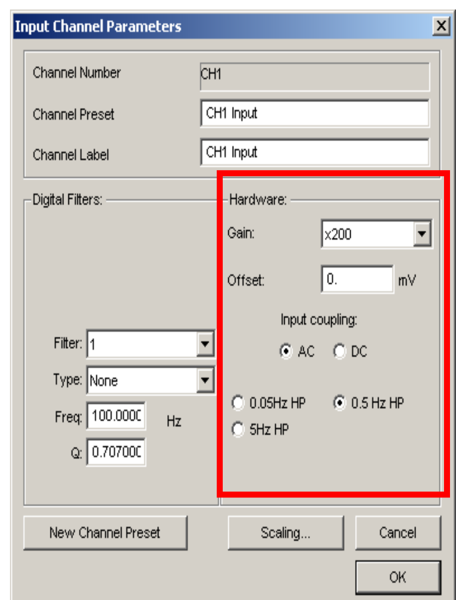
Open the Preferences dialog (right-click in the control panel or choose **File** > **Preferences** > **CH# to Output**).

Use the pull-down menu to select the desired channel CH 1-4 to use for the output.

Click OK to set the output channel and return to the control panel.

Note Only the Hardware settings (Gain, Offset, Input Coupling) from the Input Channel Parameters dialog (MP36R > Set up Channels > Wrench) will be applied since output is established prior to the processing of Digital Filters.

See **MP36R Input > Output Scaling** values on the next page.



MP36R Input > Output Scaling

The MP36R hardware can pipe signals from any channel input to the output using the "CHX to Output" control panel in the Acq*Knowledge* software—due to the difference between the input and output range, there will be a change in signal level (scaling). The output range depends on the output pin used as shown in the following table.

Output Pin (Analog Out port)	**Pin Description**	**Output Range** (Volts)
Pin 1	Headphones, A.C. Coupled	-2.048 to +2.048
Pin 2	Low Voltage Stimulator, D.C. Coupled	-10 to +10

The input range is gain-dependent. The table below shows the scaling (multiplying) factors to use for each gain setting.

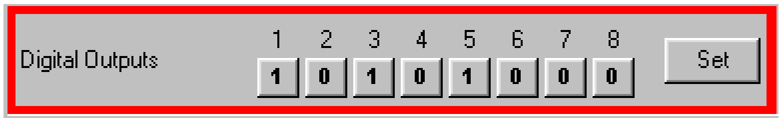
Gain	**Input Range** +- millivolts	**Output Scale**—*accurate to ±10%*** ***Factor 1***	***Factor 2***
		Pin 1 (Headphone out)	**Pin 2** (Low Voltage Stimulator)
x5	± 2 V	1.024	5
x10	± 1 V	2.048	10
x20	± 500 mV	4.095	20
x50	± 200 mV	10.238	50
x100	± 100 mV	20.475	100
x200	± 50 mV	40.950	200
x500	± 20 mV	102.375	500
x1,000	± 10 mV	204.750	1,000
x2,000	± 5 mV	409.500	2,000
x5,000	± 2 mV	1023.750	5,000
x10.000	± 1 mV	2047.500	10,000
x20,000	± 0.5 mV	4095.000	20,000
x50,000	± 0.2 mV	10238.000	50,000

Notes

***** 1: To properly measure the output signal you need at least a 2K Ohm load.

****** 2. Input to Output scaling is accurate to within 10%.

Digital Outputs Control



The Digital Outputs Control allows control of signal output on each of eight digital lines via the **I/O Port** connector on the back of the MP36R. Use it to control external devices. The digital output uses stardard TTL levels which correspond to the control panel setting as follows:

Control Panel setting	Output Voltage level (Volts)
0	0
1	+5

To display this control panel:

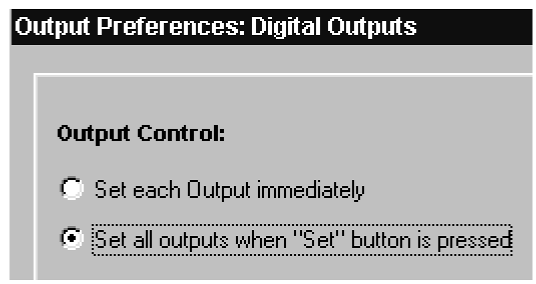
Choose **MP36R** > **Output Control** > **Digital Outputs** to open the Digital Outputs Control panel

Click each digital output line to set its digital state to 0 (off) or 1 (on).

If desired, you may set **Preferences** for Digital Outputs.

Open the Preferences dialog (right-click in the control panel or choose **File** > **Preferences** > **Digital Outputs**).

Select from the following two options:



Set each output immediately (default) allows you to toggle the state of each digital output line between 0 and 1, and change the state **immediately**. In this mode, no **Set** button is available in the control panel. Output for each line is set upon clicking its toggle button.

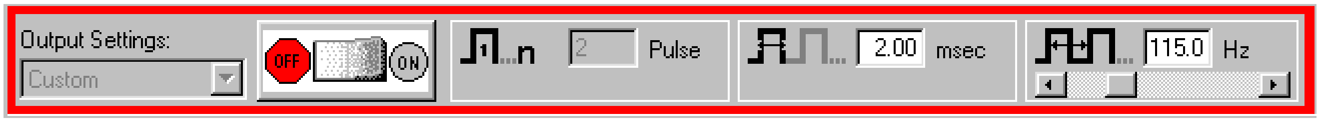
Set all outputs when Set button is pressed allows you to toggle the state of each digital output line, but the states will not physically be changed until the **Set** button is clicked on the control panel. In this mode, a **Set** button is available in the control panel. When the **Set** button is clicked, all eight digital lines will update simultaneously.

Click OK to set Preferences and return to the control panel.

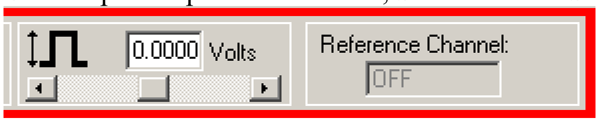
Pulses Output Control

Stimulator – BSLSTM Output Control

Stimulator – Low Voltage Output Control



Control panel options for Pulses, Stimulator – BSLSTM and Stimulator – Low Voltage



Additional control panel options for **Low Voltage Stimulator**

A variety of pulse ouput options are available. Exercise caution when using any of the options with human subjects—see the **Safety Note** on page 205.

Pulses Output Control

Select this Output Control for general pulse output, or when synchronizing to 3rd-party devices.

Use for reaction time measurements, where a subject listens with headphones for a series of "clicks" (pulses) and responds as quickly as possible with a button press. Determine reaction times by calculating the time between the start of the pulses and the responses.

Use with the **BIOPAC STP30W** Stimulus Presentation System (SuperLab) to measure responses to visual or auditory stimuli. To perform sophisticated evoked response averaging tests (e.g. P300), pair triggers with different visual or auditory stimuli.

Use to trigger another device (automatically send a pulse from the MP UNIT when acquisition starts).

Use to control a 3rd-party stimulator. BIOPAC recommends use of the BIOPAC BSLSTM Stimulator with the MP UNIT and BIOPAC software. If using the BSLSTM Stimulator, use the **Stimulator - BSLSTM Output Control** instead of this Pulses Output Control.

Stimulator – BSLSTM

Select this Output Control when using the Biopac Student Lab stimulator (BSLSTM)

Use with stimulation electrode HSTM01 for safe stimulation of human subjects (0 – 100 Volts), as well as lower voltage (0 - +10 Volt) general-purpose stimulation, such is used with amphibian muscle or nerve preparations.

Set up note Placing the BSLSTMA/B unit too close to MP UNIT hardware can result in data distortion of the BSLSTMA/B pulse width signal; distortion is more apparent at higher sampling rates.

- NEVER set the BSLSTMA/B atop an MP UNIT
- Position the BSLSTMA/B away from the MP UNIT to reduce the signal distortion

Low Voltage Stimulator

Select this Output Control for low-voltage (-10 - +10 Volt), direct drive stimulation via MP36RAnalog Out port (with or without OUT3 BNC adapter).

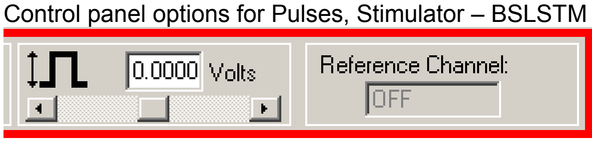
Use with stimulator electrode HSTM01for safe, stimulation of human subjects (0 – 100 Volts), as well as lower voltage (0 - +10 Volt) general-purpose stimulation, such is used with amphibian muscle or nerve preparations.

Outputs through a BNC connector so it can be used with most stimulation cables (such as those that terminate in a needle probe).

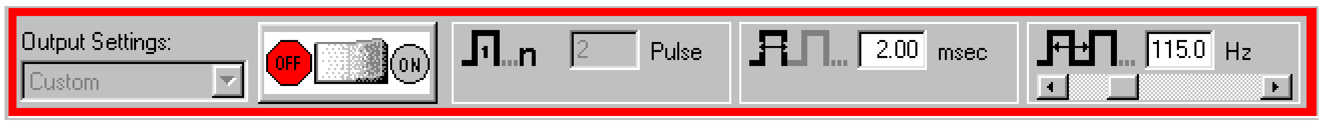
To use one of these control panels:

Choose MP UNIT > Output Control and then select Pulses, Stimulator – BSLSTM, or Low Voltage Stimulator.

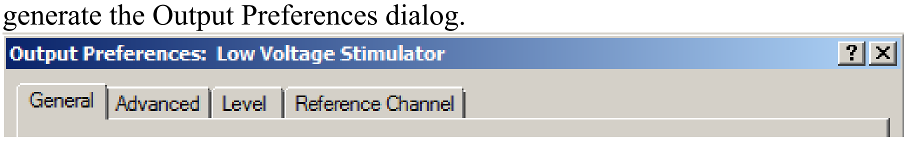
Control panel options for Pulses, Stimulator – BSLSTM and Stimulator – Low Voltage



Additional control panel options for **Low Voltage Stimulator**



Right-click in the Output Control panel (or choose **File** > **Preferences** and select from the sub-menu) to generate the Output Preferences dialog.



Set the Preferences.

General: ON/OFF, Number of pulses, Marker options — see page 195

Advanced: Pulse width, Pulse repetition (rate) — see page 198

Level (low voltage only): Pulse level — see page 202

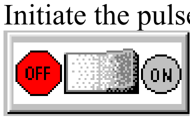
Reference Channel (low volatge only): Channel assignment, signal generation — see page 202

Once configured, Preferences may be saved using the **Save Settings** command, activated by pressing the button at the bottom of the Preferences dialog (see page 195).

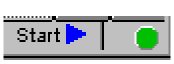
Confirm the settings in the control panel. Adjust as desired within the parameters established in Preferences.

<u>Entry limits</u>: Settings entered into the Preferences dialog may establish, or limit, the values in the Output Control panel entry boxes. You may enter pulse settings directly into the control panel only if parameters established in Stimulator Preferences allow. If an entry box is grayed or disabled, its value is set or limited by Preferences.

Initiate the pulse sequence as defined in Preferences (see page 195).



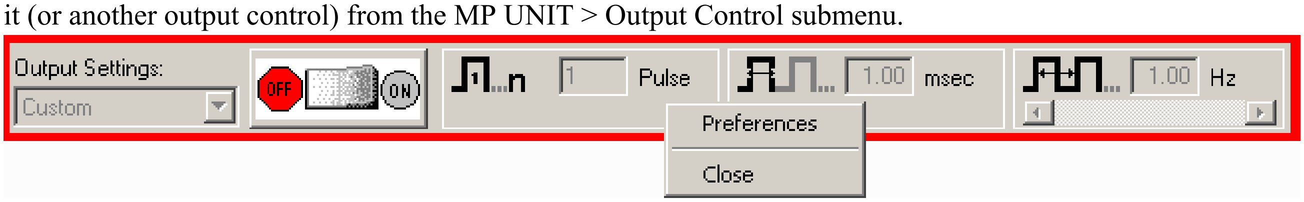
ON/OFF Button in Output Control Panel uses the switch in the Control panel.



Recording uses the **Start /Stop** button in the data acquisition window.

To close an Output Control panel:

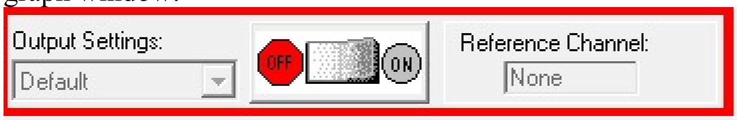
Right-click anywhere in the Ouput Control panel to generate a pop-up menu and then choose **Close**, or select it (or another output control) from the MP UNIT > Output Control submenu.



Pulse Sequence Output Control

In Acq*Knowledge 4.2* and higher, this Ouput Control allows sequences of pulse configurations and delays to be sent to the MP36R unit, making it possible to create more complex stimulus setups.

Enabling the pulse sequence output control option will display the following control panel at the top of the graph window:



Pulse sequence configuration is performed in the Preferences dialog of this output control panel. (Accessible via right-click on panel shown above or from File→Preferences) When a pulse train element is selected in the configuration, the controls will become visible in the right hand portion of the preferences dialog. The configuration makes use of three basic building blocks:

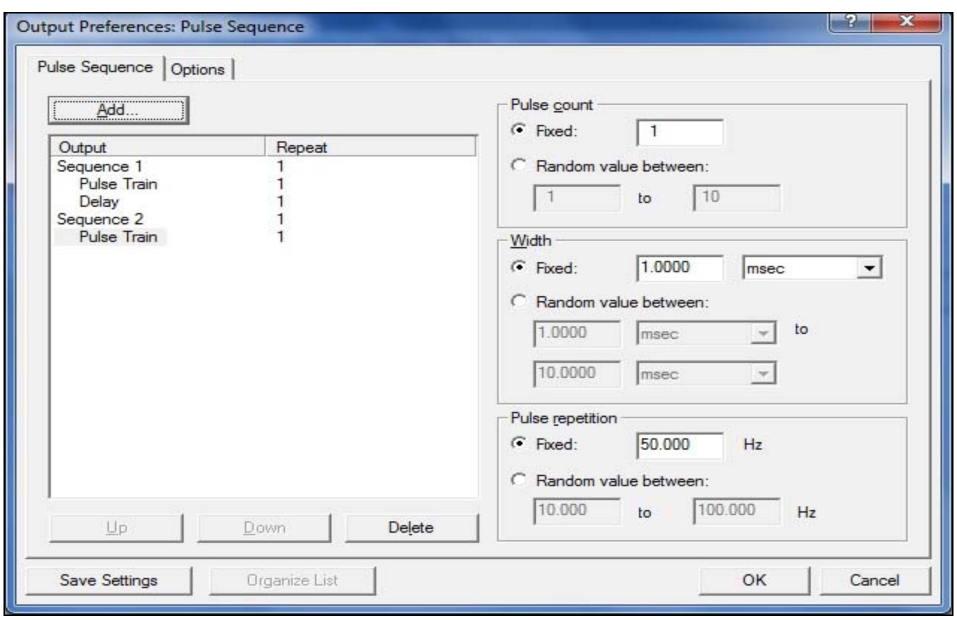
A *sequence* consisting of a number of delay and pulse train elements. The final configuration consists of one or more sequences that are outputted in order. Normally the entire configuration is outputted. There is a special operational mode on 'Start with Recording' that will take only the indexed sequence matching the current recording segment.

A *pulse train element* consisting of a fixed number of pulses of identical width output at a fixed pulse frequency.

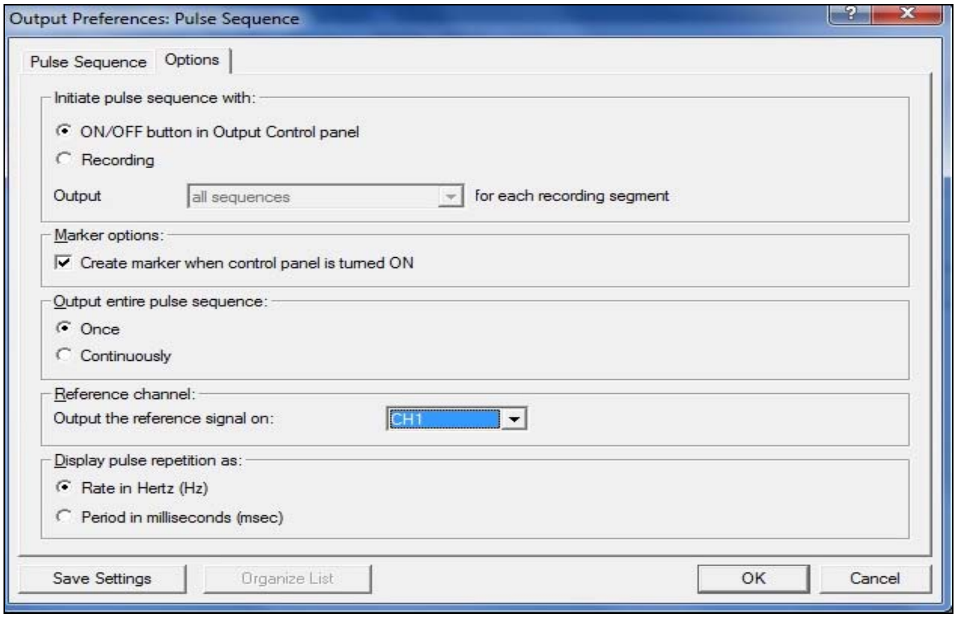
A *delay element* that allows for the introduction of time during which no pulses will be generated.

Each one of these building blocks also has a "repeat" count associated with it that will perform the action a set number of times. (Adjust by selecting the desired 'Repeat' and inputting a new value) Individual sequences, pulse trains and delays can be added, repeated and reordered as desired. In the right pane of the Preference dialog (shown below), fixed or random pulse counts, widths and repetitions can be configured and combined. As in other Output Controls, custom settings can be saved and organized in a list view. (See below for additional setup dialogs)

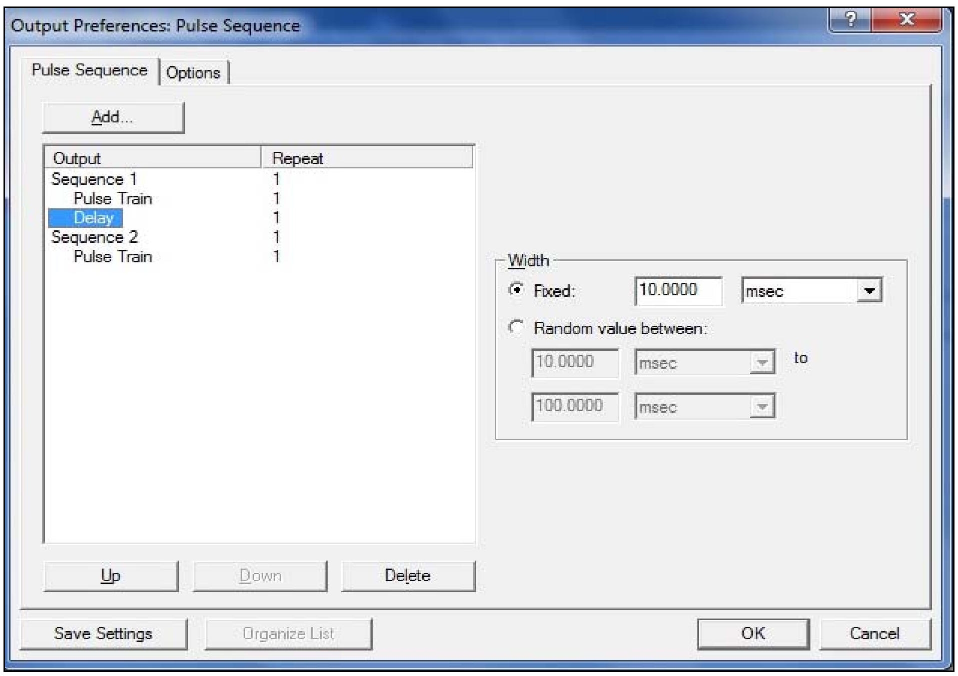
For a full explanation of preferences and tabs common to all Output Control panels, see the "Output Control" section on page 194.



Preferences available in Pulse Sequence tab

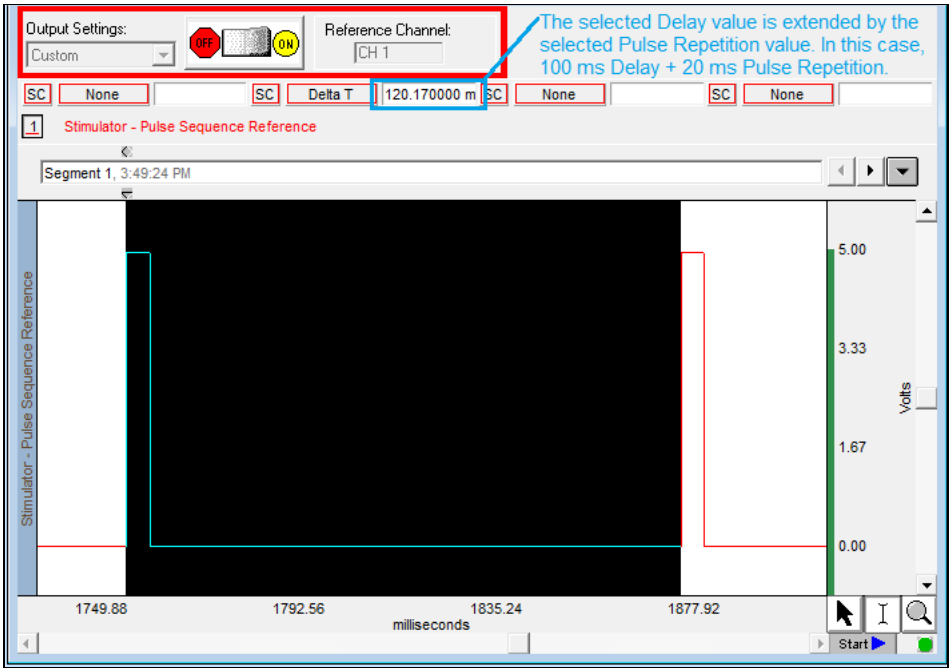


Preferences available in Options tab



Delay Preferences

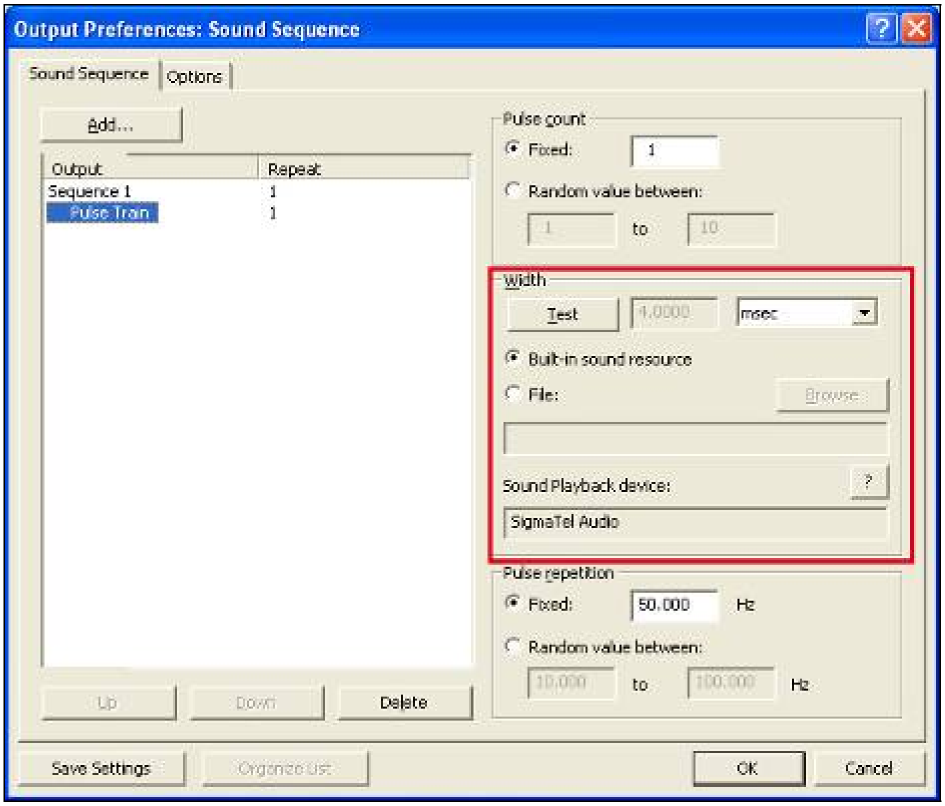
About Delay between Pulse Trains:
The amount of actual Delay between pulse trains will vary from the set value depending upon the pulse repetition value that is used. In the example sequence below, a Delay of 100 milliseconds between pulse trains has been set up, combined with a pulse repetition rate of 20 milliseconds. Because the pulse repetition rate is applied before the Delay occurs, the actual Delay between pulse trains in this case will be 120 milliseconds. If it is critical that a Delay reflect an exact value, it is advisable to subtract the selected pulse repetition value when setting up the Delay parameters.

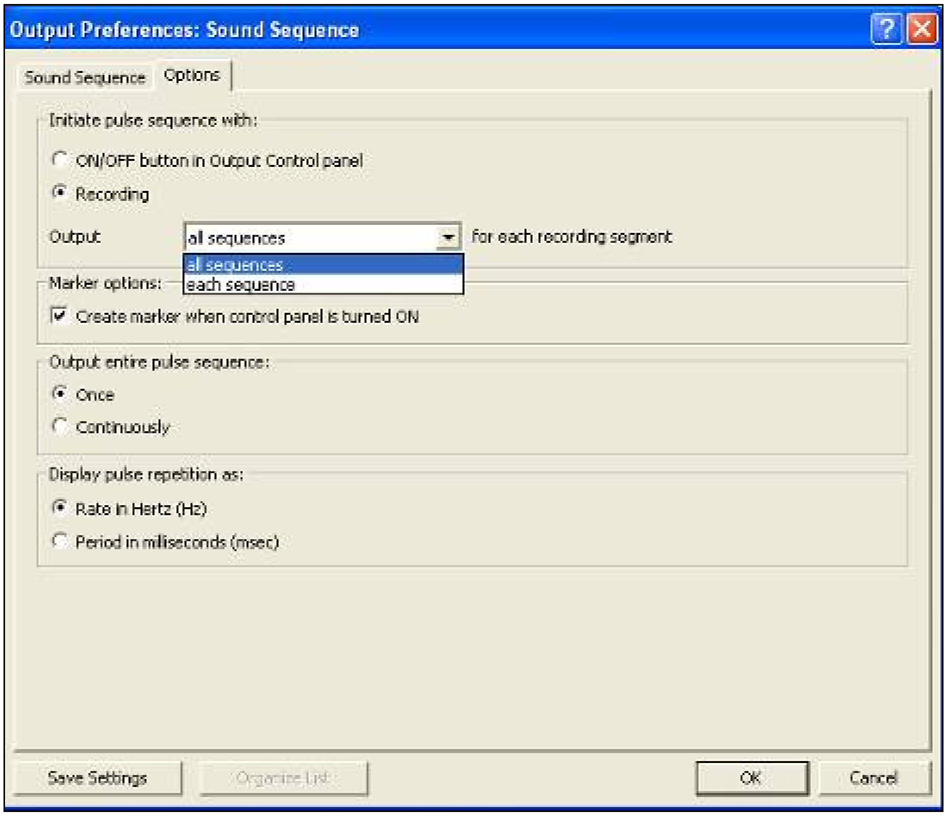


Delay between pulse trains

Sound Sequence Output Control

In Acq*Knowledge* 4.2 and higher, this Output Control offers users the option of configuring and customizing sounds to be outputted for aural stimulus experiments. The control panel and Preferences dialogs used for Sound Sequence closely resemble that of Pulse Sequence. The built-in sound resource (a default "click") may be used or any other file in *.WAV format can be substituted via the "File"and "Browse" button. The "Width" and "Pulse Repetition" values are dependent upon the duration of the sound file selected for output. The "Test" button will ouput an audio sample of the selected sound resource.

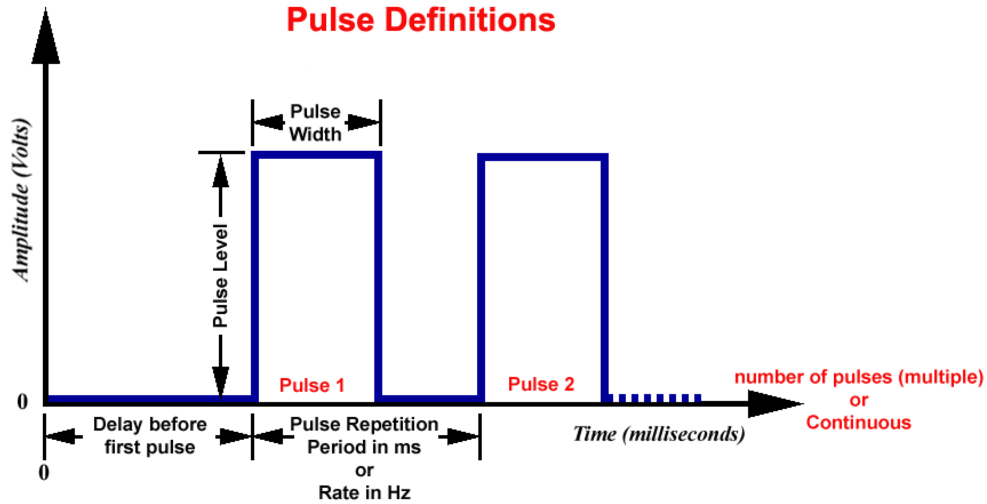




The option *all sequences* means that each configured sound sequence (regardless of number) will be outputted within the same segment. If "Once" is selected in the "Output entire pulse sequence" option, a configured sequence will be heard one time only. If "Continuously" is selected, the first Sound Sequence will be repeated after the last one has completed, looping the pattern repeatedly until the recording is stopped.

The option *each sequence* means that each sound sequence will be outputted on a segment-by segment-basis only. For example, if one Sound Sequence is configured, it will only be heard during the first recording segment, but not during the second recording segment). If two Sound Sequences are set up, the first one will be heard during the first segment and the second one during the following segment.. If no additional Sound Sequences have been configured, nothing will be heard during the third segments and beyond. (Exception: If "Save Once" acquisition mode is used, the Sound Sequence will be repeated when the recording is overwritten during subsequent passes).

The following terms are used in the Output Control panels, Preferences, and guidelines for Pulses, Stimulator – BSLSTM and Low Voltage Stimulator.



Delay before first Pulse	Initial delay from start of acquisition to start of first pulse.
Number of pulses	Number of successive pulses that will be sent out at the specified Pulse Width, Repetition and Level. Set for Single (1), Multiple, or Continuous (Cont).
Pulse Level	Amplitude of the pulse, expressed in Volts. *Note*: The output of the BSLSTM is 0 Volts when the pulse is not active.
Pulse Repetition *Also called —* Events per second Pulse frequency Pulse sequence Pulse train Repetition rate Sample train	Can be expressed as **Period** (ms) or **Rate** (Hz). *Period:* Time between pulses; measured in milliseconds from the start of one pulse to the start of the next pulse. *Rate:* Number of pulses that occur in a one-second interval; measured in Hertz. **Rate** relates to **Period** as: Rate (Hz) = 1000 / Period (ms)
Pulse Width	Time that the pulse is in the non-zero or active state.

Output Control Panel Descriptions

The Output Control panels for Pulses, Stimulator – BSLSTM and Low Voltage Stimulator work in conjunction with Preferences to control pulse output. Control panel functions are detailed here:

OUTPUT CONTROL PANELS

General Notes

Pulse parameters can interact with each other.
For example, the pulse repetition period cannot be set to a value less than the pulse width.

In order to simplify the interaction, the Pulse width entry overrides other entries as required; it is the priority parameter.
For example, if the pulse width is changed such that it exceeds the pulse repetition period, the pulse repetition period will be automatically adjusted to accomidate the new pulse width entry. If, however, the pulse repetition period is changed such that it is less than the pulse width, the repetition period will be changed, upon attempted entry, to the closest value that can be achieved without changing the pulse width.

Entries are checked and rounded (not truncated) as necessary to meet limitations of the hardware or the Preferences.
When a file is opened, the output device will not turn ON automatically. A user must manually press either the "Record" button or the "Start" button.
The exceptions are the "Voltage Output" control panel and the "Digital Outputs" control panel if "Set each Output immediately" is selected; these settings will output values immediately.

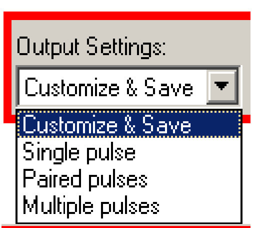
Output control settings are "local," which means that they are stored at the data file level, not the program level. Use the save as graph template (File > Save As) option to use existing Preferences in new data files.
If a file is saved with an Output Control panel visible and then closed, the panel will be visible when that file is re-opened.

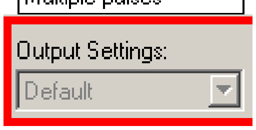
Preferences

Right-click a control panel to generate the Preferences dialog, and then select a tab for the settings you want to adjust.

You can also use the File > Preferences menu option to generate the Preferences dialog.

Output Settings

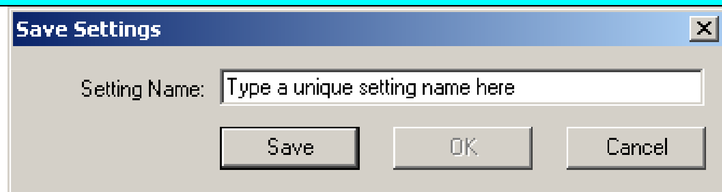




Displays the name of the current Preferences setting. The pull-down menu lists the names of all output Preferences saved using the **Save Settings** button (see page 195).
The pull-down menu is not accessible when an output pulse train is in progress.
If no settings configurations have yet been saved, when the Output Control panel is first opened and no parameters are changed, the Output Settings box displays "Default." If any parameters parameters are changed (but not yet saved), it displays "Custom."
When output settings are saved, the Output Settings box displays the name of the last selected setting. Use **Organize List** to change the display order of the menu, rename, or delete items (see page 195).
When a saved setting is selected from the pull-down menu, the Output Control panel and all Preferences dialog options will be updated.

For Reference Channel—Low Voltage only: All Output Settings must use the same reference channel assignment; other parameters can be unique for each setting.

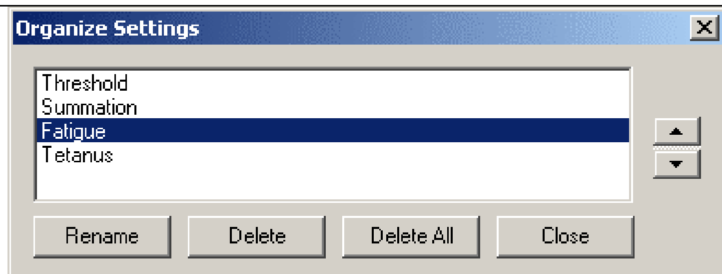
OUTPUT CONTROL PANELS



Once configured, Preferences may be saved using the **Save Settings** button at the bottom of the Preferences dialog. **Save Settings** generates a dialog to name and save a defined configuration of Stimulator output settings. Saved configurations are accessible via the Output Settings pull-down menu in the Output Control panel. When a setting is selected from the menu, all current output parameters are updated to reflect the saved settings.

You can save multiple configurations as long as each has a unique name; the Save button will be inactive if the name you enter is not unique.

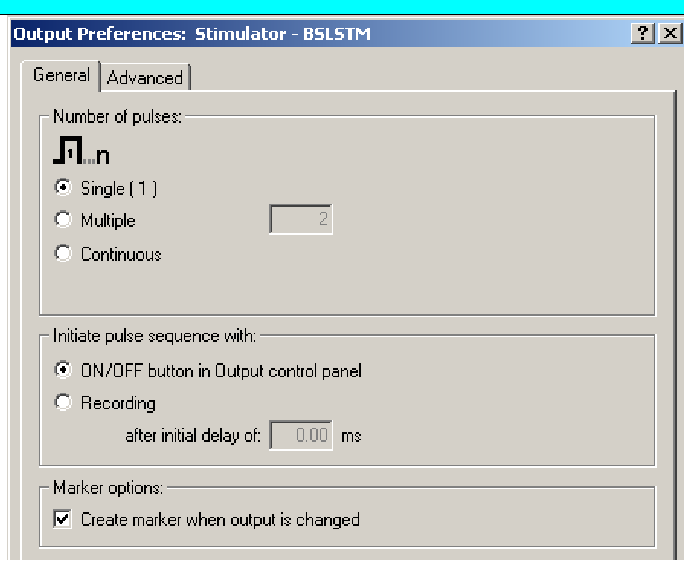
Output settings configurations are <u>local</u> presets that are saved with the data file or a template file. The data file or template file holds the output parameters as established when the file was saved plus any other named configurations of Output Settings.



Use the **Organize List** button at the bottom of the Preferences dialog to order, rename or delete saved Preferences settings. The up or down arrows are only available if two or more settings have been saved. Select a setting and then click the up and down arrows to set the position, or choose rename or delete. If you choose "Delete All," all saved settings will be deleted and the default and Custom options will be reactivated.

GENERAL TAB (OUTPUT PREFERENCES)

General Tab



GENERAL TAB (OUTPUT PREFERENCES)

Number of Pulses

Indicates the number of pulses to be output. When the Output Control panel is closed, the pulse output will be immediately stopped.

Single will establish a single pulse for outputting. All pulse repetition options, entry boxes and scroll bars in both the control panel and preferences windows will be disabled (grayed).

Multiple will establish a specific number of pulses for outputting. The selection will activate an entry box where you can enter 1-254 pulses. When this option is selected, the Pulse Repetition scroll bar is activated in the Output Control panel.

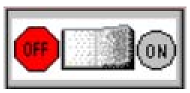
Continuous will establish a continuous pulse train for outputting. When this option is selected, the Pulse Repetition scroll bar is activated in the Output Control panel.

MP30 Only If using High Speed mode (> 2,000 s/s) and "Initiate pulse sequence with Recording" is selected, the stimulator cannot be turned off manually since the MP30 will not accept any commands from the computer until the recording has stopped.

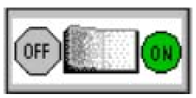
If "Initiate pulse sequence with ON/OFF button in Output control panel" is set, the pulse sequence will be stopped prior to acquisition and will have to be manually turned back on after the recording.

Initiate pulse sequence with…

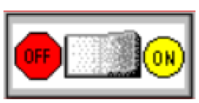
ON/OFF Button



OFF (red)



ON (green)



AUTOMATIC START (yellow)

Controls the start and stop of pulses. Changes to Pulse Width and Repetition Rate can be made in the Output Control panel entry boxes during a pulse sequence, and during a recording, if all other Preferences parameters allow it. Any change in the pulse output will occur immediately. ***This lets you change the stimulator output "on the fly."***

When "Initiate pulse sequence with **ON/OFF button**" is selected:

The ON/OFF button controls pulse output independent of the acquisition status.

OFF is always available.

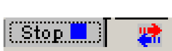
The ON/OFF button reflects the current output state, with one exception: if the pulse sequence lasts less than 0.5 seconds, the button will remain in the "ON" state for at least 0.5 seconds to indicate that the ON state occurred.

When the Number of Pulses selected is **Multiple**, ON/OFF acts as a momentary switch. Press the ON (green) button to start pulses;
it will automatically turn OFF (red) at the end of the specified pulse train.

The switch defaults to OFF. Saving a data file or saving as a Graph Template will save all stimulator preferences <u>except</u> the status of the pulse switch, which will always be saved in the OFF position.

Recording

Start button



Stop button

When "Initiate pulse sequence with **Recording**" is selected:

If the preference setting "Initiate pulse sequence with: ON/OFF button" is active, the control panel changes will take effect immediately. If settings are changed during a pulse train, changes do not take effect until the next time the stimulator starts.

Pulse output turns ON and OFF corresponding to the Start and Stop of the recording. In other words, the Pulse output can only occur during a recording.

When in this mode, and not recording, the ON button will display as yellow, indicating that pulse output will automatically begin at the "Start" of the recording.

Pulse outputting can be turned OFF during a recording, but it cannot be turned back ON until the end of the recording.

GENERAL TAB (OUTPUT PREFERENCES)

When a **Repeat** sequence is running, pressing the OFF button will turn OFF the output for the entire recording sequence and the button will display as OFF until after the last sequence, when the switch will display as yellow ON (automatic start) indicating that pulse output will begin again at the "Start" of the next recording sequence. You cannot turn pulse outputting back ON during a repeated recording sequence.

When the acquisition stops, all stimulator pulses will cease, regardless of the Output Control panel settings.

The pulse train will stop concurrent with the end of the acquisition, even if the specified pulse train is not completed before the acquisition ends. When a new acquisition is started, the pulse train will start from the beginning.

In this mode, no changes can be made in the Output Control panel until the recording stops. Changes made after recording stops will take effect when a new recording is started.

When a pulse is sent out, the marker label and indicator arrow will be generated (if the marker preference is turned ON and markers are displayed).

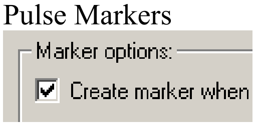
After initial delay

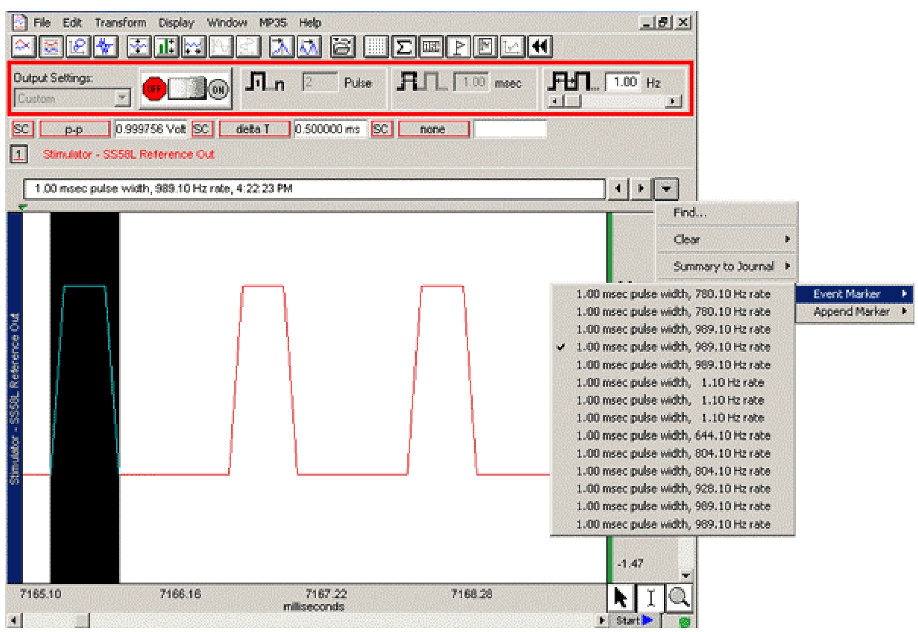
After initial delay of … is enabled only when "Initiate pulse sequence with **Recording**" is chosen. Specify a delay interval from the start of recording to the start of the first pulse. This is useful for viewing data prior to the stimulus pulse. The BIOPAC output device determines the delay range.

INITIAL PULSE DELAY	MP36R or BSLSTM	
Range	0 - 100 milliseconds	0 or .5 - 100 milliseconds*
Resolution	10 microseconds	1.953 microseconds

*Entries greater than 0 milliseconds must be at least 0.5 milliseconds.

Pulse Markers





An advantage of using the Acq*Knowledge* software for output signals is that information regarding the pulse is automatically recorded along with the data. On most chart recorders, information regarding the pulse level (amplitude), pulse rate, and pulse width must be noted by hand, a process that can be inefficient, time-consuming and error-ridden.

GENERAL TAB (OUTPUT PREFERENCES)

- The amplitude reflects the output pulse level.
- Markers can be automatically inserted and labeled for each Reference pulse or change in pulse train. The label will contain the Pulse width and Pulse rate (and system time stamp if selected).
- Markers reflect setting changes made during an acquisition.
- All output pulse information is automatically recorded and archived with the saved data.

Set the marker option by clicking in the box to “Create marker when output is changed.”

Set the time stamp option on the global Marker Preferences tab.

The marker label accurately captures pulse data, but the marker arrow may not always line up exactly with the leading edge of the pulse; this typically is not a problem because the recording will include the actual stimulus pulse which can be used for timing measurements.

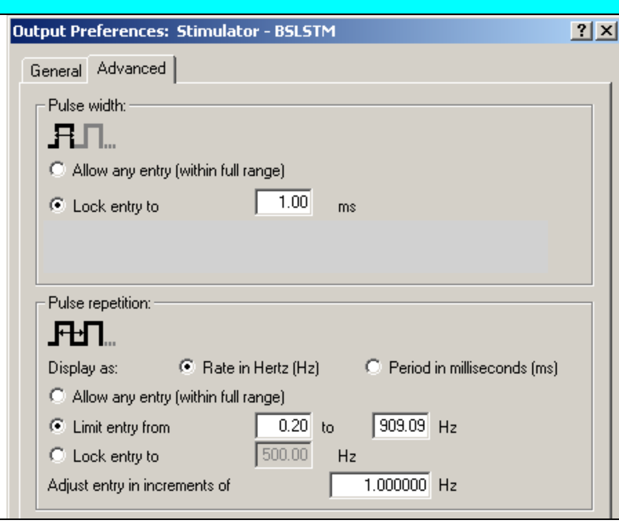
Depending on the acquisition Sample Rate, the leading edge of the pulse in the recording may not correspond to the exact time the pulse was sent—it may be off by as much as one sample period. If the marker precision is critical for your recording, increase the Sample Rate.

To display markers, use the toolbar icon or Display > Show > Markers.

The **Range** switch on the front of the **BSLSTM** stimulator should be set to 10V or 100V prior to recording and should not be changed during recording; if using a Preset, the corresponding Preset should also be selected prior to recording. The pulse level can then be determined by moving the decimal to the right or left depending on how the range was switched.

ADVANCED TAB (OUTPUT PREFERENCES)

Advanced Tab



Pulse Width

Indicates the Pulse Width setting, which determines the maximum Pulse Rate frequency. You may enter a Pulse Width value, unless limited by Preferences.

The entry is activated when the value is changed and the Tab or Enter key is pressed;

ADVANCED TAB (OUTPUT PREFERENCES)

it does not require a stimulator restart to take effect.

The Pulse width entry overrides other entries as required; it is the priority parameter.

An entry may be automatically changed if any of the following conditions apply, in which case the closest possible value will be selected:

It falls outside the allowable range.

It is rounded to .01 millisecond increments (MP36R resolution).

Width has been limited by the **Pulse Width: Limit Entry** settings of Preferences.

Allow any entry

Pulse width is limited to the output capabilities of the BIOPAC MP device. This option allows any entry within the allowable range specified below:

PULSE WIDTH RANGE MP36R unit

Range	.050 – 100 milliseconds
Resolution	10 microseconds

Lock entry to

This entry locks the width to a single, specified value (within the allowable range). No other value can be entered.

Calibration adjustment

MP30 BSLSTM only

The pulse width from the MP30 output connector is very accurate, but the BSLSTM hardware may add 0 to 150 microseconds to the pulse width in its internal circuit. This value can vary somewhat from unit to unit but mainly depends on the revision of the BSLSTM which is determined from the serial number on the back of the unit. To adjust for this, the software can subtract a specified amount of time from each requested pulse width.
To determine a calibration adjustment value which will get one very close (within +-5%) of the requested pulse width, refer to the following table:

Serial No.	Calibration adjustment value (microseconds).
<= 308A 5100	70
> = 310A 100	0 (default value)

If you are using an older model manual control (no LED) BSLSTM stimulator, try using 110ms—and then contact BIOPAC for a free product upgrade.
If pulse width accuracy greater than +- 5% is required, calibrate your specific BIOPAC BSLSTM stimulator (requires an oscilloscope) and enter a specific adjustment time from 0 to 150 microseconds (entries outside this range will be clipped).
Calibration adjustment—MP30 BSLSTM only
Connect a BNC to BNC cable from the BSLSTM output connector to an oscilloscope input.
Set the “Calibration adjustment: subtract” to “0.”

Specify a pulse width of .2 ms.

Send out a stimulus pulse.
Measure the actual pulse width out of the BSLSTM stimulator with an oscilloscope.
The Manual Test button on the back of the BSLSTM cannot be used to make the oscilloscope measurement.

Calculate the time required to make the pulse width exactly .2 ms.
Enter this time, in microseconds (1 ms = 1000 microseconds), into the “Calibration adjustment: subtract” entry box.

Pulse Repetition

Indicates the Pulse Repetition period (Hz or ms).

The **Pulse period** must be greater than the **Pulse width**. See “TBPMIN” in the

ADVANCED TAB (OUTPUT PREFERENCES)

Output Preference > Advanced Tab Limits table on the next page.

The full range of acceptable Pulse Rate values is from **.2** to **6,667 Hz (MP36R) or .2** to **6,827 Hz (MP30).**

The maximum Pulse rate (PRPMAX) depends on the Pulse width setting:

Pulse width 100 ms → maximum Pulse rate = **9 Hz**

Pulse width .020 ms → maximum Pulse rate = **3333 Hz**

The formula for pulse width vs. pulse repetition is $PRPMIN = PW + TBPMIN$

Where: *PRPMIN* = the MINimum Pulse Repetition Period allowed.
PW = Pulse Width setting
TBPMIN = MINinum Time (in ms) between successive pulses for the output device (see device specifications)

If "Limit changes from ___ to ____" is selected in Advanced preferences, then PRPMAX will be determined by the formula above or the specified limit, whichever is greater.

An entry may be automatically changed:

If it falls outside the allowable range.

To round it to .01 Hz increments (resolution of system).

To make it at least 0.1 millisecond greater than the Pulse width.

By the Pulse Repetition Rate: Limit entry Preference.

By the Pulse Repetition: Adjust entry increments Preference.

You may manually enter any value for pulse width, but when using the scroll bar or arrows, entries will be constrained by the "Adjust entry increments" Preference setting.

Pulse Repetition Scroll Bar

The Pulse Repetition **Scroll Bar** adjusts rate or period by the increment of change and limits established in Preferences. With each click of the scroll bar arrows, the rate will be increase by the specified increment.

When "Initiate pulse sequence with **ON/OFF button in Control Panel"** is selected, changes take effect upon release of the scroll box as long as the stimulator is running.

The scroll bar is disabled when Number of Pulses is set to "Single" or Pulse Repetition is set to Lock Entry to..."

Display as

Pulse repetition can be dispalyed as

Pulse Rate (expressed in Hz), or

Pulse Period (inverse of Pulse Rate, expressed in milliseconds).

Pulse Repetition Rate relates to the Pulse Repetition Period as:

Pulse Rate (Hz) = 1000 / Pulse Period (milliseconds)
The "Display as" **units** selection is also used for:
Pulse repetition entries in the control panel.
Scroll bar increments.
The Pulse Repetition Rate: Limit entry Preference.
The Pulse Repetition: Lock entry Preference.
The Pulse Repetition: Adjust entry increments Preference.

When units are changed from Rate in Hertz (Hz) or Period in milliseconds (ms), the limits

ADVANCED TAB (OUTPUT PREFERENCES)	
	of the Pulse Repetition range will be converted by the formula: Period increment in ms = Round to nearest whole number [Period Range * (Rate increment in Hz /Rate Range in Hz)] For example, if the Range was 1Hz to 10 Hz with an adjustment increment of 1Hz, the proportional calculation would be Period increment = 900 ms (1Hz / 9 Hz) = 100 ms
Allow any entry	Pulse width is limited to support the output capabilities of the BIOPAC output device. See Output Preference > Advanced Tab Limits table for allowable range.
Limit entry	Establishes minimum and maximum values that can be manually entered or changed with the scroll bar.
Lock entry	Locks the Repetition to a single, specified value (within the allowable range). No other value can be entered in the control panel.
Adjust entry	Controls the scroll bar or scroll arrow increment; does not apply to manual entry.

Advanced Tab Limits	Pulses		BSLSTM	
Pulse width				
Range (ms):	.050 – 100	.049 – 100	.050 – 100	.049 – 100
Resolution (ms):	.010	.001953	.010	.001953
Pulse Repetition				
Rate range (Hz):	.2 – 16,667	.2 – 10,204	.2 - 2,000	.2 – 2,004
Period range (ms)	.060 – 5,000	.098 - 5,000	.500 – 5,000	.499 – 5,000
TBPMIN Minimum time between Pulses (ms):	.010	.049	.450	.450
Resolution (ms):	.010	.001953	.010	.001953
Initial Pulse Delay				
Time range (ms):	0 – 100	0 or .5 - 100	0 – 100	0 or .5 - 100
Resolution (ms):	.010	.001953	.010	.001953

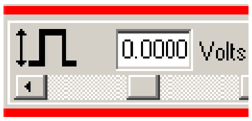
LEVEL TAB (OUTPUT PREFERENCES)

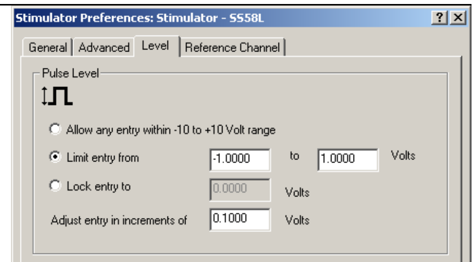
About Level

The Low Voltage Stimulator allows the software to specify the pulse amplitude. The amplitude can be set to any value within the limits of the stimulator; the range is -10 to +10 Volts.

Pulse Level

Low Voltage only





The **Level entry box** allows the user to manually enter any value within the limits of the system or within the limits of the Preference settings from the Level tab.

The Level entry box will be inactive (grayed) if:
The Level preference "Lock entry to" is active.
If "Initiate pulse sequence with Recording" is active (from the General tab) and a pulse sequence is in progress or "wait for trigger" is in progress.
Use the entry box or the scroll bar to set the Pulse level. When a value is entered which is out of range, the value will be rounded to the closest value obtainable after the "Enter" or "Tab" key is pressed.
If "Initiate pulse sequence with ON/OFF button in control panel" is active (from the General tab), then values entered during a pulse sequence will take place immediately.
If "Initiate pulse sequence with Recording" is active (from the General tab), any entry made between acquisitions will take place on the next "Start" of acquisition.

Allow any entry

The level is limited from -10 to +10 V to support the output capabilities of the stimulator. This option allows any entry within that range.

Limit entry

This entry reduces the range (within the -10 to +10 V range limit).

Lock entry

This entry locks the level to a single specified value (between -10 and +10 V).

Adjust entry

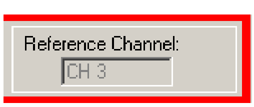
This setting affects the scroll bar or scroll arrow increment only; it does not apply to manual entry.

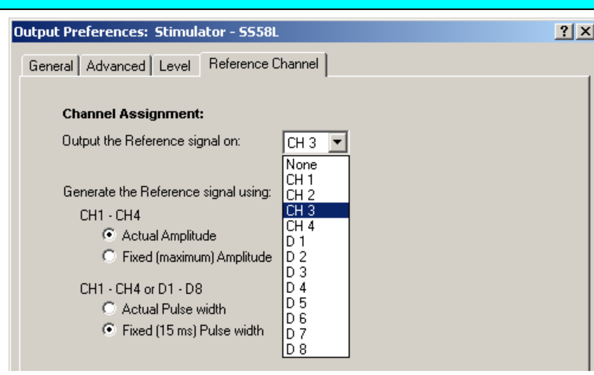
The smallest increment is 5 mV, as limited by the MP36R. The specified increment is used to round manual entries to the closest obtainable value.

REFERENCES TAB (OUTPUT PREFERENCES)

Reference Channel

SS58L only





This option allows you to "Monitor" the output signal on one of the analog or digital input channels without making any physical connections. This is an internal, hardware/firmware, feature that recreates the output signal and allows

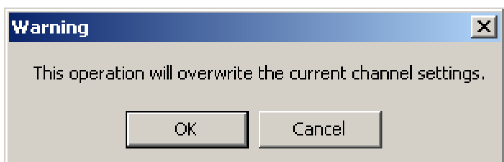
LEVEL TAB (OUTPUT PREFERENCES)

recording in "real time." The assigned reference channel will override any "real" input signal.
For example, if a transducer is connected to CH 1, and CH1 is chosen as the reference channel, then the signal coming from the transducer will not be viewable, and will not conflict with the reference signal generated internally.
The reference signal is not the real signal, but is a very accurate "estimate" of the real signal. The pulse timing accuracy will be within 100 microseconds. If an analog input channel is used as the reference channel, the pulse level will be accurate within 5%. If the SS58L encounters a load that reduces or distorts the pulse output, the reference signal will not reflect this amplitude distortion.
If a digital input channel is used as the reference channel, only a digital representation of the pulse will be generated. In other word, regardless of the pulse level, when no pulse is occurring, the level will be 0 Volts, and when the pulse is occuring, its level will be shown as +5 Volts.

Channel Assignment

Use the pull-down menu to choose which analog or digital input channel will be used as the output reference channel.

When a new reference channel is assigned, a warning will be generated to alert you that this setting will overwrite the existing Channel Setup parameters for the selected channel.



For example, if you set up CH1 for ECG data and then select CH1 for the Reference Channel, your ECG parameters will be replaced. If you then select another channel, CH1 will be restablished with the default analog input parameters, and you would need to recreate your ECG settings (by using Presets or manual entry).

The reference Channel label should read: "Low Voltage Stimulator - Reference Out".

When an Analog Input Channel is assigned as the Reference channel, that channel, as viewed from the MP UNIT > Set up Channels dialog, will be in a "Lock-Out" mode. This means that the Preset pull-down menu icon for that channel will be grayed (inactive). The assigned reference channel will be inactive for "real" inputs until the Reference Channel Preference is changed to "None" or another channel. The wrench button, when pressed for the Reference channel, will still allow viewing of the channel parameters, but all entry boxes and pull-down menus will be inactive.

When a "Low Voltage Stimulator" control panel using an assigned Reference channel is closed, the channel that was assigned as the reference channel will be removed from "Lock-Out" and will automatically change to the default, "CH X Input" settings. The reference channel assignment will be saved in the template or data file, so that if the "Low Voltage Stimulator" control panel is reopened, the reference channel will be automatically re-assigned, without any warning prompt given.

Generate using

You can specify how the Reference signal should be shown.

If using **analog** input from CH1 - CH4, you may select actual or fixed (max)

LEVEL TAB (OUTPUT PREFERENCES)	
	amplitude and actual pulse or fixed pulse width. Fixed pulse widths are useful when the pulse width is much smaller than the sample interval (1/sample rate) being used. For example, for Frog muscle stimulation, you may choose to use a 1 ms pulse width, but a sample rate of 200 samples/sec. to capture the muscle response. At this sample rate, the stimulus pulse could not be reliably recorded. By extending the displayed pulse width to 100 ms, you will be guaranteed to always record the stimulus pulse. If using **digital** input from D1 - D8, select actual or fixed (15ms) pulse width.

Usage Guidelines & Setup Summary for BSLSTM Output Control

HUMAN SUBJECT SAFETY
Before using the stimulator on human subjects, it is very important to limit the energy the stimulator outputs. For optimal safety:
Before powering on the BSLSTM stimulator, set the voltage level to zero by rotating the LEVEL knob on the front of the BSLSTM fully counterclockwise.
Use BIOPAC HSTM Series Probes. You MUST use these probes order to limit the energy the stimulator can output.
Never create an electrical path across the heart.
Never use on subjects with pacemakers.
Read this manual and the BSL Hardware Guide to become familiar with Stimulator operation.

Connect the BSLSTM Stimulator to the MP UNIT and power on both units. (For instructions on how to connect the BSLSTM to the MP UNIT Acquisition Unit, refer to the *BSL Hardware Guide*.)

Connect the Stimulator Trigger cable to the Analog Out port of the back of the MP UNIT.

Connect the Stimulator Reference Output cable to an Input Channel on the front of the MP UNIT. This channel will be set up in Step 3 as the Stimulator Reference Channel.

The **Reference pulse** has a fixed Pulse width of 15 milliseconds, so chosen so that the Sample Rate of the recording may be as low as 100 samples/second and still capture the Reference pulse.

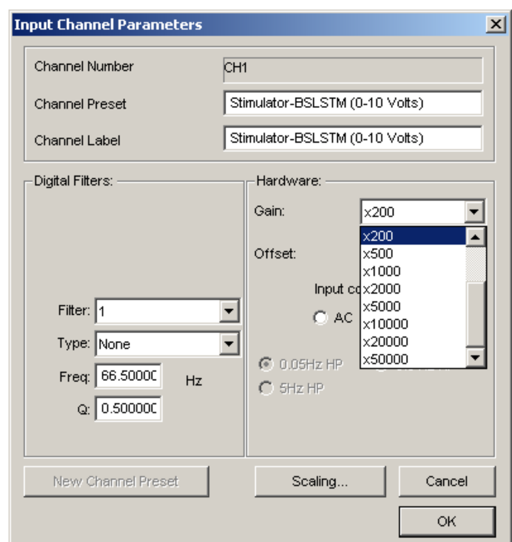
Before powering on the BSLSTM stimulator, set the voltage level to zero by rotating the LEVEL knob on the front of the BSLSTM counterclockwise all the way to the left.

Launch Acq*Knowledge* software to a new data acquisition window.

Confirm that **Markers** are activated.

Markers are activated by default. If not activated for a given recording, choose **Display** > **Show** > **Markers**.

Set up the **Stimulator Reference Channel**. This is the Analog Input Channel on the front of the MP UNIT that receives the Stimulator Reference Output cable from the back of the BSLSTM.



Choose MP UNIT > Set up Channels. This will generate a Set up Channels dialog.

Select the **Acquire**, **Plot** and **Enable** options for the analog channel to be set up as the Stimulator Reference Channel.

Click **Presets** and scroll to select “Stimulator (0-10V)” or “Stimulator (0-100V)” to match the Range switch setting on front of the BSLSTM.

Click View/Change Parameters. This will generate an Input Channel Parameters dialog.

Read the entire Stimulator section of this manual and familiarize yourself with the unit and its options before changing any preset parameters.

You may set the Gain and other input parameters as desired.

Click OK to accept the parameters.

Close the Set up Channels window.

Adjust the voltage output of the stimulator by using the **Level** control on the front of the BSLSTM.

Rotate the **Level** knob clockwise to increase and counterclockwise to decrease, reading the voltage in the BSLSTM's digital display.

Stimulator Safety Features

The stimulator cannot operate unless its Output Control panel is open.

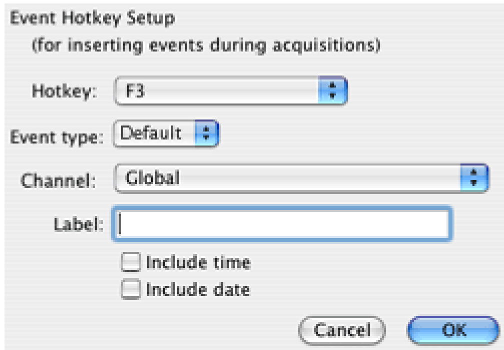
The Pulse ON/OFF Switch on the Stimulator Output Control panel must be OFF in order to open and configure Stimulator Preferences.

If the Stimulator Output Control panel (or the Acq*Knowledge* application) is closed in the middle of a pulse train while the stimulator is running, the stimulator will shut down and the pulses will stop.
If another data acquisition window is activated, the stimulator will stop and remain OFF unless restarted using the parameters associated with the new data window. The only exception is that if the stimulator is ON and the data window corresponding to current stimulator parameters is acquiring data, then the stimulator will continue to run until the end of the acquisition.

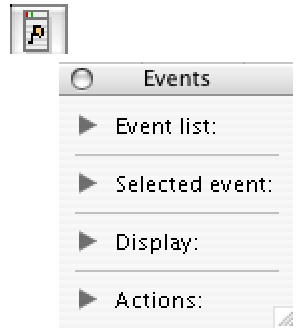
Chapter 11 Set Up Event Hotkeys

Events (Markers)

Event Toolbar



Event Insertion



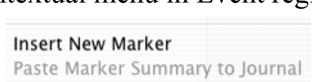
Event Control

Event (Marker) Overview

For detailed analysis, it can be useful for waveforms to have extra information associated with them. This information might include waveform boundaries from ECG analyzers, spike classifications from a spike sorter, heartbeat classification from a PhysioBank file, or even detailed user notes. Acq*Knowledge* 4 uses "event" functionality to store and manage this information.

An event is a piece of information associated with a specific time in a waveform. An event can capture points of interest within a file (i.e. subject moved, dose added) or on a particular channel (i.e. T-wave onset). Once events are marked in the file, Acq*Knowledge* can use the event information for analysis, including measurement (page 220) and cycle detection (page 308).

- An event has the following pieces of information associated with it:
  - Event type
  - Sample location: the time position in hardware samples where the event is defined.
  - Channel: the channel for which the event is relevant.
    - Some events, such as the time of the start of an appended segment, may be relevant to all of the channels of a graph—these are "Global" events.
  - Label: a string of text that can be entered either automatically or by the user to provide more information about an event. Labels can be fixed or sequential in Acq*Knowledge* 4.2 and up.
- Different event types can be entered automatically or manually. These different event types allow events to be filtered and also support analysis routines that key off of these events.
    - Event insertion tool
    - Set Up Manual Event Hotkeys (see page 210) to manually insert events during acquisitions
    - Copy/paste measurements and Copy/paste wave data operations can insert events at the selection boundaries; choose "Mark with events" under Preferences (see page 209)
    - Cycle Detector Output Events option (see page 308)
    - Contextual menu in Event region



    - Specialized Analysis (see page 331) to automatically insert markers according to complex analysis algorithms

Event Toolbar

The event toolbar displays global events and provides a quick editing area for event descriptions. The right button toggles visibility of the Event Palette for detailed control (see page 211). The palette will "refresh" when events change the event configuration, such as horizontal scrolling, scale changes, changes in the selected event via clicking in the graph window, editing of the event label by using the event bar, transformations that define new events for the graph, waveform editing operations, and additions of new events by clicking the event bar at the top of the graph window.

Event Tooltips

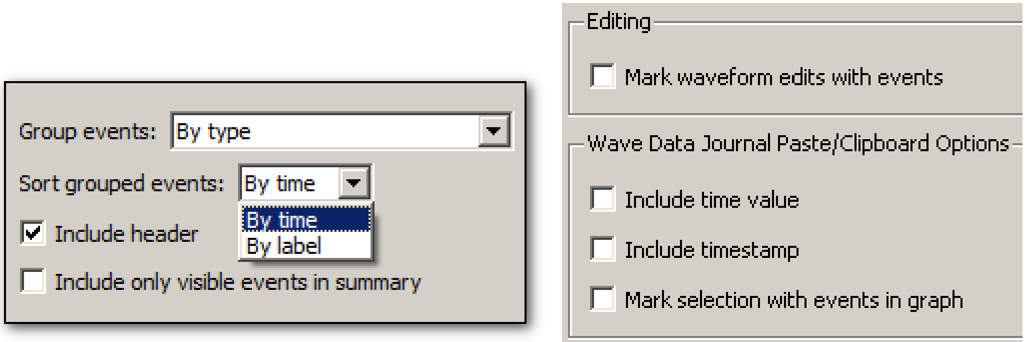
If events are being displayed within the plotting area and tooltips are enabled, a tooltip will be associated with every event in the plotting area. The tooltip includes the event type description, the user-defined label (if present), the time location of the event, and the amplitude of the waveform at the event location. While this information can be drawn directly on the graph, event tooltips assist in browsing event information when the screen becomes too crowded and there is not enough room to display all of the times, amplitudes, and labels.

Event tooltips are displayed under the event icon.

- If the event is being plotted directly on the waveform, this will be the point on the waveform associated with the event.
- If there is an indicator and the event icon is at the top of the indicator, the tooltip will be anchored at the top of the indicator.
- If the events are being plotted at the top of each track, the tooltip is anchored at the top of the plotting area directly underneath the event icon.

Event tooltips will not be displayed if tooltips are disabled, if events are only being displayed in the marker bar at the top of the screen, if X/Y mode is in use, or if events are not currently visible.

Event Preferences



Preferences > Event Summary and Waveform

Use the "Event Summary" section of the Preferences dialog to set options for pasting summaries of events into the journal. (Preferences shown above and losted below are from Acq*Knowledge* 4.2)

- Group events

  Sorted by type — sorted by event type descriptions first

  Sorted by channel — grouped based upon where they are defined (Global events appear first, followed by groups for each individual channel).

- Sort Grouped events

  Sorted by time — sorted in order by increasing time

  Sorted by label — sorted alphabetically by label

  - Include only events visible on the screen

    Determine if the summary is generated for all of the events that are in a graph, or only for those events that are currently visible on the screen. If there are thousands of events in a file, this feature allows the list to be pared down to those of interest.

Event summary options will be saved with the graph if the graph has a graph journal, and can be pasted into the journal using "Summary in Journal" Event Palette Actions command (see page 214).

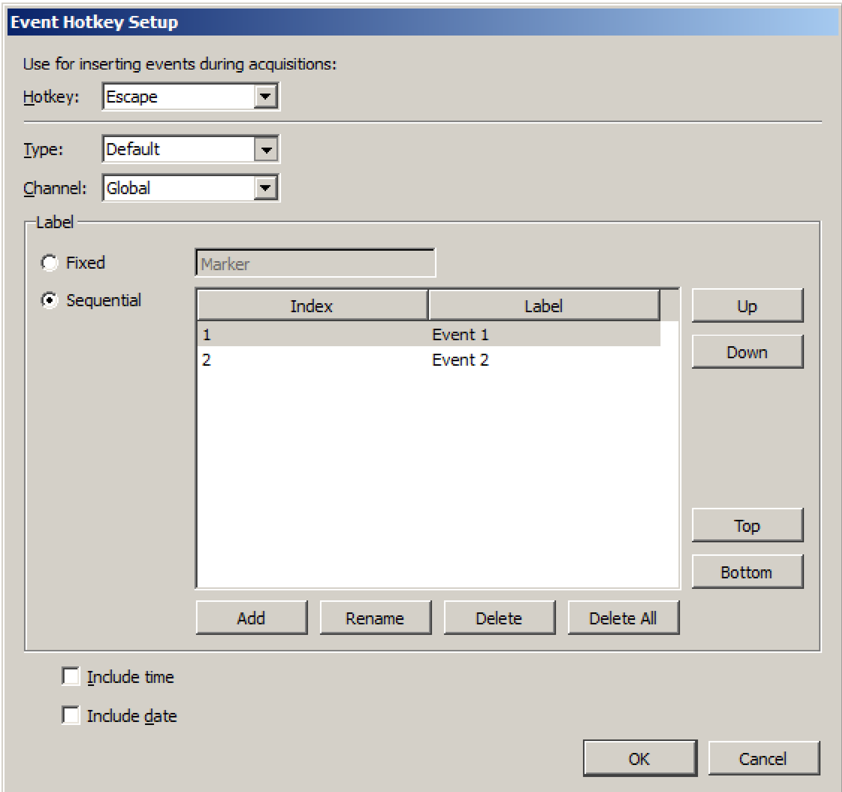
Other event preferences are available under Preferences > Waveforms

- **Mark waveform edits with events**
- **Mark selection with events in graph**—create events at data selection bounds. This includes selection events (selection begin and selection end) for global events when measurements or waveform data are pasted. When selected, measurement pasting will result in an automatic execution of the "Mark Selection" feature manually accessible from the Event Palette.
- **Include time value**— include the time value (relative to start = 0) for the paste.
- **Include timestamp**—Include time and date stamps for when the paste ocurred; this timestamp will match any timestamp pasted into the journal. When selected, any selection events added to the graph will have their labels set to match the timestamp.
- **Auto-paste results in independent journal** (Preferences > Journal)—Selection events and time stamp events can be automatically inserted to an independent Journal.

Combine these options to retain enough information to reproduce measurement results and correlate measurement results with specific areas of the graph; this helps verify the accuracy of measurement results made through manually constructed graph selections.

Any change to these settings will be retained within a saved graph file and will become the default for newly constructed graphs.

Event Hotkey Setup



Events of different types can be inserted during acquisition, whether or not events are visible in the graph. When a *hotkey* is pressed during acquisition, an event will be inserted into the graph at the end of the most recently acquired data. Each hotkey can have a different configuration, adjustable through a dialog accessible via the "MP150 > Set Up Manual Event Insertion Hotkeys..." menu item.

Hotkey — Assign Escape or F1 through F9. When a different hotkey is chosen, the other controls of the dialog change to reflect the configuration of the new hotkey.

Event type — Lists the standard hierarchical menu of available event types; Types are detailed on page 215. Choosing a new type from the pull-down menu will change the type of event inserted when the hotkey is pressed during acquisitions.

Channel — Contains a "Global" entry and all of the channels (analog, digital, or calculation) set to "Acquire" in Set Up Channels.

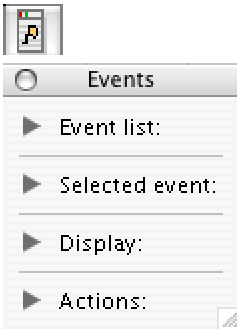
- "Global" will define global events drawn in the event bar above the graph data
- Choosing a new channel from this menu will cause events to be inserted on the appropriate channel of the graph when the hotkey is pressed.

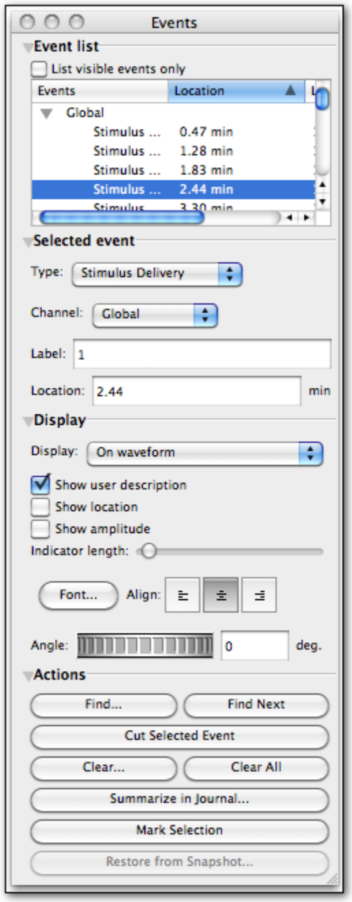
Label — Edit field for label text and toggle optional inclusion of time stamp and/or date stamp. Stamps correspond to the time of the system clock when the key was pressed, that is, the time of the event insertion in "real clock time."

- Fixed - Provides a fixed label from text entered into the label field to the right. This label is used every time the assigned hotkey is pressed. (Acq*Knowledge* 4.2 and higher)
- Sequential - Labels for events will iterate sequentially through the entries in the table index when the assigned hotkey(s) is pressed. The area under 'Label' is editable for entering text. (Acq*Knowledge* 4.2 and higher)

Additional Controls	Function
Add	Adds an editable label field to the list.
Rename	Allows renaming of the existing segment label.
Delete	Deletes a selected custom label.
Delete All	Deletes all custom labels.
Up	Incrementally moves a selected label up the list.
Down	Incrementally moves a label down the list.
Top	Moves a selected label to the top of the list.
Bottom	Moves a selected label to the bottom of the list.
Include time	Adds timestamp to labels when checked
Include date	Adds current date to labels when checked

Event Palette



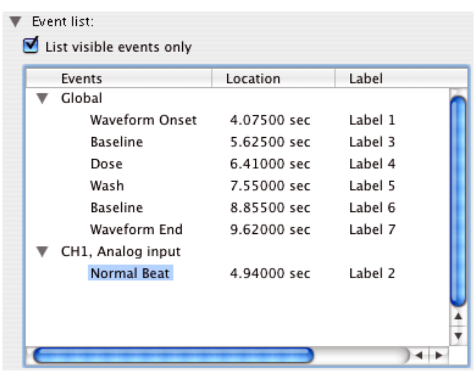


The event palette is a floating window that provides a quick summary of events for the top most graph and can used to examine, search, and modify events. Events can be extracted in a time range for a specific event type and specific channels.

There is only one visible event palette for the entire application. The palette consists of four sections: event list, selected event, display, and event actions. Each section can be shown or hidden by toggling the disclosure button next to its title.

- ➲ Event List, see page 211.
- ➲ Selected event, see page 212.
- ➲ Display, see page 212.
- ➲ Actions, see page 214.
    - o See the Event Journal Summary enhancements.

Event List



The event list provides an expandable, scrollable, hierarchical view of the events in the topmost graph. Events are grouped by their channel on the top level.

The event list has three columns of information:

- Events: the readable type for each event
- Location (Time): the time location for each event
- Label: the user defined description for the event.

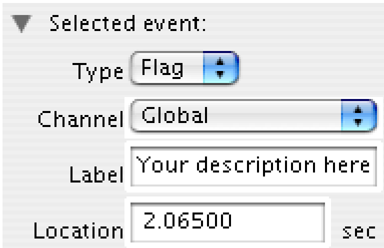
Sort the contents in ascending or descending order on each column by clicking the column header. Events and Description will sort in standard alphabetical order, Location will sort based on the numerical sample location of each event.

Select a single event from the event list by clicking on a single event. The event will be selected in the graph window and made visible if it is not currently displayed.

List visible events only toggles the checkbox to switch between the two display modes.

- When enabled, the event list will display only those events that are being displayed on the plotted portions of the graph. As the user navigates through the graph with the scrollbars, horizontal scale, or other means of changing the amount of visible data, the event list will continually refresh to contain the new set of visible events.
- When disabled, the event list will display all of the events for the entire graph. This can allow for easier navigation through graphs with hundreds of events, such as PhysioBank files.

Selected Event



Event type options are detailed on page 215.

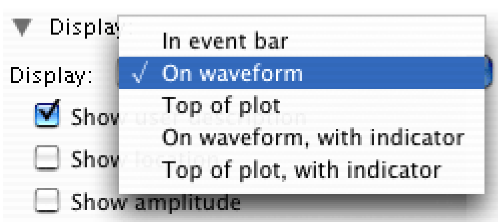
When a single event is selected, the type, channel (or "General" for global events), user-defined label, and location of the event will be filled in and can be edited. The controls can display information about only one event at a time; if no event is selected, the controls will be grayed out.

Event Location

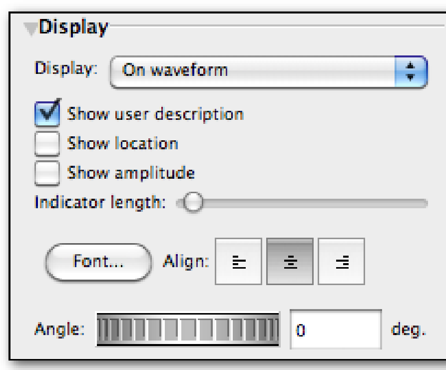
"Location defines the position where the selected event occurs, relative to the first sample in the file. To change the location of an event, change the position entered in the Location box. Precision matches the horizontal axis setting.

Events may also be repositioned using the mouse. Option-click the event icon in the graph and hold down the mouse while dragging; the event will be repositioned at the horizontal position where the mouse button is released.

Display



Event display location



Event display detail

Display controls determine the location and detail of events to be drawn in the frontmost graph.

- Location—Choose one of the five display methods (described on page 213).
- Detail—the three checkboxes to establish how much information to include with events.
- Indicator length—Set the slider to shorten or lengthen the indicator line. This option is only active if the display mode is "On waveform, with indicator" or "At top, with indicator."
- Font – Align – Selects font style and alignment of Event labels.
- Angle – Determines the angle in degrees that the Event text can be displayed in the graph. Value can be positive or negative.

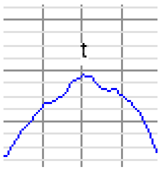
Location & Display — Description

In event bar

Event icons are displayed in the global marker bar located on top of the plot area in the graph window. This does not allow for distinguishing what channel a specific event belongs to.

- To select the event, click the icon in the marker bar.

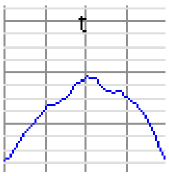
On waveform



Event icons are displayed above or below the actual sample in the source channel corresponding to the location of the event.

- To select the event, click the event icon on top of the waveform.

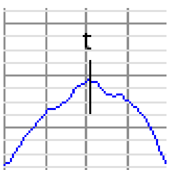
Top of plot



Event icons are displayed at the top of the channel track, either on top of the grid or in a channel-specific marker bar.

- To select the event, click the icon at the top of the channel track.

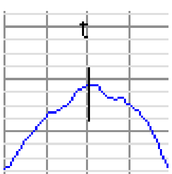
On waveform, with indicators



Event icons are displayed above the data with a vertical line of configurable length running through the data sample of the source channel at the event's location.

- To select the event, click the event icon or the indicator line.

Top of plot, with indicators



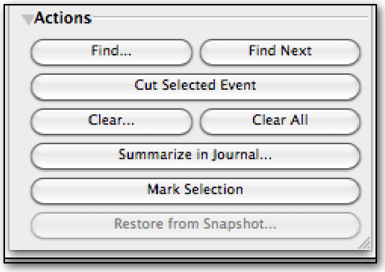
Event icons are displayed at the top of the channel track with a vertical line of configurable length running through the data sample of the source channel at the event's location.

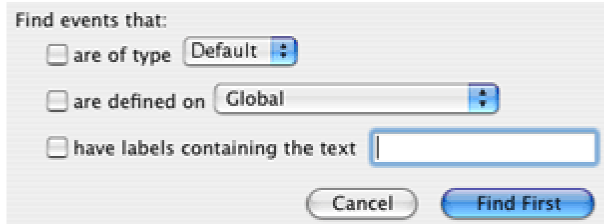
- To select the event, click the event icon or the indicator line.

Detail

When an event is being plotted within a graph, either on the top of a channel or floating above the data, the event's location, description, and amplitude of the waveform at that location can optionally be displayed along with the event icon. Plotting of additional information can be used for graphical annotations on the data and for clarifying event location for hardcopy or presentation.

Actions





Actions Button — *Description*

Find

It is easy to create many more events then one can easily scroll through and locate in a list. Find controls the automatic location of events based on established search criteria.

Click the Find button to generate the Event search criteria dialog, and then combine or restrict information to define desired events: event type, specific channel location, or label search.

Click "Find First" to search for the first event in the graph that matches the criteria. If found, the event will be selected and made visible in the graph window.

Find Next

Finds the next single event that matches the established search criteria until no remaining events match the search criteria.

Cut Selected Event

Active only when an event is selected, removes the selected event from the graph.

Clear
Clear all

Generates a search criteria dialog (identical to the Find dialog) and removes all matching events from the graph.

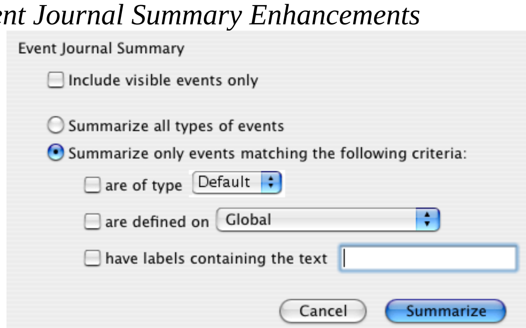
Summarize in Journal

Displays a dialog with controls that affect which events are included in the summary.

Events can be filtered by visibility on the screen. Creates a textual summary of all of the events in the journal.

- See "Event Preferences" on page 209 for more information about modifications to the traditional marker summary.

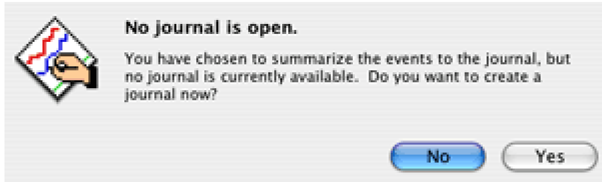
Event Journal Summary Enhancements



Events to be included in the summary can be filtered using the same criteria as Find... in the Event Palette. By adding the ability to summarize only events matching specific criteria, textual reports of arrhythmias or other infrequently occuring events of interest can be generated with ease.

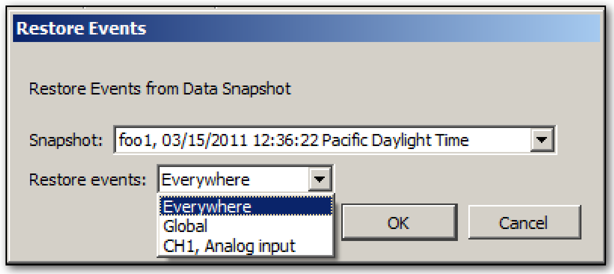
When "Summarize in Journal" is clicked on the event palette, a dialog will be displayed with controls that affect which events are included in the summary.

If there is no journal for the current graph, you will be prompted to create a journal.



Mark Selection Defines two new Global events in the graph at the precise time locations of the currently selected area (the highlighted wave data section). If there is no selection in the graph, this button has no effect. The events that are inserted will have the "Selection Begin" and "Selection End" event types.

Restore from Snapshot Enables deleted events to be restored from events present in a Data Snapshot. This option becomes active only if a Data Snapshot of the main graph is displayed. The following prompt will be displayed when Restore from Snapshot is selected.

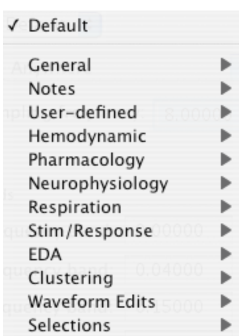


Event Type Options

Event Types are pre-defined options for assigning event information. The Event Type is for marking purposes only and does not imply any analysis has or will occur for the event (unless Specialized Analysis was performed, see page 331).

Once Event Types are defined, some analysis functions can be automated, including measurement (page 220) and cycle detection (page 308).

Event classifications:



Event classifications group similar event types together into a logical category. Event classifications present event types in a hierarchical fashion and allow other event classifications to be contained within them.

For example, the "Hemodynamic"event classification includes a "Beats" sub-class with pre-ventricular contraction and escape beat event types.

Event type	Classification
Global	This is the same as 'untyped' markers from Acq*Knowledge* 3.6 or earlier. Unrecognized event types will be classified as global events.
Append	Automatically inserted by the program on append operations. Custom Append labels can be created in MP150 > Set Up Segment Labels. (See page 225.)
Notes	Annotation event to add notes on the data.
User-defined	Hotkey insertion for user-specific events; 9 types can be inserted via the keyboard during acquisition.
Pharmacology	Basic pharmacological events: baseline, washing, and dosing.
Waveform Edits	Automatically inserted by the program on cut or paste operations in a graph file. The description consists of the edit operation performed and a timestamp. Insertion of waveform edit events is off by default, but can be turned on for GLP purposes.
Selections	Used to mark boundaries of selected areas.

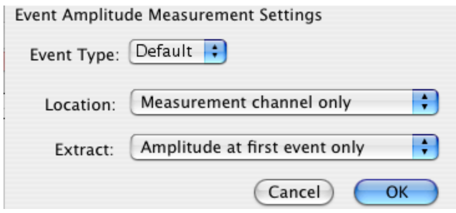
Classification	Pre-defined Event Type Options	
Default	"Esc" key inserts global event.	
General	Waveform onset or end Change in signal quality or rhythm Recovery	Maximum and minimun Reset Append
Hemodynamic > Beats	Normal Paced Fusion of paced and normal Unclassifiable Left bundle branch block Right bundle branch block Bundle branch block Atrial premature Aberrated atrial premature	Nodal premature Supraventricular premature Premature ventricular contraction R-on-T premature ventricular contraction Fusion of ventricular and normal Atrial escape Nodal escape Supraventricular escape Ventricular escape
Hemodynamic > Blood Pressure	Systole Diastole	End diastolic pressure
Hemodynamic > ECG Complexes	QRS onset, peak, and end T-wave onset, peak, and end P-wave onset, peak, and end Q-wave peak S-wave peak	U-wave peak PQ junction J-point ST segment change T-wave change
Hemodynamic > Impedance	A-point B-point C-point	O-point X-point Y-point
Hemodynamic > Monophasic AP	Plateau	Upstroke
Hemodynamic > Other	Start of ventricular flutter Ventricular flutter wave End of ventricular flutter	Pacemaker artifact Isolated QRS-like artifact Non-conducted P wave
Notes	Arrow—short, medium, or long Flag	Star
Pharmacology	Baseline Dose	Wash
User-defined	User Type 1-9	
Waveform Edits	Cut Paste begin	Paste end
Selections	Selection begin	Selection end

Event Measurements

Measurements are a quick way to extract information from a graph. Three measurements extract information from events. When combined with the Cycle/Peak Detector (page 308), they are also powerful data reduction tools. These event measurements can provide quick summaries of event information, compute mean intervals between event types, and detail other operations.

- evt_ampl   Event Amplitude Measurement (see below)
- evt_count   Event Count Measurement (see page 218)
- evt_loc   Event Location Measurement (see page 218)

Event Amplitude Measurement



evt_amp   Extracts measurement results where events are defined. Note that the amplitude is always taken from the measurement channel, which may be different from the channel on which the events are defined. Useful for extracting information such as the average T wave height within the selected interval. The measurement result is displayed without units (matching Value and other amplitude events).

Select Event Amplitude or click the measurement info button to generate the settings dialog.

Event Type   Determines the type of events that will be processed; Types are detailed on page 215.

Location   Determines where the processed events need to be defined. The menu options are:

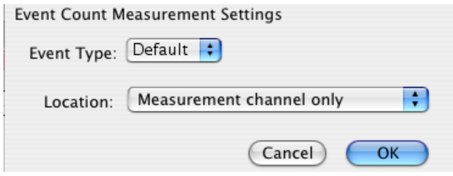
- Measurement channel only—Only extracts amplitude values for events that are defined on the channel specified in the measurement channel pull-down menu. Global events and other channel events are *not* included.
- Global events only—Only extracts amplitude values for events that are defined as global events appearing in the marker bar; changing the measurement channel will not affect the measurement result. Channel events are *not* included.
- Anywhere—Extracts amplitude values for events defined on any channel and also global events; changing the measurement channel will not affect the result

Extract   Determines what processing will be performed on the amplitude values extracted from events that match the Type and Location settings. The processing options are:

- Amplitude at first event only—The value of the measurement channel at the time of the first matching event in the selected area.
- Amplitude at last event only—The value of the measurement channel at the time of the final matching event in the selected area.
- Sum of amplitudes at all events—Computes the sum of the value of the measurement channel from each matching event within the selected area.
- Mean amplitude from all events—Computes the average amplitude value of the measurement channel from all of the event locations within the selected area.
- Minimum amplitude from all events
- Maximum amplitude from all events

If there are no matching events of the selected type in the selection, the measurement result will be zero.

Event Count Measurement



evt_count Evaluates the number of events within the selected area. The measurement result is unitless.

Select Event Count or click the measurement info button to generate the settings dialog.

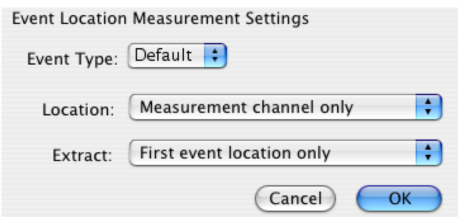
Event Type Determines the type of events that will be counted; Types are detailed on page 215.

Location Determines where the counted events need to be defined: the pull-down menu options are:

- Measurement channel only—Only includes events that are defined on the channel specified in the measurement channel pull-down menu; global events and other channel events are *not* included.
- Global events only—Only includes events that are defined as global events appearing in the marker bar; channel events are *not* included. Changing the measurement channel will not affect the measurement result.
- Anywhere—Includes events defined on any channel and also global events. Changing the measurement channel will not affect the measurement result.

If there are no matching events of the selected type in the selection, the measurement result will be zero.

Event Location Measurement



evt_loc Extracts information about the times of events. The measurement result will take on the units of the horizontal axis; if specific units were set for time or frequency via Preferences, those units will be used.

Select Event Location or click the measurement info button to generate the settings dialog.

Event Type Determines the type of events that will be processed; Types are detailed on page 215.

Location Determines where the processed events need to be defined. The menu options are:

- Measurement channel only—Only extracts the time of events that are defined on the channel specified in the measurement channel pull-down menu; global events and other channel events are *not* included.
- Global events only—Only extracts the time of events that are defined as global events appearing in the marker bar; channel events are *not* included. Changing the measurement channel will not affect the measurement result.
- Anywhere—Extracts the time of events defined on any channel and also global events. Changing the measurement channel will not affect the measurement result

Extract Determines what will be extracted from events that match the Type and Location settings:

- First event location only—The measurement will equal the time at which the first matching event in the selected area is defined.
- Last event location only—The measurement will equal the time at which the final event within the selected area is defined.
- Sum of all event locations—The times at which all matching events are defined are added together to produce the measurement result. This sum of times can be combined with Event Count measurements to compute average intervals over the selected area.

If there are no matching events of the selected type in the selection, the measurement result will be zero.

Printing Events

When a graph is printed and events are displayed onscreen for the graph, event icons will print as they are displayed. Event icons will be scaled, depending on the printer's DPI, to be proportional to the vertical scale plotted on the screen. If events are located at linearly interpolated positions, event icons will be dimmed on the printout (see the Variable Sample Rate section).

Event display setting	*Printed result*
Global events	Global events are drawn above and outside of the data plotting rectangle in the printout. If the event labels are close together, their alignment will be staggered to show separate lines of label text. (Acq*Knowledge* 4.2 and higher)

In event bar	All events are drawn above the data area of the printout. Only labels may be drawn with the events.
Top of plot *or* Top of plot, with indicator	Channel-specific events are drawn at the top edge of their channel's track. No indicator lines are drawn. Depending on the display settings of the graph, the event label, amplitude of waveform at the event location, and Time of the event may be printed *below* the event icon
On waveform *or* On waveform, with indicator	Channel-specific events are drawn immediately above the position of the waveform sample at their location and will appear to be printed immediately above the data of the waveform. No indicator lines are drawn. The vertical printing position of an event icon will be identical for "On waveform" and "On waveform, with indicator" displays. Depending on the display settings of the graph, the event label, amplitude of the waveform at the event location, and time of the event may be printed *above* the event icon.

"Draw vertical divider at event locations" option in the Print Setup dialog.

- Enabled: draws a dashed vertical line at the precise time location of each event. Vertical divider lines for the event type will extend

Global	Through all channels of data
In event bar	Through all channels of data
Top of plot	From the top to the bottom of the relevant channel track
On waveform	From the top to the bottom of the relevant channel track

- Disabled: prints only the event icon, label, amplitude, and time. No indicator lines will be printed for the event display. The vertical divider can be used in place of indicator line drawing.

Event Selection

Individual events can be selected according to click locations.

When an event is selected, the event icon will be drawn based on the graphic type:

- Specific "selected" graphic—the selected graphic is drawn or if none, an inverted global graphic.
- No associated graphics—the global event graphic will be used.

Events and Graph Selections

When an event on a waveform plot occurs within a selected area of the graph, the event icon and indicator line (if present) will be inverted along with the grid, background, and wavedata. Event types that don't have a selected graphic will appear as global events if the events are selected events and they are contained in an I-beam selection.

Events and Waveform Editing

Waveform editing will adjust event locations for channel-specific events. Waveform editing will never alter the time values for Global events (not associated with any specific channel, such as append events).

Copy When a portion of a waveform is copied the channel events will also be copied to the clipboard.

Cut When a portion of a waveform is cut, any channel events within that selected area will be removed and channel events to the right of the removed area will be shifted to the left.

- If waveform editing event insertion is active, a waveform edit event will be inserted at the location of the edit operation indicating a "Cut" operation in its description.

Paste When the waveform is pasted from the clipboard, the channel events will appear at their same locations and any channel events to the right of the end of the pasted segment will be shifted by the length of the pasted segment.

- If waveform event insertion is active, a waveform event marker will be inserted at the beginning and at the end of the pasted segment.

Constructing Graph Selections from Events

Graph selections can be defined from events (in addition to the I-beam tool). Holding down the Command/Open-Apple key while double-clicking an event icon in the graph window will place a cursor at the event location; this is a zero-width selection, equivalent to single-clicking with the I-beam tool without dragging.

- To create a graph selection from events, hold down the Command key and select an event by clicking on the event icon in the graph window or its entry in the event list.
- To align the boundaries of the graph selection with the time of the previously selected event location and the time of the newly selected event, hold the Command key when selecting the new event.
- To make a graph selection match the time between two events, clickce to select the first event, hold down the Command key, click again to select the second event. On this second click, the selected area of the graph will change to align with the two events.

Event Plotting and Variable Sampling Rate

Event positions are defined in terms of the hardware sampling rate. The Variable Sampling Rate feature can generate waveforms with a sampling rate lower than the hardware sampling rate. Through explicit event definition, waveform downsampling, or other operations, events on a downsampled channel may not align with an actual waveform sample, but rather occur at a hardware sample position in between waveform samples. These events will be drawn using linear interpolation when applicable, and only if the waveform is being drawn in line plot mode. In step plot and dot plot modes, regular event drawing routines will be used with the vertical position and amplitude of the nearest waveform sample to the event's left.

When an event is to be drawn on an intermediate position on a waveform, the linearly interpolated value will be calculated for the hardware sample location. The interpolated value will be derived from the closest waveform sample to the left and to the right. The vertical position on the waveform of the marker and indicator line will match the vertical position of the linearly interpolated sample amplitude. This will place it immediately above the line connecting the two waveform samples on screen.

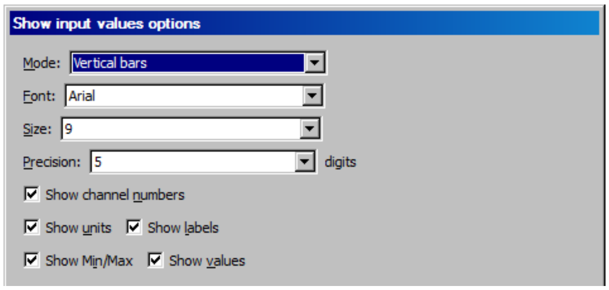
If an event is being drawn using linear interpolation

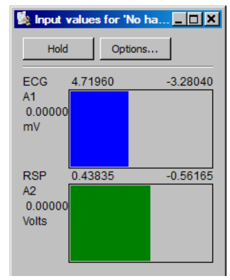
- Event icons will be dimmed, regardless of their display position (on waveform or top of the plot).
- Indicator lines will be drawn on the waveform at a linearly interpolated position and the indicator line will be a gray dashed line instead of a solid black line. (Indicator lines are never printed.)
- Amplitude labels, if included with the event, will correspond to the linearly interpolated amplitude at the event location and the linearly interpolated amplitude will be drawn in *italicized text*.

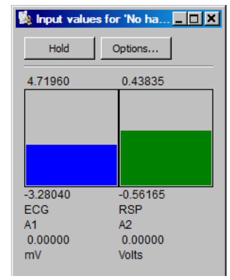
Chapter 12 Other MP menu Commands

BioHarness™ users should see the **BioHarness User Guide** *available under the Help menu and installed to the User Support folder in the program folder.*

Show Input Values







The Show Input Values option of the MP menu generates an Input Values window, which displays channel values in real time, whether an acquisition is in progress or not—which allows you to display values prior to or after an acquisition.

The Input Values display can be set to numeric, horizontal or vertical bar graph format, and it can be resized and moved to any position on the screen. To set the display mode, use the “Mode” menu generated via the “Options” button.

Note The Input Values window only displays values for channels that were Set Up with the “Values” box checked (see page 105 for more information).

Hold Regardless of the display options selected, the display can be “frozen” at any point in time by clicking the the Hold button. Clicking this icon will hold the values at their level(s) when the icon was pressed. The window will remain frozen until the icon is clicked again. Once the values are “unfrozen,” the values will return to the standard real time display mode.

Options **Mode** controls the format of the values display.

- Numeric Values—displays the voltages of the appropriate channels numerically.
- Bars: Horizontal bars or Vertical bars—the range of values of the bar graphs corresponds to the range for that channel in the graph window. To see the bar “bounce” less for a particular channel, increase the units per division; to fill more of the window space, decrease the units per division in the graph window.

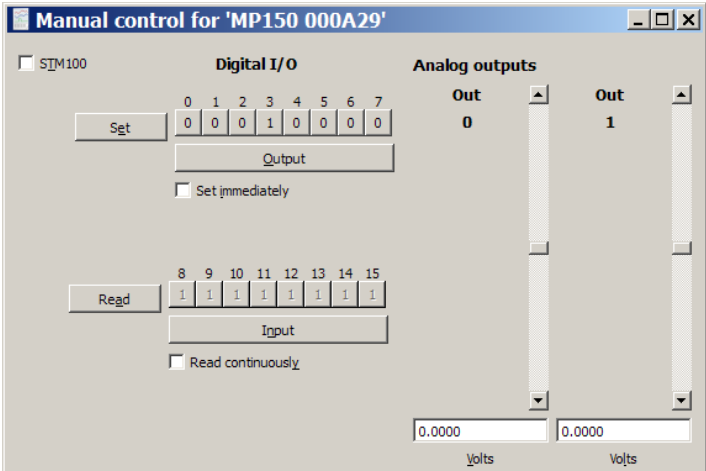
Font and **Size** determine text display from fonts installed on your computer

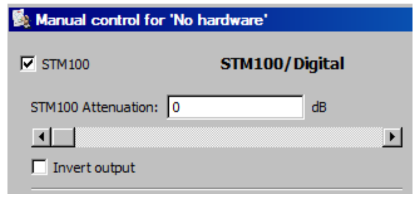
Precision controls *the total number of digits* displayed.

Show controls the amount and type of information displayed regarding each channel. Click in the box next to each option to activate it.

- **Channel Numbers** will display the channel numbers (A1 for the first analog channel, for example).
- **Units** will display the units for each channel (as indicated in the main graph window). By default, each channel’s display units are scaled in terms of Volts, but this can be changed by clicking in the amplitude scale units area in the graph window.
- **Labels** will display the channel labels (ECG 1, Respiration, etc.) along with the input values. This feature is especially useful when values from multiple channels are being displayed simultaneously.
- **Min/Max** will display the range of values associated with the data. This range corresponds to the upper and lower display limits for each channel as it appears in the graph window.
- **Values** will display number values along with the horizontal or vertical bar chart.

Manual Control





STM100 option

The Manual Control dialog allows you to monitor and/or output pulses through the digital input/output (I/O) channels, as well as manually set the magnitude of the signal on either of the analog output channels. The digital outputs in Manual Control cannot be used to trigger an online Averaging acquisition.

Stimulator Usage Note

Use Manual Control to specify the stimulation output level

a. If the wide range of waveform output options available in the Stimulator Setup dialog cannot match your specifications.
b. For pre-stimulation and post-stimulation.

See page 174 for important Analog Output details

The 16 digital channels are sectioned off into two blocks, with the first block consisting of I/O channels 0 through 7, and the second block consists of I/O 8 through 15.

- All the channels within a given block are programmed together and can be set as either inputs or outputs.
- The two blocks can be set independently.
  - In other words, the lower block can be set to input data while the upper block outputs data. You can set channels in the lower block to either read in data or do nothing (as opposed to outputting data) while channels in the upper block either output data or do nothing (as opposed to reading data).

To read incoming values for a given block of digital channels, click the Input button below the row of channels for which you wish to have input values displayed. This enables a block of digital channels to receive incoming data. To read the values for the entire block simultaneously, click the Read button to the left of the channel boxes for that block. Since these are digital channels, the values on the individual channel boxes will toggle between 0 and 1.

- When Acq*Knowledge* is launched, values for digital channels #0-7 always read "0" and #8-15 always read "1" to allow for compatibility with the STM100C module, which utilizes the lower eight digital lines for attenuation control.

When Read Continuously is enabled (below the Input button), the values will be read in real time. When unchecked, the displayed values correspond to the values for that block of channels as of the last time the Read button was depressed. This mode provides much the same information as the Show Input Values mode.

To output values for a given channel, the block containing that channel must first be enabled to output data. To do this, click the bar below the channel boxes so the button reads "Output." You can then program the individual channels within that block. These channels will toggle between 0 and 1, with a 0 corresponding to zero Volts and a 1 corresponding to + 5 Volts. To output a digital 1 on I/O channel 3, the dialog would be setup as shown above.

The function buttons toggle as follows:

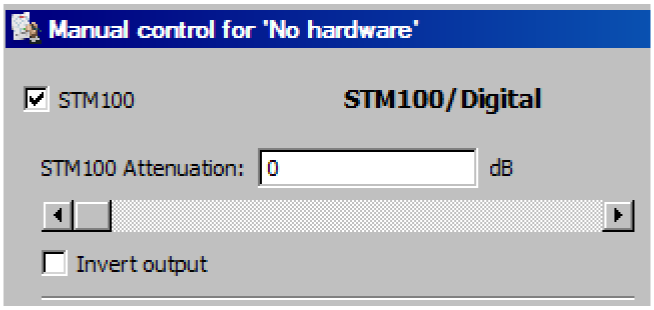
Input toggles to Output	When Input is selected, the checkbox is "Read continuously."
Set toggles to Read	When Output is selected, the checkbox is "Set immediately."

To output a signal on Channel 3, click the Set button to the left of the channel box. If the Set immediately box is checked, the signal will be output when the channel button is clicked.

IMPORTANT

Potential use conflicts can arise between the parameters set in the Manual Control window and those set for digital channels in the Set Up Channels window.

STM100 option



STM100 option

When the STM100C stimulator module is connected to an MP150 System, the output level can be controlled via the STM100 option of the Manual Control dialog.

Attenuation: Attenuate the output signal by a given number of decibels (dB) for controlled stimulus applications. To output a signal with no attenuation, simply set the "Stim 100 Attenuation" to 0 dB.

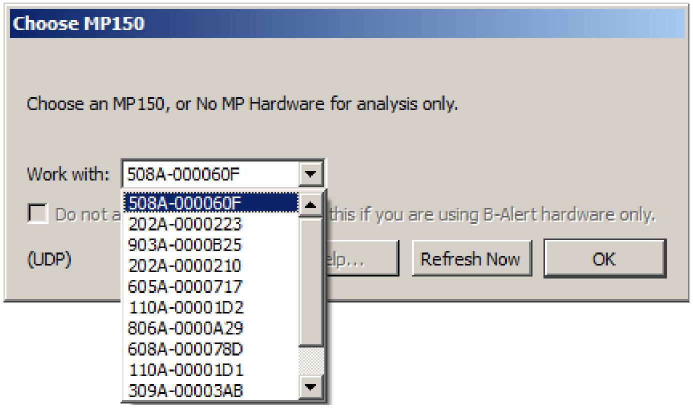
Manually outputting a value on a digital channel can stop an acquisition if data is being collected at very high speeds (greater than 10,000 samples per second aggregate).

Invert output: Check this box to invert the polarity of the signal output through the STM100C.

This function can also be achieved by flipping the polarity switch on the STM100C from positive (POS) to negative (NEG).

For more information on the STM100C stimulator output module, see the *BIOPAC MP Hardware Guide.pdf*.

Select MP150



The pull-down menu lists all MP150 units that are powered ON and sitting on the same local area network. The software can't determine the lock status until a user attempts to communicate directly to a MP150 unit—each MP150 unit needs to be tried to determine if it is locked or unlocked.

When "No MP Hardware mode" is selected, the menu of available MP150 units is grayed out and becomes unselectable.

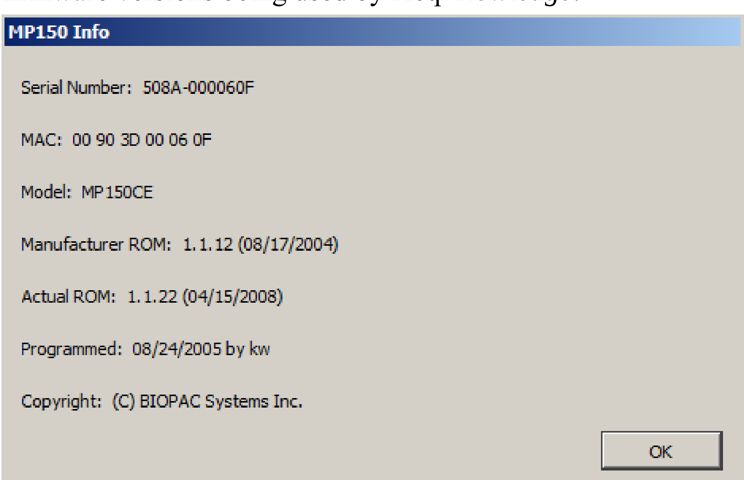
Enable "Do not ask me again" to hold your selection as the default.

The fact that MAC (Ethernet) addresses appear in the user's "Select MP150" dialog does not imply that the MP150 unit is, in fact, unlocked and available. If a user attempts to connect to a locked MP150, an error message will be generated to advise that the MP150 unit is locked to a different computer.

Acq*Knowledge* locks an MP150 as soon as it connects to it, which tells the MP150 to only respond to commands from that particular computer and the communication method (serial or Ethernet). The lock has a timeout which is reset every time the MP150 unit receives a command from the computer that locked it. To locate MP150s in the local network, Acq*Knowledge* sends a broadcast packet to the local area network that asks all the MP150s in the network to respond. All the MP150s—whether locked or unlocked—will respond to this prompt. This means that the "Select MP150" menu may allow a user to select an MP150 that is locked. In such cases, Acq*Knowledge* will fail to connect (to a locked MP150 unit, as expected). To resolve this issue, unlock or power cycle the MP150 unit. See Locking/Unlocking the MP150 (Appendix E—page 476) for more details.

MP150 Info

Select MP150 Info from the MP150 menu to generate a dialog with information about the software and firmware versions being used by Acq*Knowledge*:



Manufacturer ROM is the the factory-installed firmware version; check this before you "Reset" the MP150 unit for a Firmware Rollback (see page 478).

- Factory-installed Firmware version 1.1.2 or previous (purchased approximately November 2002 or before) may not reset to a level compatible with UDP communication. In such cases, you will need to install Acq*Knowledge* 3.7.2 or previous (non-UDP) and update to UDP in stages; contact BIOPAC for additional support.

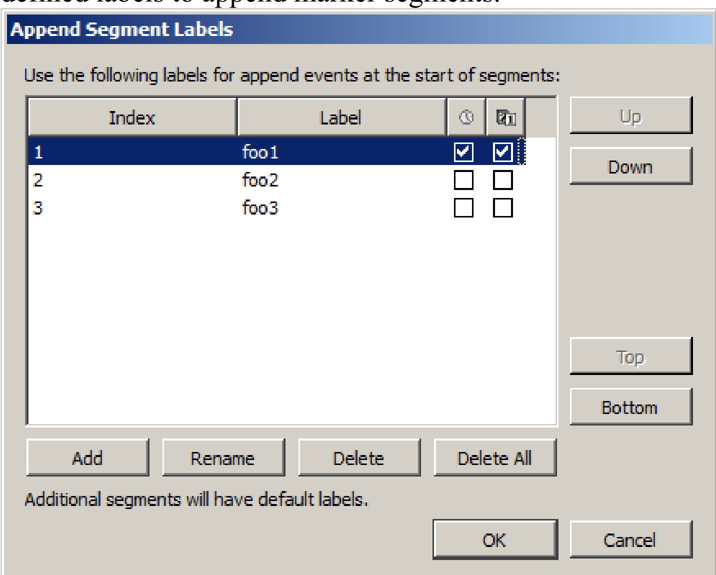
Note: For information about Acq*Knowledge* software, click Help > About Acq*Knowledge*.

Update Firmware

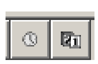
This menu item is is used to upload MPB firmware files provided to you by a BIOPAC support technician. Unless a firmware warning is diplayed at application launch, your MP150 already has the latest firmware revision and no further action is necessary. If a firmware warning is displayed, contact BIOPAC technical support for more information.

Segment Labels

Selecting Set Up Segment Labels from the MP menu launches a setup dialog enabling assignment of user-defined labels to append marker segments.



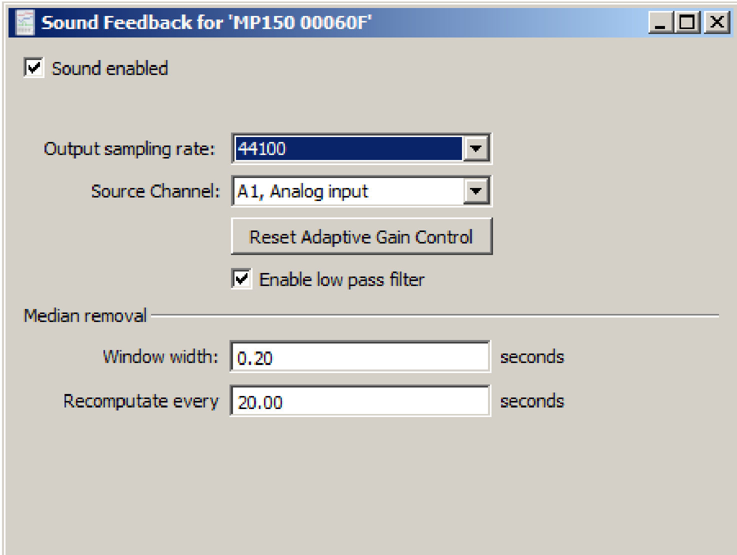
- Add	Adds a segment number to index. Segment text can be edited under ‘Label’.
- Rename	Used to rename an existing segment label.
- Delete	Deletes a selected segment from Index.
- Delete All	Deletes all segments from Index.
- Up/Down	Incrementally moves a selected segment up or down the Index.
- Top/Bottom	Moves selected segment to top or bottom of Index.

Enabling checkboxes below the  icons adds time/date stamps to the segment label.

NOTE: Set Up Segment Labels option is available in Acq*Knowledge* 4.2 and higher only.

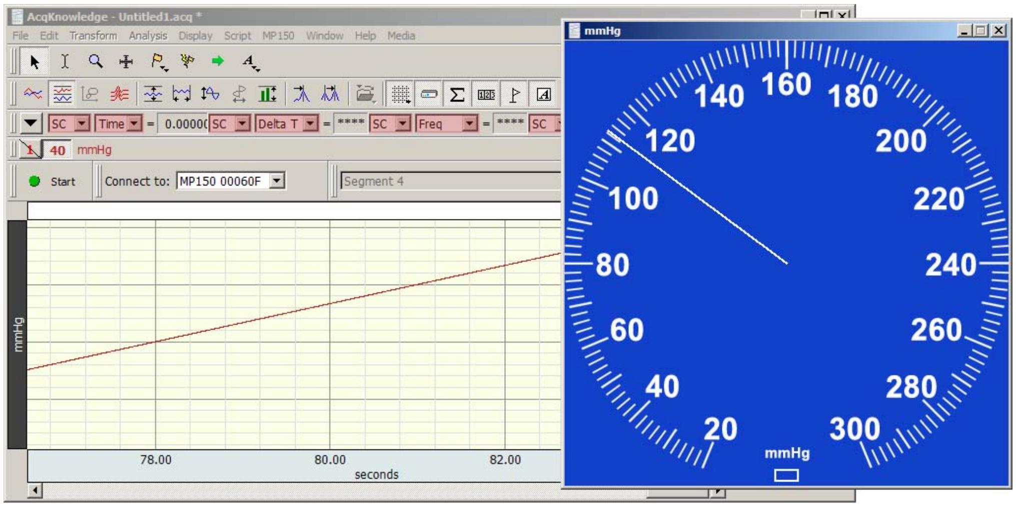
Sound Feedback

Set Up Sound Feedback generates a setup enabling acquired data to be redirected to the computer's default audio output device. This feature can be used to monitor waveform data as sound through the computer speakers or headphones. (Acq*Knowledge* 4.2 and higher only)



SOUND FEEDBACK CONTROLS	FUNCTIONS
Sound enabled	Turns sound feedback of data on and off.
Output Sampling Rate	Selects from available sampling rates of the default audio device.
Source Channel	Selects the analog, digital or calculation channel from which the audio will be acquired.
Reset Adaptive Gain Control	Resets gain control to adapt to the current level of the signal. Use after sound feedback has started to re-adjust the level after accidental spikes or large artifacts.
Enable low pass filter	Applies a low pass filter at the Nyquist frequency (50% of the acquisition sampling rate). This IIR filter can help smooth out transition artifacts due to upsampling of data to the audio sampling rate. (Enabled by default)
Median removal controls (Window width, Recomputate)	Removes baseline offset from the output signal.
Window width	Sets width of median removal window (in seconds). Must be a positive value.
Recomputate every	Provides the time duration (in seconds) after which the median of the data is regenerated from the raw source data. Must be a positive value.

Gauge



The Gauge is accessed via MP150/MP36 > Show Gauge. The optional "Gauge" display shows one channel of data in a gauge/dial indicator format.

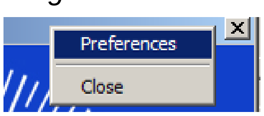
The Gauge displays as a separate window, viewed simultaneously with graph and other windows.

NOTE: The Gauge feature is available in Acq*Knowledge* 4.2 and higher only.

The Gauge window:

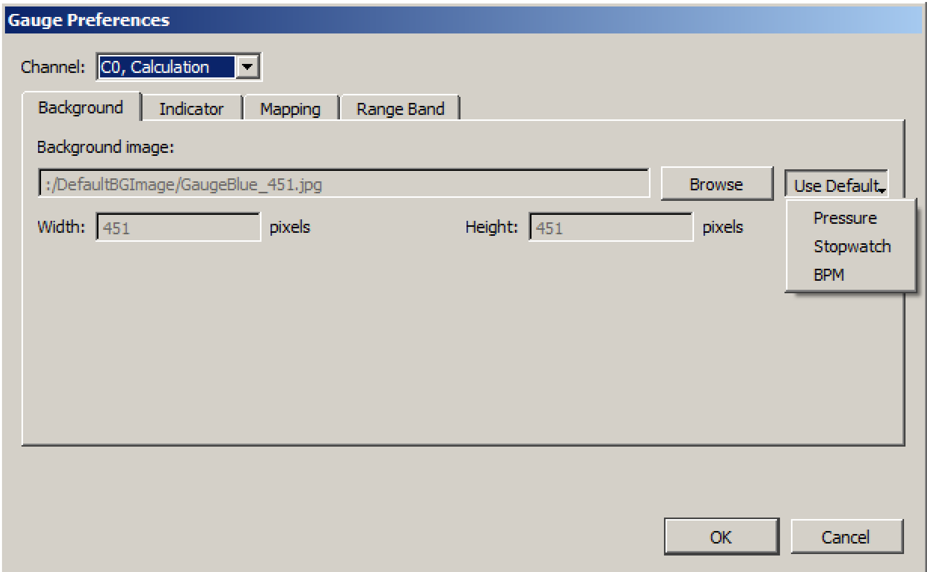
- Will display one channel of data: (analog or calculation)
- Updates and displays simultaneously with the graph window. For analog channels only, the display will update when the recording is stopped, but at a slower rate when recording is running.
- Can update during and in between acquisitions for all MP devices; display may be updated at a rate slower than the sample rate and may display a value that represents the average of several samples.
- The background image (BMP, JPG or TIFF), indicator origin, range, length, thickness and color are all user-configurable. An optional range band overlay can also be enabled.
- Selectable gauge bitmaps include Blood Pressure Cuff, BPM or Stopwatch
- All window preferences as well as the window visibility, size and position will be saved with the file.
- Window sizing is "fixed" to the size of the background image, meaning it will have a 1 to 1 correspondence with the monitor pixels

Gauge Preferences



Gauge Preferences are accessed by right-clicking over the gauge and using the contextual menu. There are four tabs for setting the various Gauge parameters.

Background is the default tab presented in Gauge Preferences and contains options for setting the Background image.



Channel Provides a pop-up menu for assigning any one of the ENABLED analog or calculation channels.

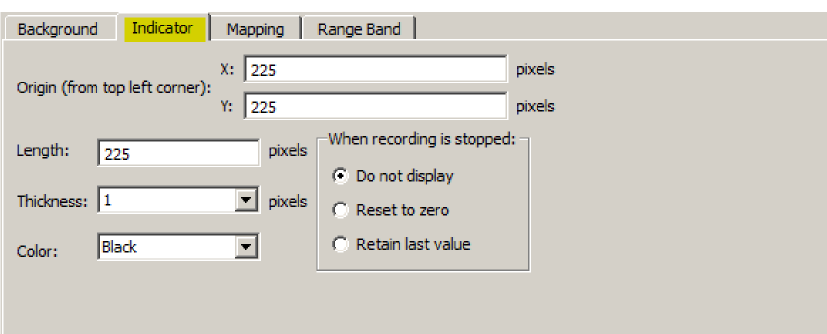
Background Image Displays the path and file name of the current background image. The default image is a blue blood pressure gauge sized at 451 x 451 pixels.

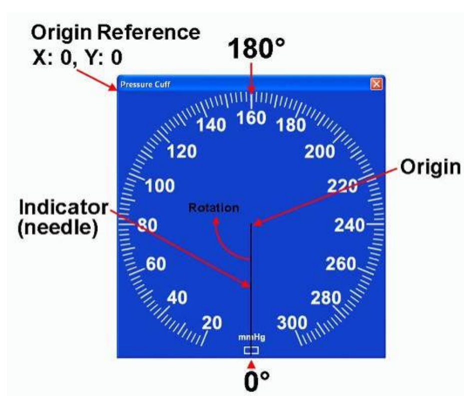
Browse Allows alternative background images in different directories to be used in place of the default gauges. The Browse location will default to the file path used by the currently selected background image. To change the background image, click the “Browse” button and locate the desired file. After the background image is specified, the pixel **Width** and **Height** will be updated. The **Width** and **Height** fields are not editable.

Use Default Displays a menu of available default background images. **(Pressure, Stopwatch and BPM**).

Indicator

The “indicator” or “needle” is a simple line vector drawn from an assigned center point to an endpoint calculated according to the “Length” parameter. The indicator always rotates around the origin from low to high values in a “**clockwise**” fashion.





Origin Is the center point of the indicator line referenced from the top left of the image not the top left of the window meaning neither the frame of window nor the title bar is included. The “X” parameter specifies the horizontal distance in pixels and the “Y” parameter the vertical distance. “X” cannot exceed the Width of the background image and “Y” cannot exceed the image Height. The *default* values are: Origin: X: Width/2, Y: Height/2. **Note that the pixel count starts at “0” so a 225 pixel square image will have its center point at 112 pixels.**

Length Specifies indicator span in pixels starting from the “Origin”. Default is the smallest of the Length or Width dimensions divided by 2.

Thickness Specifies the indicator width in pixels, with a selectable range between 1 and 10. The default is 1 pixel.

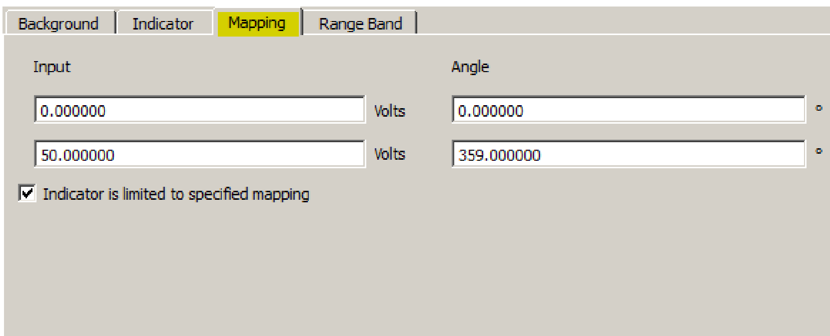
Color Specifies color of the indicator “needle” as Black (default) or White.

When recording is stopped

If the source channel is a Calculation channel, no gauge updating will occur when the recording is stopped. Under this circumstance, the “When recording is stopped” options become available. This allows the user to specify whether the indicator should not be displayed, should be reset to zero, or should retain the last value.

Mapping

For setting up two point mapping: Input to Angle



Input Defines the input values in the scaled units. The units shown in the example are volts, but would reflect the units of the source channel (mmHg, psi, etc.). The Input mapping of the upper scale value is set to a default of 50 of the source channel unit type.

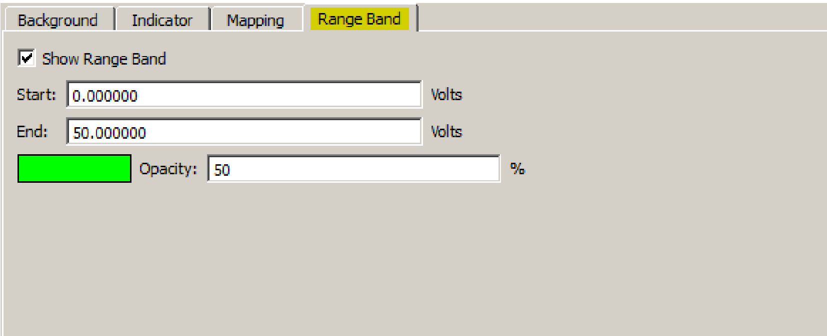
Angle Any angle can be entered, but 0, 360, 720, etc degrees means that the indicator will always be pointing straight down.

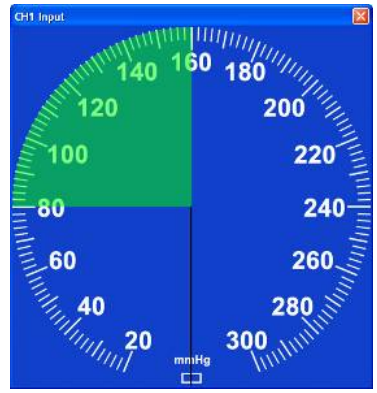
When assigning mapping angles: Because the indicator “needle” must rotate clockwise, the first value should be the lower angle. The first value also defines the indicator’s starting angle but does not to need to be 0 degrees. For example, the Stopwatch Gauge’s starting angle should be 180 degrees (pointing straight up). If half-circle gauges are used, the starting angle may be 90 degrees.

Indicator is limited to specific mapping

If this option is enabled, and the indicator needle reaches its mapped upper limit, it will stop rotating and turn red. If this preference is not selected, the needle will not change color if the defined mapping limits are exceeded and the needle will just continue in a clockwise rotation.

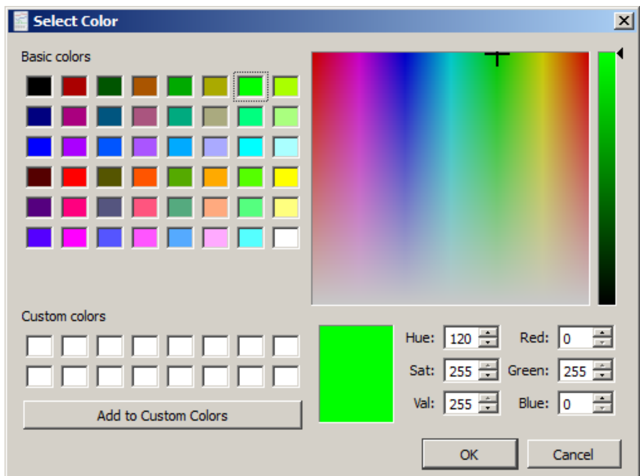
Range Band (Default OFF)
Use the Range Band as an optional feature to highlight a specified area of the Gauge View.





Start/End Defines a “pie” shape (defined by Mapping values) sourced from Gauge center and superimposed over the background image.

Color Clicking on the color bar will bring up the following palette, which allows any color to be selected. The default color is green.



Opacity Used to adjust the transparency of the Range Band. 100% means the background image will be fully obscured behind the range band, and 0% means the Range Band itself will not be visible. The default setting is 50%.

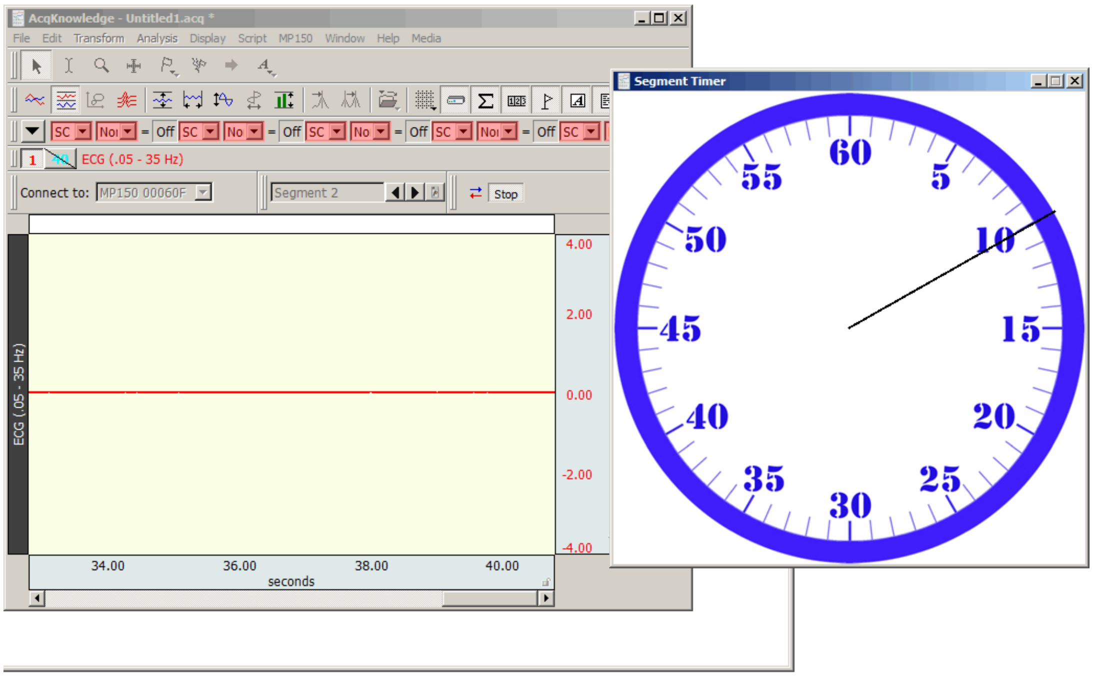
Segment Timer “Stopwatch” option

(Available in Acq*Knowledge* 4.2 and higher only)
In addition to the standard Gauge described above, the Segment Timer Gauge option offers an analog “Stopwatch” view of an acquisition in progress. As the recording progresses, a circular onscreen stopwatch gauge displays the elapsed time with a sweep-second indicator. All customizable parameters shown above for the default Gauge view are applicable to the Stopwatch view. A custom mapping for the Stopwatch view can be created, or use the pre-configured “Segment Timer Gauge” graph template in the Sample Data folder.

Using the Segment Timer graph template – open the sample template in the following directory:

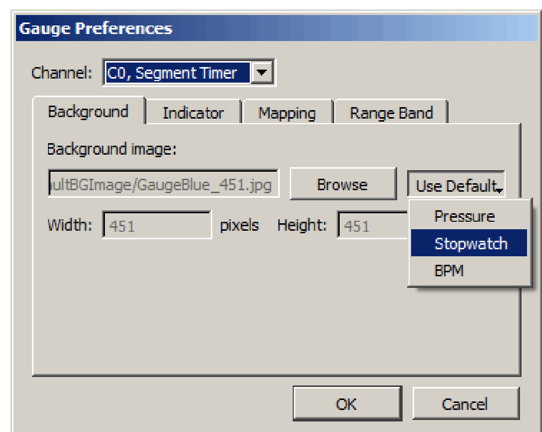
Main drive\Program Data\Biopac Systems, Inc\AcqKnowledge 4.2\Sample Data\Segment Timer Gauge.gtl

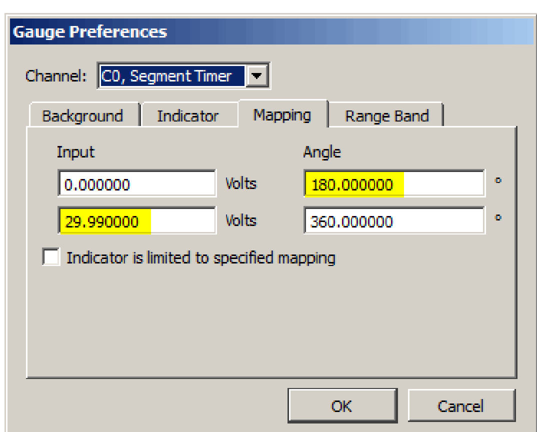
Clicking ‘Start’ will show the Stopwatch in progress. The template is setup to record ECG Lead II on CH 1 and is tied to a new Segment Timer calculation channel. However, no connections are needed to verify the segment timer and the template can be customized as desired. To change parameters, choose Preferences from right contextual menu with mouse positioned over the gauge window. When the recording is stopped, timer indicator will also stop. When the next recording segment begins, the segment timer will reset to 0. (This default can be changed in the Gauge Preferences).



To configure a new Segment Timer Stopwatch view:

1. Set up desired acquisition parameters and channels.
2. MP menu > Set Up Channels > Calculation tab and choose the Segment Timer preset.
3. MP menu > Show Gauge and open Preferences by right-clicking the contextual menu over the Gauge window.
4. In the Gauge Preferences, choose “C0 – Segment Timer” for the Channel and “Stopwatch”, as shown on right.
5. Choose the “Mapping” tab, enter the following Input to Angle mapping values and click **OK**:





6. Start the acquisition. Note the Stopwatch view will accurately reflect the time scale of the recording in progress.

MP36R support

NEW! MP36R is a four channel data acquisition unit designed to work with Acq*Knowledge* for the research market. Acq*Knowledge* 4.1 support for the MP36R unit includes:

- Standard data acquisition and data acquisition features (triggering, multiple channels, variable sampling rate, input values)
- Output control functionality for controlling stimulators, digital channel, and channel redirection to output
- Standard analog presets for all SS series transducers
- Electrode Check support
- Multiple-MP device support. Similar to multiple MP150 support, each graph may acquire from a maximum of one unique MP device.
- Control channel support for changing digital output lines based on calculation channel analysis

Note Acq*Knowledge* software does not support MP36 units from the Biopac Student Lab product line (without the "R" suffix for research systems).

Autoplot

Scroll

Both Autoplot and Scroll control how data appears on the screen. By default, Acq*Knowledge* displays the most recently collected data first, and if more than one screen of data is to be collected, then the time scale will "scroll" so that the newest data is always on the right edge of the screen.

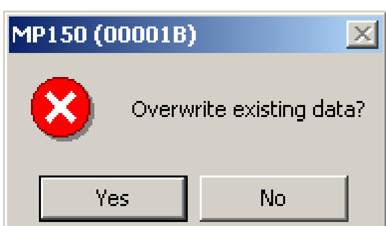
When Scroll is deselected and Autoplot is checked, the screen will be cleared when the data reaches the right edge of the screen, and plotting continues from the left again.

When both Scroll and Autoplot are unchecked, the incoming data will be plotted until the screen is full. Once the screen is full, data will continue to be collected, but only the first screen is displayed. By default, the MP will display the first eight seconds of the data record, but this can be reset manually by changing the horizontal scale. To toggle Autoplot ON or OFF in the middle of an acquisition:

- select Ctrl+T (Winodws) or Command+T (Mac OS X) on the keyboard, or
- pull down the MP150 menu and choose "Autoplot" ON or OFF

Warn on Overwrite

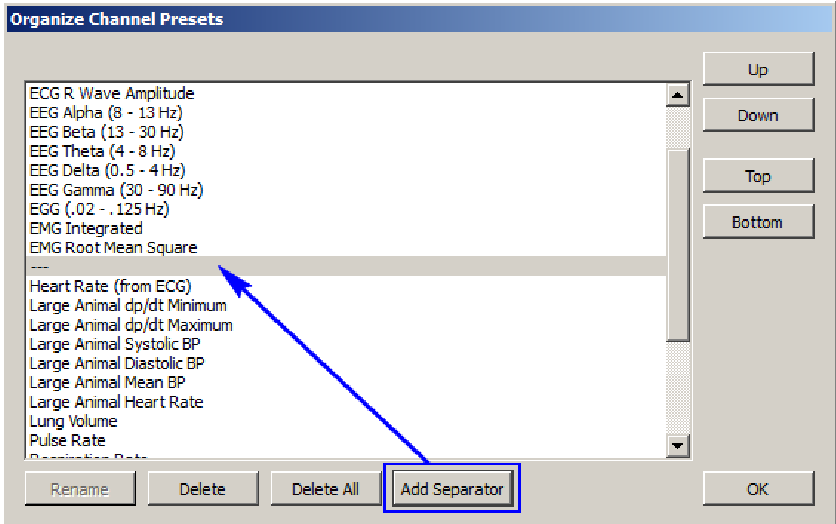
Selecting the "Warn on overwrite" option from the MP150 menu will generate a prompt each time you start a new acquisition:



If you click "Yes," then Acq*Knowledge* will erase your current file and overwrite with a new acquisition. If you don't want to erase the file you're working in, click "No" and then open up a new file to work in.

This prompt will appear at the beginning of each acquisition when the MP System is in Repeating/Autosave mode, so you will probably want to uncheck the "Warn on Overwrite" under the MP150 menu.

Organize Channel Presets



The Organize Channel Presets option controls the channel presets (established or new) in the MP 150 > Set Up Channels dialog; you can rename, rearrange or delete Presets. You might use this option to place the most frequently selected Presets at the top of the menu or group related Presets, such as established ECG Presets and new channel Presets you've created.

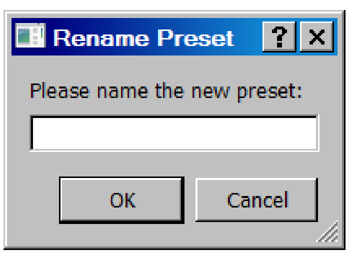
Click a Preset description to select it, and then use the buttons to organize the Presets.

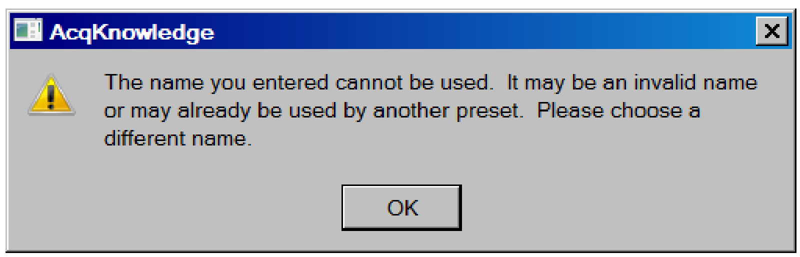
Up and **Down** buttons move the selection one space at a time.

Top and **Bottom** buttons jump to the start or end of the list.

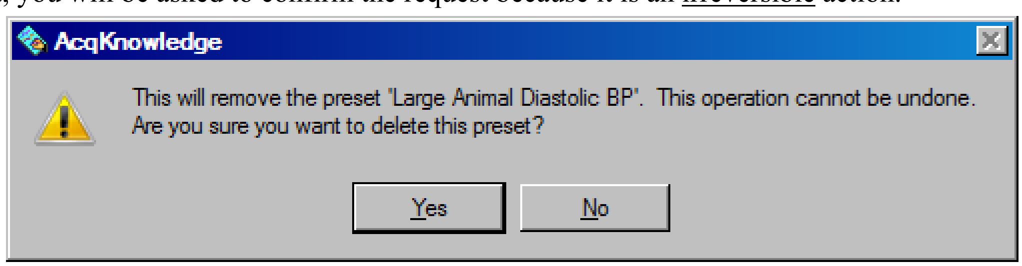
Rename a Preset by typing in a new description and clicking OK.

You can't use any name currently used by a Preset or any name that matches a Calculation type (Integrate, Rate, etc.).





Delete a Preset by selecting that option. You cannot delete the Default Analog Input preset. When you delete a Preset, you will be asked to confirm the request because it is an irreversible action.



Add Separator adds a new Separator entry to the Preset list and is useful for dividing different Preset types. If a Preset is currently selected in the list, the Separator will be added below it. (See diagram above) If no preset is selected, the separator will be added to the end of the list. Separators can be rearranged or deleted in the same manner as Presets. (Acq*Knowledge* 4.2 and higher only)

The default location for Preset files is Computer > Local Disk > ProgramData > BIOPAC Systems, Inc > AcqKnowledge 4.2 > Presets.

Check for Hardware

This MP menu option becomes active when the application is launched in “No Hardware” mode. This feature enables quick connection to available supported hardware types. (Acq*Knowledge* 4.2 and higher)

Exit Playback Mode

This option is enabled when Open File for Playback (see page 44) has been selected. Select to resume acquisition functionality (change Playback menu to MP150 menu, Replay button to Start button).

Part C—Analysis Functions

OVERVIEW

This part describes how to analyze data; in most cases, analysis is performed after the data has been collected. This involves creating, managing, and saving files, as well as editing data, performing mathematical transformations, and displaying data in various ways. Many of the functions covered here are also discussed in *Part A—Getting Started*. Features that can be computed during an acquisition (primarily transformations and calculations) are discussed in *Part B—Acquisition Functions*.

For general information about sections of the graph window, and to become familiar with the "look and feel" of Acq*Knowledge*, turn to the *Editing and Analysis Features* chapter. Descriptions of functions can be found in the chapters describing each menu. All of the commands discussed here can be found under the File, Edit, Transform, or Display menu items.

Menu	See…	Type of Commands
File	Page 236	General file management commands, including opening, saving, and closing files. Export data files.
Edit	Page 256	Cut, copy, and paste between and within files. Export data files.
Transform	Page 265	Operations that primarily modify the data in the graph.
Analysis	Page 296	Operations that primarily derive data and measurements from the graph.
Specialized Analysis	Page 331	A courtesy copy of the new *Specialized Analysis* package with automation and scoring routines.is included under the Analysis menu.
Display	Page 403	Control how data appears on the screen either during or after an acquisition.
Media	Page 431	Capture and Playback controls to synchronize video/audio with data.

Toolbars

Many of the most commonly used features in Acq*Knowledge* can easily be executed with a mouse click. The toolbar contains shortcuts for some of the most frequently used Acq*Knowledge* commands; icons are grayed out when they are not applicable.

Click Display > Show > Tool Bar to view the icons. Click an icon to activate it.

See page 55 for Toolbar icon definitions.

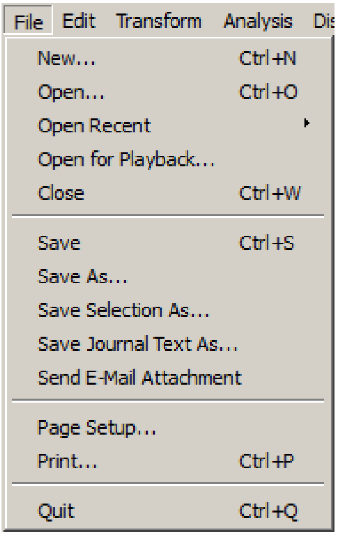
Shortcuts

Keyboard shortcuts are detailed on page 64.

Mouse shortcuts are detailed on page 68, including contextual menus.

Chapter 13 File Menu Commands

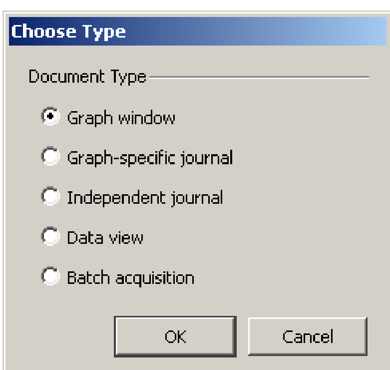
Overview



Most of the items in the File menu are standard menu items and follow the standard Windows conventions (for MPWSW) or Macintosh conventions (for MPWS). By default, all files are created and saved in the Acq*Knowledge* file format, a proprietary format used to store binary data. Data can be read in from either text files or Acq*Knowledge* files, and can be saved in text, graphic, or binary format. As a rule, storing data in the Acq*Knowledge* format saves information in the most compact format possible and takes up less disk space than other file formats. In most cases, you will probably be working with graph windows and saving data in the Acq*Knowledge* format.

Acq*Knowledge* also supports an online journal that can be used to store waveform data (in numeric format) or to make notations and comments in a text file.

New



Graph Window

In almost all cases, you will need to create a new graph window before beginning an acquisition so that the data may be displayed on the screen. When a new graph window is created, you can modify any of the window parameters, including horizontal scale, vertical scale, window size and position. In addition, you can also set the acquisition parameters for sampling rate, number of channels, and acquisition length. These settings take effect once an acquisition begins.

New > Graph-specific Journal

Creates a graph-specific journal; see page 52 for details.

New > Independent Journal

Creates an independent journal; see page 52 for details.

New > Data View

Creates a new Data View for the active (frontmost) graph, and names the new window “Data View of ‘Filename’”. 

. For Data View details, see page 45.

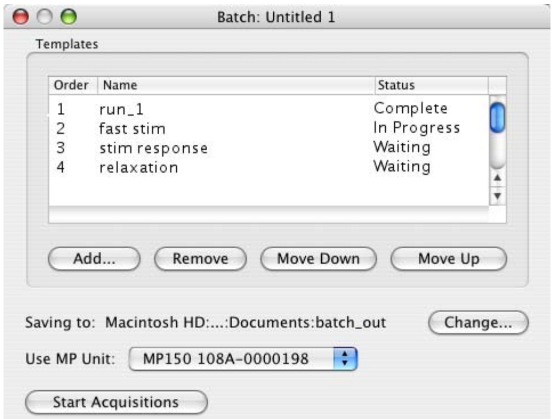
New > Batch Acquisition

Use the Batch Acquisition feature to configure advanced experimental setups and acquire data from a sequence of templates. Each template in the Batch may have different acquisition settings, channel configurations, and stimulator setups. Use a Batch for long duration experiments with hardware setting changes across segments, to automate routines, or to run multiple experiments on the same experimental setup in succession.

- For example, if an experiment has a preparatory period, a stimulus period, and a response period, three graph templates could be batched:
  - A template to acquire for the length of the preparatory period
  - A second template with a stimulator configured for the stimulus period
  - A third template to acquire the response period without stimulation

All three templates could be added in sequence to a single Batch Acquisition, which would then acquire all of the data for all three templates with a single start.

To create a new batch, choose File > New > Batch Acquisition to generate the Batch dialog.



The Templates controls at the top allow you to add, remove, or re-order the templates.

- Double click a template in the list to open the output graph from the most recent acquisition.
- Batch acquisition cannot combine acquisitions that do not end, so the acquisition storage mode for template files cannot be set to "Save last," "Autosave"or "Repeat forever."

Status	
N/A	No status is available for the template, no batch acquisition has been performed.
In Progress	Data is currently being acquired for the template.
Waiting	A batch acquisition is in progress but has not yet reached the step where the template is used.
Complete	Data acquisition for the template has been finished successfully and has been saved to disk at the batch output location.
Error	A batch acquisition was aborted manually or due to communication errors. The data for the template may not have been saved or may be unreliable.

Batch Errors

Misconfigured templates and misconfigured averaging templates may generate the Adjust Length/Adjust Latency/Abort Acq warning prior to the start of acquisition. Clicking "Abort" will halt the batch acquisition. Misconfigured templates may result in those rare cases where data was acquired into a graph template with a different hardware configuration prior to saving the template to disk.

Saving to:

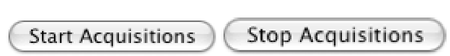
Use the "Change" button to specify the directory where the acquisition output should be saved.

Use MP Unit:

Specify the MP150 unit that should be used for the Batch Acquisition.

This menu lists all of the available hardware units. Entire menu dimmed out while batch acquisitions are in progress.

Start/Stop Acquisitions

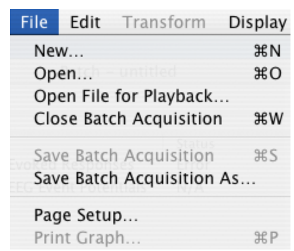


Toggles to starts and stop batch acquisitions; dimmed when the specified MP150 unit is being used to acquire data unless it is a batch acquisition that is in progress. Batch acquisitions may be terminated by using either a control in the batch user interface or by clicking the "Stop" button in the graph window actively acquiring data for the current template of the batch. During the execution of an individual template acquisition, errors may occur that abnormally terminate that acquisition (i.e., communications errors with the MP150 unit, errors in calculation channel, disk errors, etc.). When the acquisition in progress is terminated due to an error, the batch acquisition will be halted as well.

- If a batch acquisition is aborted early, the batch output directory will contain the full result graphs for all of the templates that were previously completed successfully. It will also contain a partial graph file for the template that was being used at the time the acquisition was aborted. Templates that were not used will not have any associated graph files.

Resume

When a batch acquisition is terminated prematurely, the acquisition may be restarted from the first template in the sequence or from where it was stopped (e.g. the template with the error status).



Batch Acquisitions can be saved for use at a later time using File > Save Batch Acquisition As. Batch Acquisition files retain all of the settings for their individual templates and can be used even if the original templates used to configure the batch no longer exist or have been moved. Each template is acquired and saved into an output graph file that can be opened at a later point in time to examine the results.

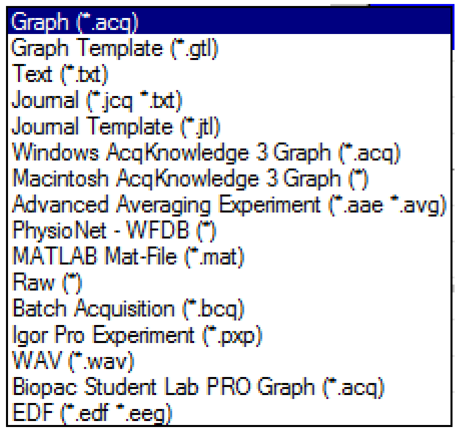
To open a Batch Acquisition, use File > Open and select type “Batch Acquisition.”

When a batch acquisition is started, the templates will be executed in the order indicated in the batch to acquire data from the specified MP150 unit. Files are autosaved before the next acquisition is started.

- If the batch acquisition completes successfully, the batch output directory will contain all of the graph files that were created during the acquisition. Each output graph is saved into a user-specified directory and is titled “Batch *n* - template name” where *n* is the order in the acquisition sequence.

Open

The File > Open command generates the standard file open menu, and allows you to open a variety of different file formats from the popup menu at the bottom of the dialog.



Multiple files

To open multiple files in a single dialog, hold the Shift key down and select multiple files. The Command-A key combination will “Select All” files in the dialog. Acq*Knowledge* can only recognize one Journal file at a time, so multiple selection is disabled when the file type is set to Journal or Journal Template.

Graph The default file formats (*.acq) is referred to as “Acq*Knowledge*” files. The Acq*Knowledge* file format is the standard way of displaying waveforms in Acq*Knowledge*. These files are stored in a compact format that retains information about how the data was collected (i.e., for how long and at what rate) and takes relatively little time to read in (compared to text files, for instance). Acq*Knowledge* files are editable and can be modified and saved, or exported to other formats using the Save as command. Format options for the graph file include

- **Graph**—Acq*Knowledge* 4
- **Windows Acq*Knowledge* 3 Graph**—previous release format
- **Macintosh Acq*Knowledge* 3**—previous release format
- **Biopac Student Lab *PRO* Graph**—import files created using the Biopac Student Lab *PRO* software; to open BSL Lesson files (.ldd), manually add the extension “.acq” to the end of the file.
  BSL File Import Notes

  BIOPAC produces two different software lines, the Acq*Knowledge* software for research and the BSL software for higher education. These two applications use different file formats, making it difficult to analyze data recorded in one with the other.

  Acq*Knowledge* can directly import data files that were created in Biopac Student Lab *PRO*. This allows data acquired with an MP36, MP35 or MP30 to be analyzed using the advanced analysis routines of Acq*Knowledge*.

  Hardware and calculation channel settings are also imported. This allows for the migration of some BSL *PRO* templates to Acq*Knowledge*. Only basic analog, digital, and calculation channels can be acquired; templates that use any of the BSLSTM or other output options are not supported.

  Importing is limited to graph files created with BSL 3.6.6 or higher. It is not possible to import files created with earlier versions of BSL. To import from earlier BSL versions, those files must first be opened with BSL 3.6.6 or higher and re-saved to disk to update the file format. The updated files can then be imported directly into Acq*Knowledge*.

When saving files, Acq*Knowledge* must save using the Acq*Knowledge* graph file format or another available export format. It is not possible to open Acq*Knowledge* graph files with BSL Lessons or BSL *PRO*.

Template Graph Template files (*.GTL)

This powerful feature allows for creation of a template file with predefined experiment parameters. Simply click "Start" to run the experiment.

The Graph Template option allows you to open a copy of a master file so you can maintain the master settings. Graph template files open to previously saved setup parameters (as established under the MP150 menu) primary graph window size.

This feature can be especially useful for recreating protocols in the laboratory. You can Set Up an experiment and save it as a Graph template, then simply open the Graph template file and click the Start button to acquire data under the same settings.

When a Graph template file is opened:

NOTE

a) The graph window will not contain any data. (Since no data is saved in the template, arbitrary waveform output setups, which require a source date file, will not function in a template.)
b) The journal window will contain text you entered and saved with the template—this is a handy way for you to place instructions or information about the experiment for yourself or others.

Acq*Knowledge* "***Quick Start***" (*.gtl graph template) files are available for over 40 applications. Just open the graph template file to establish appropriate settings for the selected application, and then click Start. ***Quick Start*** files were installed to the Sample Data folder and can be used to establish the settings required for a particular application or as a good starting point for customized applications.

Text *.TXT*. Text files are a convenient way of transferring information between applications, and most spreadsheet and statistics programs are capable of importing or exporting data in a text file format. Acq*Knowledge* assumes that the text file contains numeric data laid out in columns and rows, and that there is some delimiter between each column. It also assumes that each column represents a distinct variable or channel of data. Normally, the values in each row represent the state of each variable at different points in time. When a text file is opened, the numeric values will be plotted as waveform data in a standard graph window and non-numeric values will be ignored. Each column of data is read in as a separate channel.

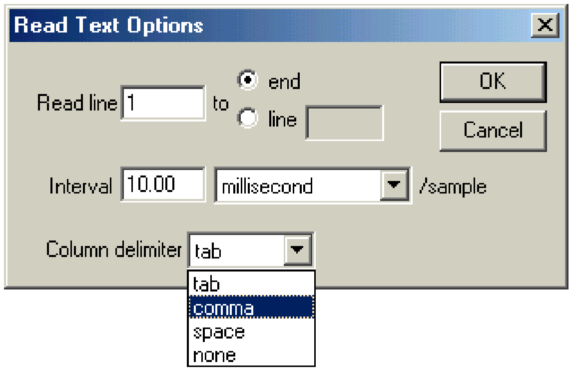
Journal **.JCQ*—Opens an independent journal; see page 52 for details.

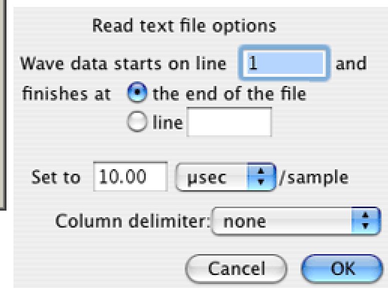
Open the journal file from the File Menu (File > Open > Journal); right-clicking or double-clicking a saved Journal file will open a blank application window.

Jrnl Temp **.JTL*—Opens a journal template; see page 52 for details.

Options

When the Files of type: Text option is select, an Options button is activated. Clicking on this button generates another dialog that allows you to control the amount and type of data to be read in, as well as the time scale for data display.





Read Line

To control how much data is read in, enter a value in the read line box at the top of the dialog. This tells Acq*Knowledge* which row contains the first data point in the series. By default, this is set to 1, although you may want to set it to another value since some applications (usually spreadsheets) generate a “header,” or text information at the top of a file. You can also read in a limited amount of data by entering a value in the box to the right of the line box. This value indicates the last line to be read in as data. By default, text files will be read in starting at line one and data will continue being read in until the end of the file is reached.

Interval

To control the horizontal scale (usually time) for the text file after it is displayed in the graph window, change the Interval between sample points, which can be expressed either in terms of time or frequency. For example, if data was collected at 50 samples per second, there is an interval between sample points of 0.02 seconds. Acq*Knowledge* would then assume that there is a 0.02 second “gap” between the data point in row two and the data point in row three (and all subsequent pairs of adjacent rows). Likewise, if you have a data file that spans 10 seconds and has 100 rows of data, the interval between sample points will be 0.01 seconds.

Most files contain time domain data, although some applications generate frequency domain data (the results of a spectral analysis, for example). The principle here is the same as with time data, that there is some interval between different frequencies. If a text file contains 20 sample points covering the range between 0 and 60 Hz, then the interval would be set to 3Hz per sample.

Column Delimiter

This setting tells Acq*Knowledge* what characters indicate a “gap” between two columns. This can be set to tab, comma, or space. All text files must have some sort of column delimiter, unless there is only one channel of data present.

- Tab delimited text files —the most common type— have a tab between each column for every row of data. These files are most often generated by spreadsheets and similar packages.
- Comma delimited files place a comma between each column of data for each row, much the same way as a tab delimited file. Statistics programs such as BMDP and SAS frequently create these types of files.
- Space delimited files are also commonly created by statistics packages, and place some number of spaces (usually two) between each column of data for every row which contains information.
- None. If you are not sure which delimiter to use, select auto and Acq*Knowledge* will automatically select a delimiter.

When either tab or comma is selected, Acq*Knowledge* will read in a new column each time it sees a delimiter, even if there are no numeric values between delimiters. For example, the following text file will read in three channels of data, although the channels will be of different lengths.

```
0.301424, 0.276737, 0.045015
0.338723, 0.808811, 0.542627
0.354271, 0.506313, 0.715995
0.001325, 0.762115
946207, 0.894992
0.926409,
```

Sample text file

The first channel will contain six data points, the first being 0.301424 and the last value being 0.926409. The next channel will contain three data points, starting with 0.276737 and continuing through 0.506313. The software considers that there is no other data values for channel two. The third channel starts with the entry 0.045015 and the last data point for this channel is 0.894992. There are only five data points in the last channel.

AVG Advanced Averaging Experiment—not supported in Acq*Knowledg*e 4.0.

PhysioNet PhysioBank is a public service of PhysioNet and offers downloadable archives of gigabytes of "standard" data for cardiac arrhythmias, gait analysis, and other types of physiological signals. Acq*Knowledge* can use PhysioBank data directly and can be integrated with other software tools that understand this interchange format.

A PhysioBank file is usually comprised of several files, including a header file (usually "*.hea"), and all of the files must be located in the same directory for the PhysioBank record to open successfully. Open using the header file.

Opening a PhysioNet file will import data and annotations into a new graph window. If "atruth" annotations exist, they will be translated into appropriate events on the appropriate channel. All annotation types are retained except LEARN annotations, which are treated as UNKNOWN.

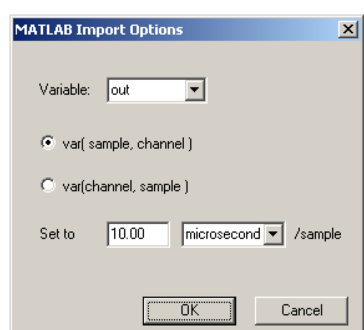
MAT MATLAB® format Acq*Knowledge* can open files created as a MATLAB work space.

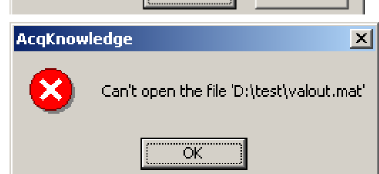
- Windows™ can open MATLAB v6 compatible MAT files, including MATLAB 7 if the "v6" flag is specified in MATLAB before saving.
- Mac™ can open MATLAB v7 compatible MAT files, including V7 format. Only ASCII text is supported; Unicode text within MATLAB v7 is not supported.
- Interoperability with earlier versions of MATLAB is not guaranteed.

Uses the "MAT-file" binary format to load numerical and textual information. If the MAT-file is properly formatted with the following arrays, Acq*Knowledge* will reconstruct the graph with appropriate sampling rate, channel labels, units, and data:

data units labels isi isi_units start_sample

- MATLAB files open with no Start button.
- If the MAT file is missing any of the expected variables or contains extra variables, only one two-dimensional array variable can be imported into a graph. A MATLAB Import Options dialog will be generated. Choose which variable data is stored in, what dimension maps to samples, channel indices, and sample rate, and then click OK to open the file.
- If Acq*Knowledge* can't recognize the file format, an error prompt will be generated and a blank graph window will be opened.





Raw This low-level data exchange option interprets all data at a single sample rate; variable sample rates are not supported. All of the data will be unscaled when opening (importing) files. That is, a value of 0 will be imported as a zero voltage. Scaling will need to be manually applied to the data. Options to open (import) raw data:

Data type: 32-bit or 64-bit IEEE floating point format or 8-, 16-, and 32-bit integer formatted data

# of channels: Enter the number of channels stored in the data file as a positive integer less than or equal to 60.

Layout: *Packed sequential*: All of the data for an individual file is located in a single block of the file and multiple channels follow one another.

Interleaved: Data is grouped into a single "frame" for each sample location with one data element for each channel, so data for a particular channel is spread throughout the file (similar to Linear PCM audio file format).

Endian: Little and big endian byte ordering, matching the data formats of x86 and PowerPC/Sparc, respectively. Set to big for Mac-Power PC generated raw files (default), or to little for Mac-Intel generated or Windows-generated raw files.

Set to *x*/sample: Specify the *inter sample interval* of data in the file, which will be translated into an appropriate sampling rate. The edit field will accept an arbitrary floating point number. The units menu contains μsec, msec, sec, MHz, kHz, Hz. The edit field will be dynamically converted to match the units selection; no conversion will be used when switching between frequency and time.

Batch

Igor Pro Igor Pro Experiments (compatible with Igor Pro 3.1, 4.0, and 5.0).

The waves contained in an Igor Pro packed experiment can be opened (imported) in Acq*Knowledge* provided that the packed experiment files comply with the following:

- ≤ 59 waves
- no text waves
- no complex waves
- all waves in Version 2 or Version 5 format (Igor defaults)
- all waves one-dimensional (vectors)
- all waves multiples of the same fundamental inter sample interval

If the wave has an associated wave note, it will be used as the channel label.

WAV WAV files containing 60 channels or less can be imported. When this format is chosen, the list of available files will be filtered such that only files ending in the ".wav" extension or having the "WAVE" type are shown. When a WAV file is selected, it will be analyzed to determine if it is compatible with the Acq*Knowledge* application.
If the file is compatible, a new graph window will be created displaying the data contents of the WAV file.

- Each channel will be numbered "Channel *n*" where *n* is an increasing digit. These channels will be unitless in amplitude.
- All of the data will be converted into the 64 bit floating point format for storage in memory and in the ACQ formatted files on disk.
- The horizontal axis of this graph will be set to time and the sampling rate set to match the rate as specified in the WAV file headers.
- This graph will be marked as an imported graph into which data cannot be

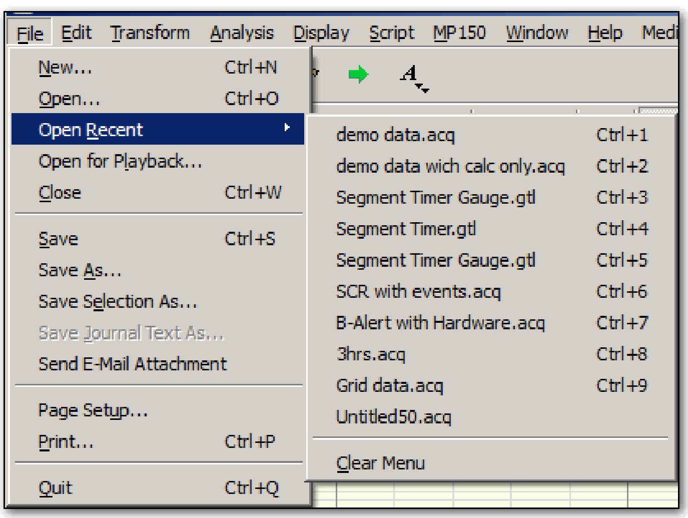
acquired.
- This will dim the start button and any appropriate hardware menu entries that would be used to access the invalid hardware settings.

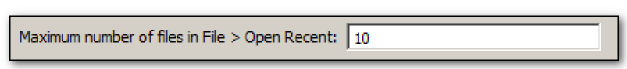
EDF Opens files with .eeg and .edf extensions saved in European Data Format (EDF). Data is imported entirely into memory in a newly created graph window titled after the filename, similar to other file import routines. All scaling factors will be applied to the data as it is imported, and it will be converted to double precision floating point format. Since EDF format includes data that is not used by Acq*Knowledge*, only the following items are imported:
- channel data
- channel labels
- units
- sampling rate (taken from maximum sample rate of all channels)

All other information stored in the EDF file will be discarded when the file is imported. Only 60 channels of data can be imported from an EDF file. Channels will be imported starting with the graph file index 1. If there is a 60th channel, it will be placed into the channel with index 0. If an EDF file contains more than 60 channels, only the first 60 channels will be imported and a prompt will advise that not all of the channels could be imported.

Open Recent

The File > Open Recent command generates a list of recently used files. These files can be opened directly from the list or with a Ctrl (PC) or Command (Mac) keystroke combination. (File > Open Recent is available in Acq*Knowledge* 4.2 and higher).





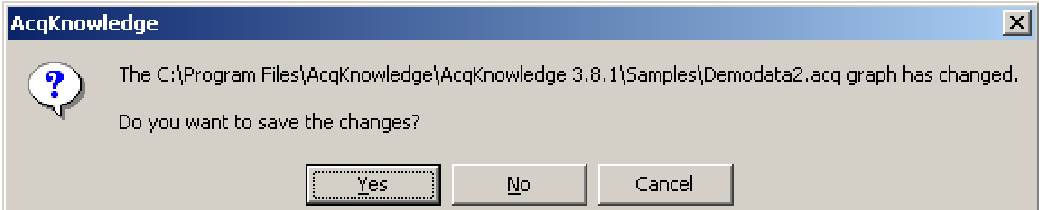
The listed files appear in the order they were opened, with the most recently-opened file appearing at the top. Default number of files appearing in the list can be modified in the Preferences. (Display > Preferences >Other)

Open for Playback

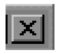
The File > Open for Playback command generates a standard file open dialog; see page 44 for Playback details.

Close

This File menu command will close the active file window and prompt you to save if necessary.

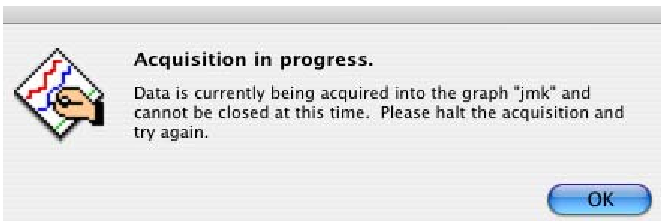


Close without saving

- *Windows*—click the  in the upper right corner of the file window
- *Mac OS X*—click the  in the upper left corner of the file window

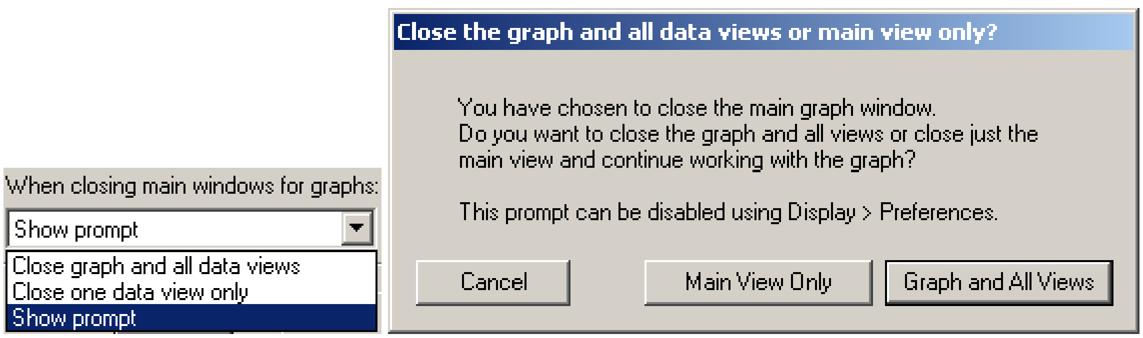
Click “No” when Acq*Knowledge* asks you if you want to save the changes.

Close during acquisition

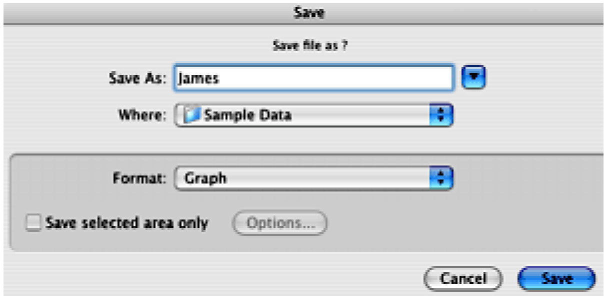


Close multiple data views

Set the level of close functionality under Display > Preferences > General.



Save



This menu command will save any changes made to a file. If more than one file is open, this command only applies to the active window. For untitled files, you will be prompted to name the file you wish the data to be saved in. The file will remain open after you have saved it, allowing you to continue working.

- The Save menu is dynamic and corresponds to the type of file you are trying to save, i.e. Save Graph, Save Journal.

Files should be less than 2 GB, except Acq*Knowledge* 3.9 "Graph" files on the Mac, which can be larger if not compressed. Data files greater than 2GB can be opened, but edit, transformation and analysis operation cannot be performed.

To save data in another format (such as a text file), use File > Save As.

Save As

Graph (*.acq)

Graph (*.acq)
Graph Template (*.gtl)
Text (*.txt)
Windows AcqKnowledge 3 Graph (*.acq)
PhysioNet - WFDB (*)
MATLAB Mat-File (*.mat)
Raw (*)
Igor Pro Experiment (*.pxp)
WAV (*.wav)
EDF (*.edf *.eeg)
JPEG (*.jpeg)
Compressed Graph (*.acq)
Excel Spreadsheet (*.xls)

Choosing File > Save As produces a standard dialog that allows you to save data in a variety of different formats and to any location. As with all save last dialoges, you can use this to save a file to a different file name or directory than the default settings.

Graph

Acq*Knowledge* format

The default file format for the File > Save as command is to save files as an Acq*Knowledge* 4.0 file, which is designed to be as compact as possible. These files can only be opened by Acq*Knowledge* 4.0, but data can be exported to other formats once it has been read in.

- To save in the previous relase format, choose **Windows AcqKnowledge 3 Graph**. When a file is saved in Acq*Knowledge* 3 format, the following calculation channel types will revert to Integrate: Band Stop Comb Filter, Adaptive Filter, FLC, WFLC, CWFLC, Rescale and Metachannels.

File Compatibility

Windows Acq*Knowledge* cannot save as Macintosh Acq*Knowledge* files.

Macintosh Acq*Knowledge* 3.9 and above can save as "Graph (Windows)" files, but it saves in Windows Acq*Knowledge* 3.7.1 format. In this earlier format, all data is retained, but new Windows Acq*Knowledge* features (like dual stimulation, data views, embedded archives, etc.) are lost along with any settings specific to Macintosh Acq*Knowledge* (like events, adaptive scaling settings, etc.).

- Macintosh Acq*Knowledge* 3.9 and above can save PC-compatible Graph (*.acq) and Graph Template (*.gtl) files. Variable sampling rate information and hardware settings are retained, and Journals can be read from and written to PC files. Choose the format "Graph (Windows)" to create PC-compatible files.

The Mac version does not save PC GLP files or compressed PC files.

Files must end on a multiple of the lowest channel sampling rate to be fully PC compatible.

GTL

Graph Template

This feature can be especially useful for recreating protocols in the laboratory. You can Set Up an experiment and save it as a Graph template, then simply open the Graph template file and click the Start button to acquire data under the same settings.

TIP: Check the existing ***Quick Start*** template files listed on page 240 before creating or saving a new template. With over 40 templates provided, you may find one to establish the settings required for your particular application or to use as a good starting point for customized applications.

The Save As Graph template option saves the setup parameters established under the MP150 menu and retains the size of the primary graph window. In general, the minimum file size for graph templates is 700 K-800 K; file size may increase as setup options are enabled.

When a file is saved as a Graph Template:

a) No graph data will be saved.

NOTE

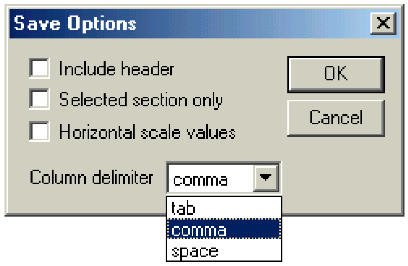
- Since no data is saved in the template, arbitrary waveform output setups, which require a source date file, will not function in a template.
- You must select Save / Save as and select "File of type .ACQ" to save the graph data.

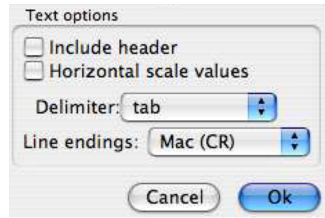
b) Journal text will be preserved. Any text you entered will be saved to the Journal window and stored with the template—this is a handy way for you to place instructions or information about the experiment for yourself or others.

When this feature is used with the menu.dsc customization feature it is easy to comply with GLP standards and save your protocol as an SOP. When you change the menu.dsc file for a graph template file, save the "menu.dsc" file with the exact same name but save it to the new lesson folder you have created. For full GLP features, contact BIOPAC about the *Lab Assistant GLP System*.

TXT *Text*

Saves graph data in text format. When Save As Text is selected, an Options button is generated. Clicking on this button generates a Save Options dialog that allows you to control how much data is saved and the format it is saved in.





Header

When the first box is checked, a "header" is included at the top of the text file that contains information about the sampling rate, number of channels, date created, and other information relating to the data. This information is frequently useful, but some programs will attempt to read in the header information as data, which could result in nonsensical results. You may wish to include the header as it can always be edited out later using a text editor or the journal.

Selected Section

Checking the second box instructs Acq*Knowledge* to save only the selected section of the file. This is useful for saving a brief segment of a long file. When this option is checked, the highlighted area of data will be saved from all channels. When only one data point is selected, the entire file will be saved. If you want to save only a portion of the selected channel, you can either remove other channels or copy the data through the clipboard. See page 262 for more information on how to copy data through the clipboard.

Horizontal Scale

The third checkbox allows you to include the horizontal scale (usually time) values in the text file, along with the data to be saved. This allows you to produce time series plots in other applications, as well as correlating events to time indexes in graphing and statistical packages. Since a separate row is generated for each sample point, To exceed the limitations of programs if data is collected at a fast sampling rate (many spreadsheet programs are limited to about 16,000 rows). You may wish to consult the section on resampling data after an acquisition is completed (page 292).

Column Delimiter

When data is saved as a text file, each channel of data is saved as a separate column, with the number values for each data point saved in rows. Use the pop-up menu to select the delimiter to separate the columns of data in the text file. By default, a tab is placed between each column for every row of data; this format is called a tab-delimited text file and almost all applications will read in tab-delimited text files. However, you may also save data in a comma-delimited format or a space-delimited format.

Line endings

Use to create text files that are compatible with Classic Mac OS applications (Mac), Unix-compatible applications (Unix), or PC-compatible applications (DOS).

PhysioNet This format requires that the WFDB library is on your computer. PhysioBank is a public service of PhysioNet and offers downloadable archives of gigabytes of "standard" data for cardiac arrhythmias, gait analysis, and other types of physiological signals. Acq*Knowledge* can use PhysioBank data directly and can be integrated with other software tools that understand this interchange format.

Saving a file in PhysioNet (WFDB) format will export the entire contents of the graph to a PhysioBank record. The record will consist of multiple files, all in the location specified for export. There will be a header file (*.hea) and a single data file for each channel of the graph (starting with "d" and ending with the base name of the header file). The files must not be separated for a successful move or copy.

Export Limitations

Precision	Some precision may be lost due to differences in binary representation between Acq*Knowledge* and PhysioBank formats.
Events	Events will not be exported to the PhysioNet format.
Channels	Only 32 channels of data can be exported from a graph (the max allowed in a PhysioBank file).
Rate	If you are exporting a graph that uses variable sampling rates, all of the channels in the exported file will be downsampled to the lowest waveform sampling rate of the source graph.

*.MAT MATLAB

MATLAB® format. Uses the "MAT-file" binary format to save numerical and textual information as Filename.mat.

- Windows™ and Mac™ create MATLAB Version 6 files, which are compatible with both MATLAB Version 6 and MATLAB Version 7.
- Interoperability with earlier versions of MATLAB is not guaranteed.

The following variables will be in the workspace when the file is opened in MatLab.

data	Contains the data of the graph in floating point format, for all of the channels of the array. The first dimension of this array is the amount of data in each channel, the second dimension increments with each channel. Therefore, each column contains a full channel of data that can be accessed in MATLAB via data (1:length, [channel number]).
units	This string array contains the textual representation of the units of the samples stored in data, with one element per channel of data.
labels	This string array contains the labels of each of the channels, with one element per channel.
isi	This floating point array of one element gives the number of units of a single inter sample interval of the data.
isi_units	This single string array provides a units string for a single unit of isi. Time data will always be "ms," frequency data will always be "kHz," and other values will be represented by an Arbitrary horizontal axis type in an ACQ graph.
start_sample	Contains the time offset of the index 0 sample of data in isi units. This will be 0 for many graphs, but if only a selected area of a graph was exported into the MAT file, the start_sample will contain the offset from the original data corresponding to the start of the data array in the MAT file.

Raw

Options to save (export) data for low-level data exchange are:

Data type:	32-bit or 64-bit IEEE floating point
Layout:	*Packed sequential*: All of the data for an individual file is located in a single block of the file and multiple channels follow one another. *Interleaved*: Data is grouped into a single "frame" for each sample location with one data element for each channel, so data for a particular channel is spread throughout the file (similar to Linear PCM audio file format).
Endian:	Little and big endian byte ordering match x86 and PowerPC/Sparc data formats, respectively. To exchange with Windows applications or Mac-Intel, set to little endian; to exchange with standard Mac applications, set

to big endian.

Raw Data Export Limitations

Formats Raw export only allows data to be saved in 32-bit and 64-bit IEEE floating point format.

Rates All files will be interpreted at a single sample rate; variable sample rates are not supported. If a graph with variable sampling rates is exported, channel data for downloaded channels will be padded to match the highest waveform sampling rate.

Length If channels have unequal lengths, the overall file length will match the longest channel. Shorter channels will be padded at the end using their final sample value so that all channels contained in exported files will be equal in length.

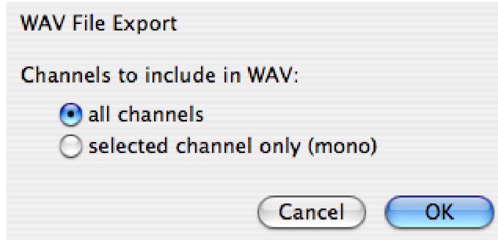
Scaling When integer-valued analog channels are exported from Acq*Knowledge* to raw files, all relevant scaling and offset will be applied—the data in the file will appear the same as if the channel had been internally converted to floating point format before export.

If the value of a channel is outside the maximum/minimum value that a chosen export data type can represent, the value will be clipped accordingly. (Acq*Knowledge* uses a 64-bit data type, so this should only be a problem if exporting to 32-bit floating point values.)

Igor Pro Igor Pro Experiment format.
An Acq*Knowledge* graph will be saved (exported) to a single packed experiment file, with each channel saved into a separate Igor wave that preserves the channel label, waveform sampling rate, and unit information. Vertical units will be stored as data units, and horizontal units will be stored dimension units; extended units are supported. The scaling of each wave will be adjusted to match the waveform sampling rate. All data will be stored in 64-bit floating point format in a one-dimensional wave. The waves will be named incrementally from "wave0" and the channel label will be stored in the wave note field. Files will have the type/creator pair "IgsU/IGRO" and a ".pxp" extension will be added to the file name for compatibility with Igor Pro for Windows™.

WAV This option saves the graph data into a WAV audio file for exchange with other applications. The ".wav" extension extension will automatically be added if the save as filename does not end with it.
The "Selected area only" checkbox will be active for WAV export. When checked, only the highlighted area will be exported to the WAV file. The final sample of this range is not included in the export, mirroring the other file export routines of Acq*Knowledge*.
All exported WAV files use the 64 bit floating point format. This format preserves full operational precision. Most audio applications should be able to support floating point WAV files. Exported data will not be normalized when it is exported. Any normalization to audio ranges should be performed prior to exporting the data.
WAV files are normally either one or two channels (e.g. mono or stereo). Acq*Knowledge* graph files, however, usually contain more than two channels. Although they can contain more than two channels, most audio applications may not be able to recognize these multiple channel files.

- If a graph file contains only one or two channels of data, a WAV file will automatically be created without further interaction.
  - Graphs with a single channel will result in mono WAV files.
  - Graphs with two channels will result in stereo WAV files.
- If a graph contains more than two channels, the user will be presented with the following choice:



- **all channels**—create a multiple-channel WAV file with one channel per channel of data in the graph. While this WAV file may be easily opened by some applications, it may not be fully compatible with audio applications and other applications expecting two channels or less.
- **selected channel only**—create a single channel mono WAV file using only the data of the selected channel. This will be the selected channel in chart mode, the active channel in scope mode, or the vertical channel in X/Y mode. This single channel export may be useful for exporting audio channels that are recorded along with physiological data, such as heart sounds, audio stimuli, and the like.

After a WAV file is exported, the WAV file will not be reopened; the open graph will be left unmodified. To view the exported file, import the WAV file.

EDF

Saves file in European Data Format (EDF). The saved file will automatically have an .edf extension added onto it if the user did not include it. Users will be able to save either the entire graph or only a selected portion of data.

AcqKnowledge does not retain sufficient information to accurately complete an EDF header. When exporting, the following default values will be used:

EDF Header Element	***Default***
subject ID	Empty*
recording ID	Empty*
recording date	Set to the modification date of the graph file on disk. If no graph file is on disk, the current date is used.
recording time	Set to the modification time of the graph file on disk. If no graph file is on disk, the current time is used.
transducer description	Empty*
filter description	Empty*

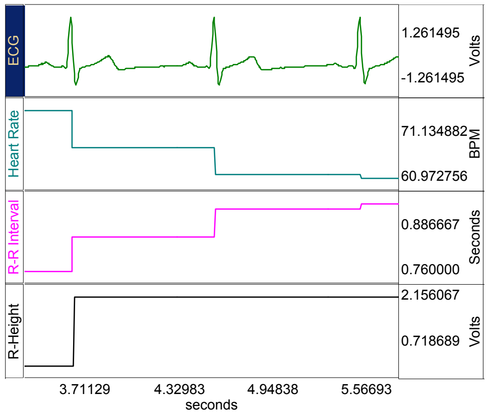
* Empty: indicates that the field will be left blank

All other fields will be filled with corresponding information from the graph, including channel titles, sampling rates, channel units, and scaling factors. Variable sampling rate information will be preserved as it can be expressed in the EDF format.

EDF is used by many applications and online recording databases to store information, particularly EEG recordings. EDF is an open file format originally developed for sleep studies. It stores continuous time recordings of data in a binary format. Since its original proposal, EDF has been adopted by a number of open source and commercial tools as a supported data file format. Usage has also expanded beyond sleep studies into other types of recording.

JPG

Acq*Knowledge* also supports formats for saving graphical information. Most drawing, page layout, and word processing programs can read .JPG files. This is particularly useful for writing reports. A. JPG file can be opened in any standard drawing program and can then be embellished or used to highlight any particular phenomena of interest.



When data is saved as a graphic, only the data currently on the screen is saved. So, if you have a data file that spans eight hours but only two minutes is displayed on the screen, only two minutes of data will be converted to a graphic file. Since Acq*Knowledge* uses information about the computer screen in creating the graphic file, the default resolution of the file will be the same as the window. Most word processors and graphics packages allow for some way to resize and scale graphics.

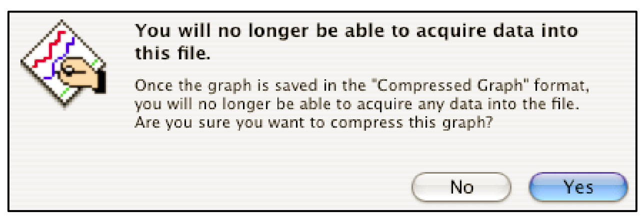
Compressed

Saves a compressed Acq*Knowledge* formatted file. The degree of compression varies based on data characteristics, but will generally achieve about 60% compression. Saving small files (less than 200K) may have little effect. Using a sample file as an example:

Compressed graphs no longer allow data acquisition and will open with no Start button.

Resave the compressed file in standard format to enable a Start button.

A warning prompt will be generated when you try to compress a graph in which data can be acquired (Start button active):



Excel Spread-sheet

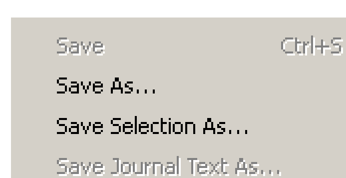
Excel Spreadsheet Export—Graph data can be saved directly to an Excel spreadsheet by using the Excel Spreadsheet format in File > Save As. Each channel will be placed into its own column of the spreadsheet. Only 65K sample points can be exported at a time, however, so long or high sample rate data acquisitions may not be able to be saved in a single spreadsheet.

- Also available for File > Save Journal Text As, Find All Cycles journal, and Specialized Analysis tools.

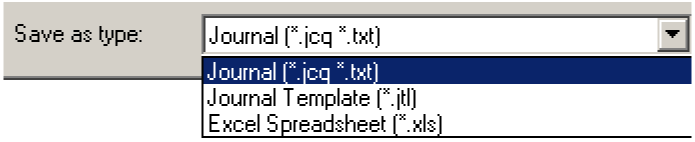
Note The Excel spreadsheet option requires Excel or a compatible spreadsheet application that can read Excel files (OOo, Symphony, etc.). If Analysis results are exported to an Excel spreadsheet, and a compatible application is not available, results will open as a text document the data and nonsense characters.

Save Selection As

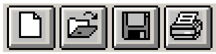
To save only the data that has been selected with the I-beam tool, choose File > **Save Selection As**; this option saves the selected area to another file and does not affect the current file that you are working in. Specify file name and file type and then click Save.



Save Journal Text As



Choosing File > Save Journal generates a save dialog to save the journal text as a separate file. Specify file name and file type and then click Save.

Journal 

Text (.TXT) format*—Saves an independent journal; see page 52 for details.

Jrnl Temp *.JTL format*—Saves a journal template; see page 52 for details.

Excel Spread-sheet

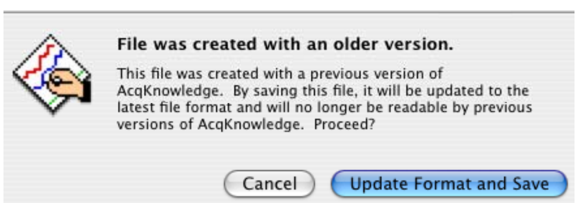
Excel Spreadsheet File (.XLS)*—Journal text can be exported directly into an Excel spreadsheet by using the File > Save Journal Text As with the Excel Spreadsheet format. Each line of text in the journal will be saved as a single row with tabs separating columns. A selected portion of a journal can also be written to a spreadsheet. This export allows for textual data reduction results to be easily exported into a spreadsheet to allow for further analysis.

- Also available for File > Save As, Find All Cycles journal, and, for Specialized Analysis tools.

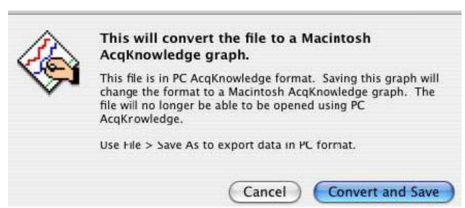
Note The Excel spreadsheet option requires Excel or a compatible spreadsheet application that can read Excel files (OOo, Symphony, etc.). If Analysis results are exported to an Excel spreadsheet, and a compatible application is not available, results will open as a text document the data and nonsense characters.

File Format prompts

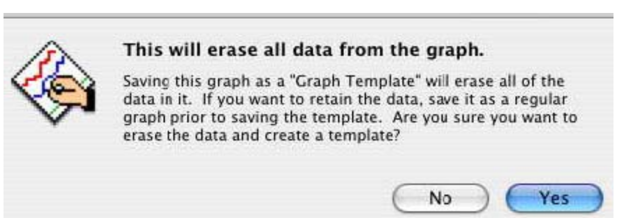
When a file open or save function requires a format change for compatibility or alters file content, a prompt will be generated to require the user to confirm the option to update format or convert and save.



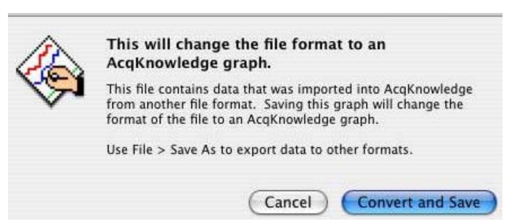
Created with a previous version of Acq*Knowledge*



Windows PC Acq*Knowledge* format



Saving as a “Graph Template” will erase all data



Imported from another file format

Send Email Attachment

Use this feature to create an email attachment containing an image of the active AcqKnowledge graph, along with the journal contents. (Acq*Knowledge* 4.2 and higher only).

When using this feature:

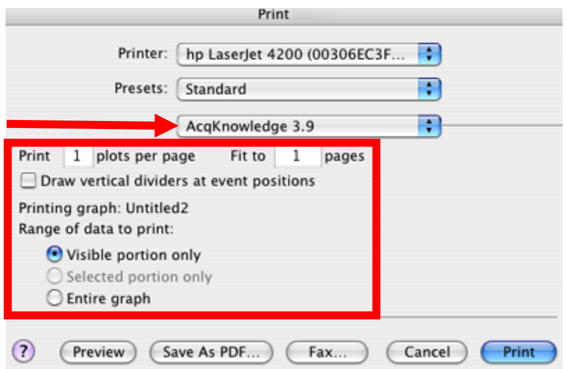
- The default email program will launch, along with a 'compose new email' window.
- An Open Document (*.odt) text file containing an image of the currently opened graph and associated journal text will be copied to the attachment field. The formatting and images present in the journal should be preserved.
- Further details can be typed into the body of the email prior to sending.

In order to open the attachment, the email recipient must have a word processing application compatible with *.odt file format, such as OpenOffice, NeoOffice or Microsoft Word™.

Page setup

Choosing File > Page Setup produces a standard printer setup dialog that allows you to setup any available printers. All the options in this dialog function as described in your system manual. There is also an options button that allows you to make several printing adjustments with respect to fonts, image orientation, and graphics presentation.

Range of Data options



Select "MP150…" for Print range options

Event Divider

Toggle "Draw vertical divider at event locations" to enable/disable this option. See Printing Events on page 219 for details.

Based on the range selection, the software will make appropriate adjustments before printing. For visible area, friendly grid scaling will be applied, and onscreen and printed precision will match, even if horizontal grids are unlocked. For selected area and entire area, onscreen and printed precision will not match when grids are unlocked because friendly grid scaling is applied on screen, but is not used during printing where the range is fixed to fill the entire page.

The automatic software adjustments before printing will set the horizontal scale as if it had been used to display the relevant data on the screen. When printing is completed, the scale and offset parameters of the graph will be restored to the previous settings.

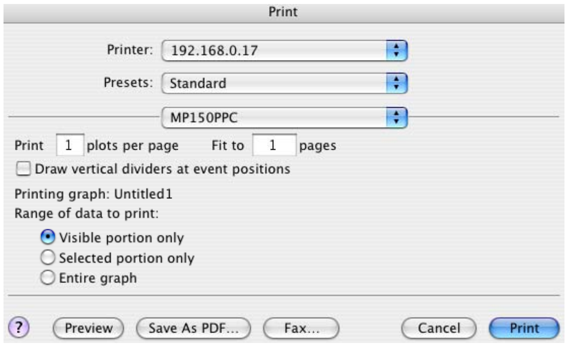
Print

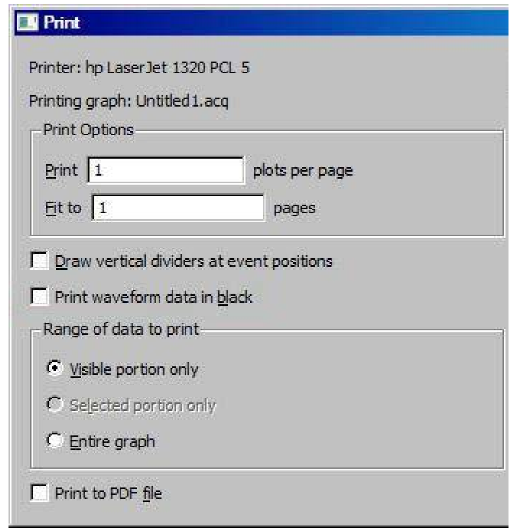
The File > Print menu that Acq*Knowledge* uses is similar to the standard computer print dialog; however, there are additional options available

The Print menu is dynamic and corresponds to the type of file you are trying to print, i.e. Print Graph, Print Journal.

Windows OS: Click print for more options.

Mac OS X: Select “MP150…” in the print dialog:





- Print Options
  - **Plots per page**—Control how many plots appear per page when the file is printed. Printing more than one plot per page has the effect of “snaking” graphs on a page much the same way text appears in a newspaper. For example, if this option was selected so that two plots were printed per page, Acq*Knowledge* would divide the amount of data to be printed on that page into two graphs—one graph printing at the top of the page, the second graph printing at the bottom of the page. This option allows you to print records on considerably fewer pages than standard printouts, and is most effective when only a few channels of data are being printed.
  - **Fit to pages**—Print the contents of a window across multiple pages. When a record is printed over multiple pages, the amount of data on the screen (the amount of data to be printed) is divided by the number of pages entered in the dialog. The graph on the screen is then printed across the number of pages specified in the Total pages box at the bottom of the File > Print dialog. These two options apply only to graph windows, and do not apply to Journals.
- **Draw vertical dividers** at event positions
- **Print waveform data in black**
- Range Options—determine the range of data that will be included in the printout
  - **Visible portion only** synchronizes the range of data in the printout to match the range of data that is visible on the screen.
  - **Selected portion only** prints only the data that is selected in the graph. This option is disabled if there is no selection in the graph. When working with Journals, it is easy to generate large amounts of text content in the window. Only a portion of this information may actually be of interest and this feature allows for only portions of the text to be printed. If there is no selected text, the entire journal or modification log will be printed regardless of this setting.
  - **Entire graph** prints all of the data contained in the graph from zero to the maximum length channel.
- **Print to PDF file**—generate a PDF file.

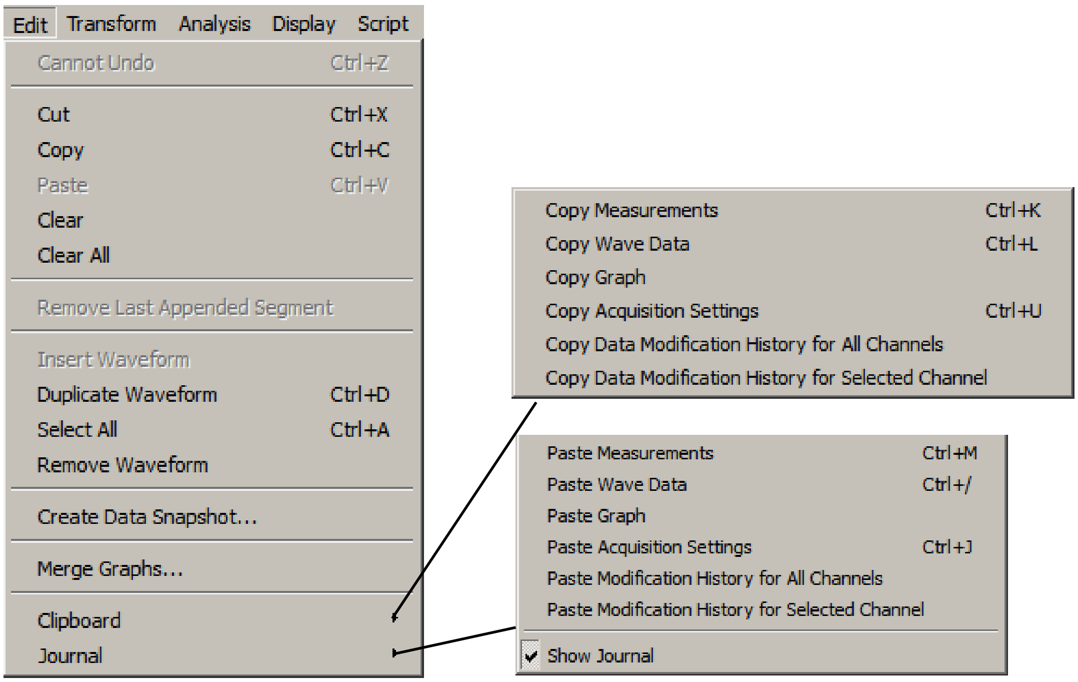
Quit

Select Quit from the File menu to exit Acq*Knowledge* software; you will be prompted to save any open graph files that have been modified since they were last saved.

Mac OS X only—Use Quit under the Acq*Knowledge* menu (page 429) to exit the software.

Chapter 14 Edit menu commands

Overview



One of the most useful features in Acq*Knowledge* is the ability to edit and work with data by cutting sections and copying sections from one window to another. In this sense, the MP System (MP150 or MP36R) allows you to work with data much as a word processor lets you work with text. When working with data, you will usually want to select a section of data to work with. To select a section of data, use the editing tool to highlight an area. The selection tool is used for a variety of purposes including cutting and pasting waveform data, making measurements and determining which portion of a waveform to save as text values. To select the tool, click its icon in the lower right hand corner. You will notice that the cursor changes into the familiar "I-beam" cursor when you move it within the graph area. Click the mouse and drag to select a portion of the waveform.

IMPORTANT

When multiple waveforms are present, the highlighted area appears to include all of the waveforms, but most modifications and transformations apply only to the selected channel.

Once you have selected a section of a waveform, you can perform such as editing, transformations, saving data to the journal, saving as text, and using the measurement functions on the selected area. The cursor always selects at least one sample point; when there is no defined area, a single sample point will be selected, and the cursor will blink. You can highlight a larger area by positioning the cursor over the first point you are interested in, holding down the mouse button, and dragging the cursor either left or right to highlight an area. This is similar to highlighting a series of letters or words in a word processor. You can modify the selected area by placing the cursor anywhere on the graph, then holding down the shift key and clicking the mouse. This feature is useful for fine-tuning the selected area. To fine tune, first coarsely select an area. By zooming in (with the zoom tool) on either edge, you can then use the shift key to precisely align the edges of the selected area.

Acq*Knowledge* also allows you to select an area that spans multiple screens. To do this, first select an area that contains the leading edge of the portion of the graph that you are interested in. Next, use the horizontal scroll bar to scroll to the end of the area that you are interested in. Then place the mouse near the area of interest and click the button while holding down the shift key. While still depressing the mouse button, move the cursor to the exact position desired.

By using the selection tool to select areas of the waveform, the Cut, Copy, Paste and Clear functions are designed to work in much the same manner as a word processor. These functions operate only on areas selected by the selection tool.

Edit menu functionality during acquisition

The following Edit menu functions may move or alter memory and cannot be performed during acquisition: Undo, Cut, Clear, Clear All, Paste, Insert Waveform, Duplicate waveform, and Remove Waveform.

Undo / Can't undo

The Undo command allows you to restore data that was unintentionally deleted or modified. Undo applies to editing commands and transformations (such as digital filtering and mathematical operations).

There are some important exceptions to the Undo command.

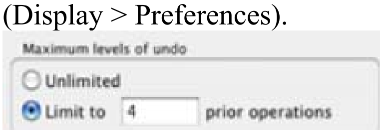
First, neither Edit > Clear all nor Edit > Remove waveform can be undone. It is a good idea to make backup files before performing any editing, especially when using these commands.

Second, changes in the display options (i.e., changing the horizontal scale or changing the color of a waveform) cannot be undone, since they are easier to manipulate and less drastic than cutting data out of a waveform. If you modify the screen scale (or other display parameters) you will still be able to undo your latest data modification, which is much more difficult to recover than a screen parameter change.

TIP: If you accidentally remove a waveform or choose Clear All, one way to recover the data is to close the file without saving the changes. The data file can now be reopened, as it was when it was last saved; any changes made since it was last saved will be lost.

Perform multiple levels of undo on a per graph basis; Journal undo remains unchanged at one step. Complex data analysis in Acq*Knowledge* is rarely performed with a single transformation; multiple transformations are frequently cascaded together to produce a result. Acq*Knowledge* will "stack" the transformations and the user will be able to undo one step at a time until this stack is exhausted.

- Undo may move or alter memory and cannot be performed during acquisition.
- Undo operations may occupy large amounts of memory, particularly for transformations that affect entire waveforms or multiple markers. Users without large amounts of RAM or working with large data sets may require the available computer memory for performing transformations. To accommodate these users, the maximum size of the undo stack can be limited using the *Levels of undo* Preference (Display > Preferences).



- Specialized Analysis (page 331) scripts are complex and undo may not function for all steps.

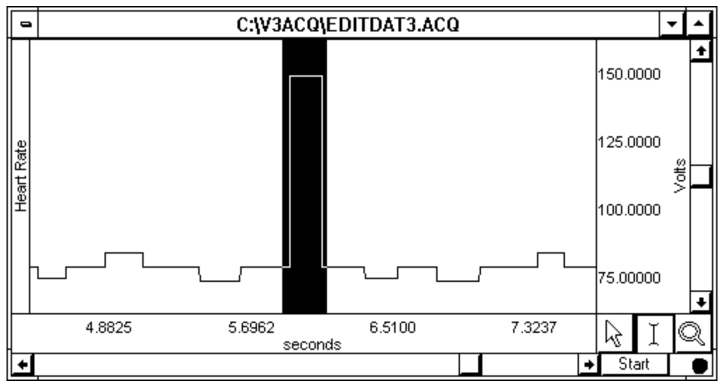
Cut

When Cut is selected from the Edit menu, the highlighted portion of the active window (Graph, Journal, entry prompt or dialog) is removed and copied to a clipboard, where it is available for pasting into other windows.

Cut may move or alter memory and cannot be performed during acquisition.

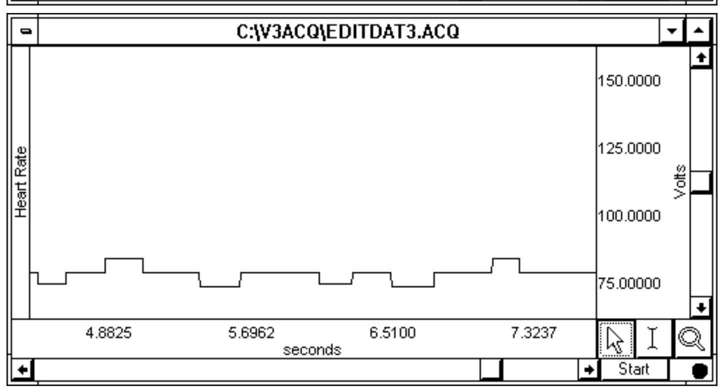
- When a selected area is removed from a waveform, the data will shift left to "fill in" the deleted area. So, if ten sample points are deleted, all data after the selected area will be shifted over ten sample points. Since this alters the relationship of events to the time base, you might want to consider alternatives to cutting sections of data—such as using smoothing, digital filtering, or the connect endpoints functions to transform the section of data.

Area selected using the editing tool →



Same data with selected area Cut out →

Note that the data after the selected area has shifted forward in time.



Copy

Choosing Edit > Copy will copy the selected area of the active window (Graph, Journal, entry prompt or dialog) to the clipboard without modifying the text/waveform on the screen.

- Once the area has been copied, it can be inserted in another window using the Edit > Paste command or, for waveforms, the Edit > Insert waveform command.
- To copy a waveform to another channel in the same graph window, choose the Edit > Duplicate waveform command.

Paste

The Edit > Paste command will take the contents of the clipboard and paste it into the currently selected area of the active window (Graph, Journal, entry prompt or dialog).

- If no area is selected, the data is pasted at the beginning of the waveform in a Graph window or the end of the text a Journal window

Note Copy/Paste operations require Acq*Knowledge* to allocate additional memory and then load the data into memory; when these operations are executed on large data files, the application may crash.

Clear

The Edit > Clear command works much the same way as the Cut command, with the key difference being that data is not copied to the clipboard. This function deletes the selected area from the selected channel only. If the entire waveform is selected (as with the Edit > Select all command), the clear command will delete all the waveform data and leave an empty channel.

Clear may move or alter memory and cannot be performed during acquisition.

- As with the cut command, the clear function operates on only one channel, and when a portion of the waveform is deleted, the remaining data will shift left. If multiple channels of data are present, one channel will be "shorter" than the others.
- To remove a selected area of data from multiple channels, use the Edit > Clear all command.

Clear all

Choosing Edit > Clear all will delete the selected area from *all* channels. This is similar to the clear function in that data is removed and is not copied to the clipboard. The Clear all command, however, removes a section of data from all waveforms, whereas the clear command applies only to the selected channel.

Clear All may move or alter memory and cannot be performed during acquisition.

- When Edit > Select all is chosen prior to performing the Clear all function, all waveform data for all channels will be deleted.
- The Edit > Undo command does not work for Clear all.

Select All

When Select all is chosen from the Edit menu, the entire selected channel becomes highlighted. For almost all commands, when a waveform is selected using Select all, subsequent operations apply to the selected channel only.

- The exception is when Edit > Clear all is chosen after Edit > Select all. When this occurs, all data from all waveforms will be deleted.

Insert waveform

The Edit > Insert waveform command is useful for copying a waveform (or a section of a waveform) from one window to another. To do this, first select the area to be copied using the cursor and the Edit > Copy command. Next open the graph window you wish to insert the waveform into. To insert the waveform into the same graph it was copied from, although the Edit > Duplicate waveform is a much more straightforward way to do this.

Once you have selected the graph you wish to insert the waveform into, choose Insert waveform from the Edit menu. A new (empty) channel will then be created and the data will be copied into the empty channel. The new channel will always take on the lowest channel number available (including zero).

Insert waveform may move or alter memory and cannot be performed during acquisition.

- This command cannot be undone directly, although selecting the inserted channel and choosing Remove waveform from the Edit menu effectively undoes this operation.

Duplicate waveform

Choosing Edit > Duplicate waveform will create a new channel in a graph window and copy an entire waveform (or a selected area) to the new channel. When a portion of the waveform is selected, only the highlighted area will be duplicated.

Duplicate waveform may move or alter memory and cannot be performed during acquisition.

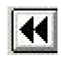
- To duplicate the entire waveform, choose Edit > Select all and then select Duplicate from the Edit menu or click the right mouse button and select Duplicate from the pull-down menu.

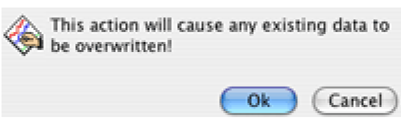
Remove waveform

Deletes the entire selected waveform, regardless of what other options are selected.Remove waveform may move or alter memory and cannot be performed during acquisition.

- The Edit > Undo command does not work for Remove waveform.

Remove last appended segment

Removes the last appended segment. Equivalent to the  Rewind toolbar icon.



- Edit > Undo does not work for Remove last appended segment.

Create Data Snapshot

The Snapshot options store "snapshots" of the original acquired data at specific stages along with the full graph file. Use snapshots for analysis or reporting to compare results to original waveforms or intermediate stages of analysis. This is essentially an embedded archive; it is not a backup tool.

IMPORTANT: Archive functions do not create a new file—they are not backup functions.
Original data is copied and pasted to the end of the original file.
You cannot use this feature to recover lost or damaged graph files.

See page 53 for Snapshot details.

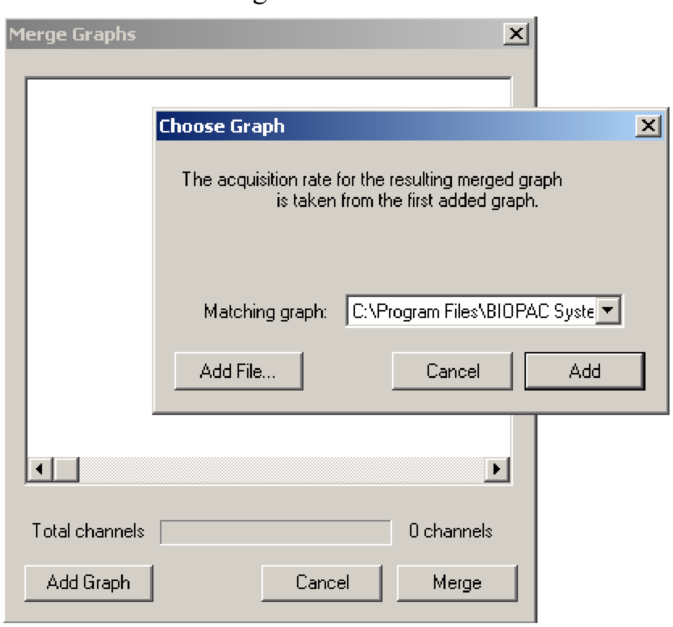
Merge Graphs

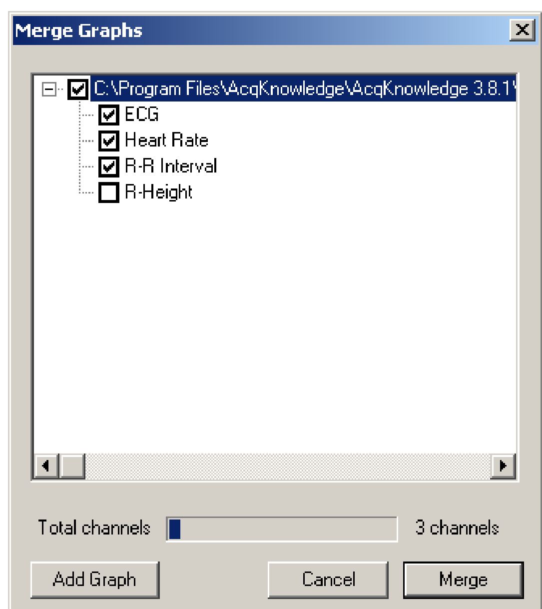
Combine multiple graph files into a single file for performing cross-file analysis and storage. Use merge with the multiple-hardware capabilities to produce single graph files containing multiple streams of data from an individual subject.

Use Merge Graphs to combine up to 60 channels from multiple graph files acquired with the same acquisition rate into one merged graph file.

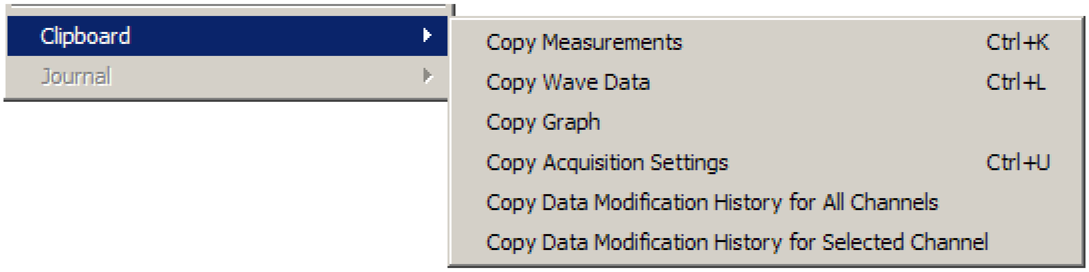
Note Merge Graphs requires Acq*Knowledge* to allocate additional memory and then load the data into memory; when this operation is executed on large data files, the application may crash—on Windows OS, the resulting file size of a merge should be less than 2GB; data files greater than 2GB can be opened, but edit, transformation and analysis operation cannot be performed.

1. Select Edit > Merge Graphs to generate the Merge Graphs dialog.
2. Click Add Graph to generate the Choose Graph dialog.
3. Choose a file to add to the merge.
   - "Add" the "Matching graph" listed (this pull-down menu includes all open files with the same acquisition rate)
   - "Add File…" to browse and select a file that is not already open
4. Adjust the selection for individual channels if desired.
   - Click the "+" to list individual channels in the graph file.
   - Toggle the checkbox to add or remove the associated channel/graph file.
   - You cannot delete a file name from the list, but you can remove it from the merge.
5. Repeat as desired for multiple files.
6. Click Merge and wait (you can check the status in the Total Channels bar).
7. Save the merged file.





Clipboard



All of the clipboard commands involve copying data from Acq*Knowledge* to the standard Windows clipboard, where the contents of the clipboard are made available for other applications. Transferring data through the clipboard allows you to copy data from Acq*Knowledge* to other applications even after you have closed the graph window and/or quit Acq*Knowledge*.

Data can be copied to the clipboard in two formats:

Text/Alphanumeric	Copy Measurement and Copy Wave Data save information to the clipboard in text/numeric format.
Graphic format	Copy Graph transfers the image in the window to the clipboard.

- Copy Measurements

  Copies the contents of all visible measurement popup menus, along with the values associated with these windows. By default, three windows are displayed (on most monitors); you can change this by increasing or decreasing the width of the window. Once the measurements have been copied, they can be pasted into any application that allows paste functions, including word processors, drawing packages, and page layout programs. A sample of measurements pasted from Acq*Knowledge* into a word processor follows:

  BPM = 85.714 BPM   delta T = 0.700 sec   p-p = 0.8170 Volts

- Copy Wave Data

  Copies the data (in numeric form) for all channels from the Acq*Knowledge* graph into the clipboard. When an area is selected, only the data in the highlighted area will be copied to the clipboard. As with the copy measurement command, once the data is stored in the clipboard, it can be pasted into virtually any application.

  When multiple channels of data are copied to the clipboard, the data is stored in columns and rows, with data from each channel stored in a separate column. For a four-channel record, four columns of data will be copied to the clipboard. As with a text file, Acq*Knowledge* will insert a delimiter between each column of data. The default delimiter is a tab; you can change the delimiter to either a space or tab in the options dialog in the File > Save as dialog. See page 240 for more detailed instructions on how to set the column delimiter. Transferring data through the clipboard performs essentially the same function as saving data as a text file (using the File > Save As command), with the obvious exception that transferring data through the clipboard does not save data to disk.

  Note Using Copy Wave Data on larger files may crash the application due to the excessive number of text lines generated (the problem is not the data size). For instance, one large file sample was 300,002 lines—a 3 MB text file.

- Copy graph

  Copies the graph window as it appears on the screen to the clipboard, where it is stored in graphic format. You can then place the graphic into a number of different types of documents, including word processors, drawing programs, and page layout programs. The JPEG graphich format are common to almost all applications, and images saved in these formats can be edited in most graphics packages and many word processors.

  Using the copy graph function is similar to saving a graph window as a JPEG (using the File > Save As command), except that using the file save command writes a file to disk, whereas transferring data through the clipboard does not save a file.

- Copy Acquisition Settings

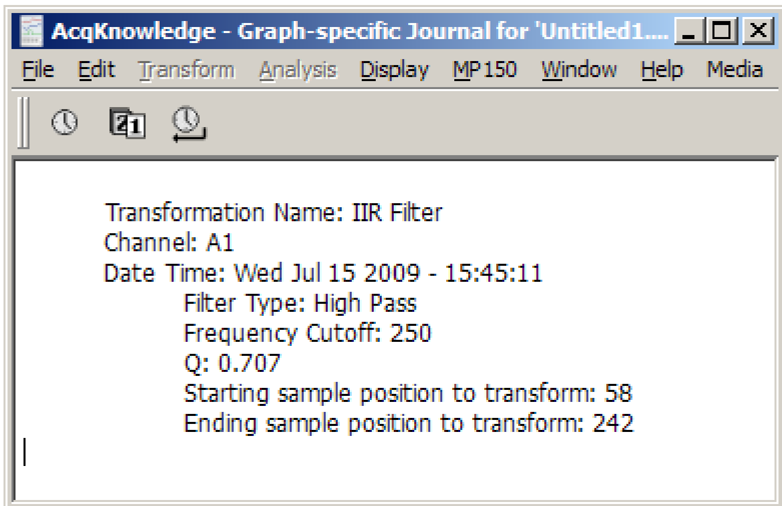
  Creates a textual summary of the current acquisition settings and sends it to the clipboard, where it can be pasted into the journal via Edit > Journal > Paste Acquisition settings, or pasted to another program.

  The summary includes sampling rates, channel configuration, calculation channel settings, triggering options, averaging options, and if any stimulator is active. This is useful for retaining records for acquisition parameters (and for technical support, if necessary). Use this feature to keep a textual record or printout of the configuration of your MP150 unit along with your data.

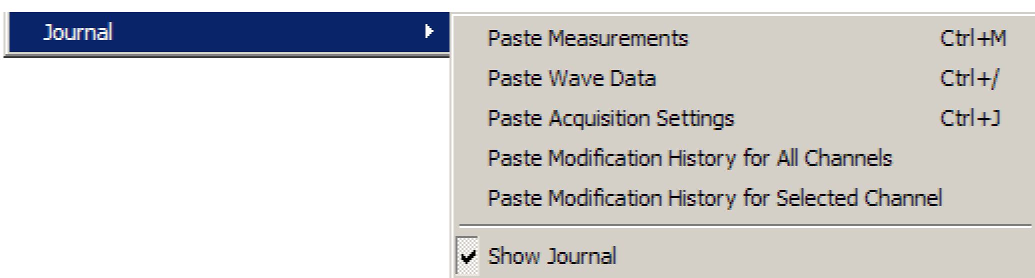
- Copy Data Modification History…

  Copies the transformation history to the clipboard for all channels or the selected channel. Modification history includes the transformation name, channel (analog, calculation, or digital), date & time, and relevant transformation parameters, including starting and ending sample position.

  Use Edit > Paste to move it from the clipboard to an active Journal window or other word processing application.



Journal



The Edit > Journal sub-menu options are similar to those found in the Edit > Clipboard menu. The key difference is that data (whether measurements or raw data) is pasted directly into the journal rather than copied to the clipboard.

- Paste Measurements

  Choosing Paste Measurements from the Edit > Journal menu will cause all visible measurement windows to be pasted into the journal. Each time this is selected, the measurements and values are pasted into the journal using the precision specified in the Display > Preferences dialog. You can also change the total number of measurements displayed by adding more rows of measurements. Use the Preferences menu (see page 420) to change the number of measurement rows or the measurement precision displayed on the screen.

  Paste Measurement shortcuts:

  - Keyboard: Ctrl + M
  - Mouse: Right-click in the Journal and choose "Paste Measurement"

- Paste Wave Data

  Converts the selected area of the waveform to numeric format and paste it into the journal in standard text file format. As with the copy wave data command (in the Edit > Clipboard submenu) this will paste the selected area from all channels, not just the selected channel, and will place a delimiter between the columns when two or more channels are being pasted to the journal. By default, tab characters are used to separate columns; you can change to comma or space delimiters in the File > Save As > Options dialog. See the Save As section on page 246 for more information on how to change the column delimiter.

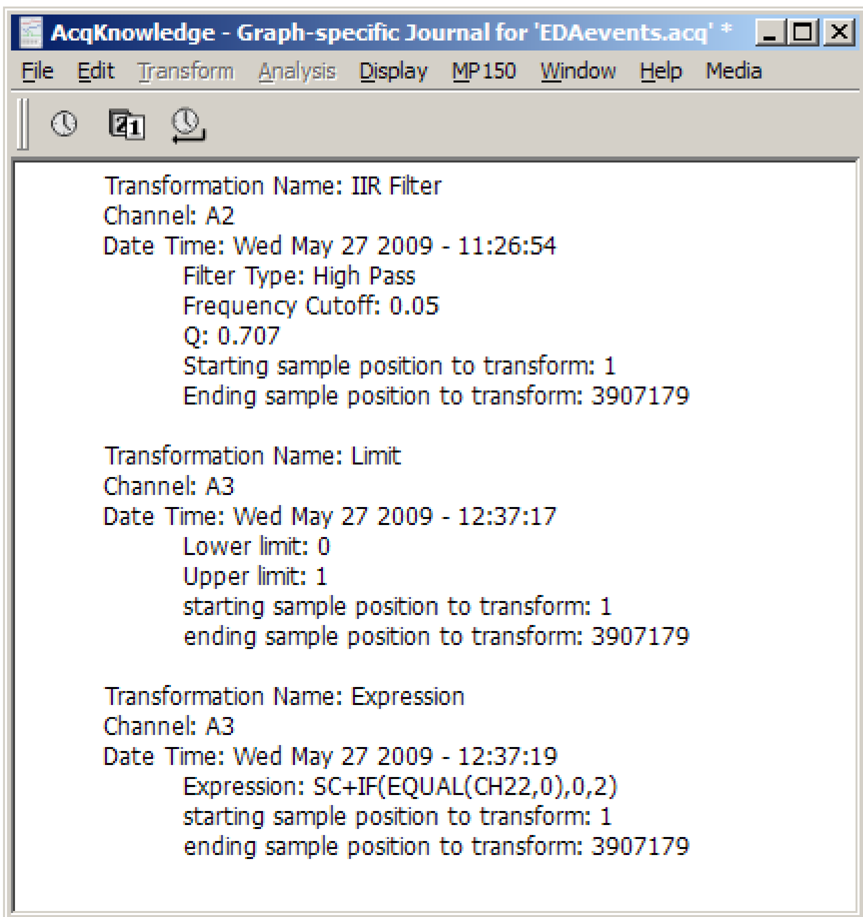
  Note Using Paste Wave Data on larger files may crash the application due to the excessive number of text lines generated (the problem is not the data size). For instance, one large file sample was 300,002 lines—a 3 MB text file.

- Paste Acquisition Settings

  Pastes the acquisition settings to the journal as they were copied via Edit > Clipboard > Copy Acquisition settings.

- Paste Modification History…

  Use after Copy Data Modification History… to paste the transformation history from the clipboard for all channels or for the selected channel to an active Journal window or other word processing application. Modification history includes the transformation name, channel (analog, calc, or digital), date & time, and relevant transformation parameters, including starting and ending sample position.

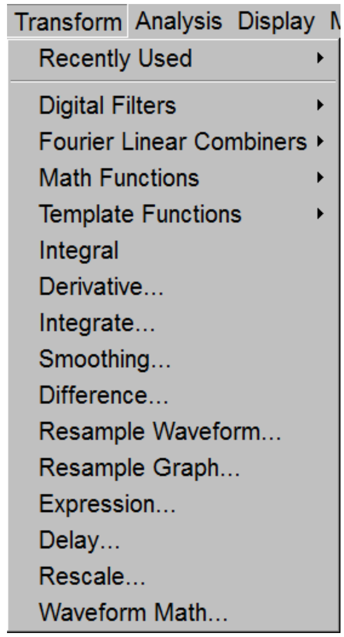


- Show Journal

  Toggle to display/hide the Journal window.

Chapter 15 Transform menu commands

Overview



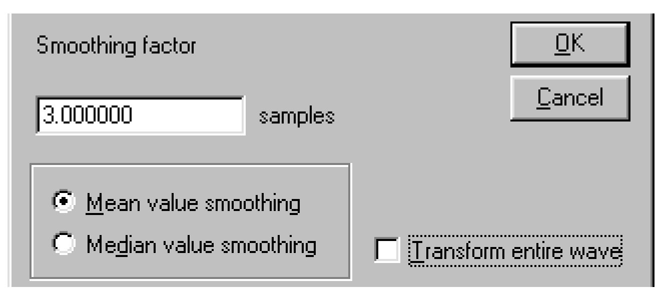
The Transform menu contains operations that primarily modify the data in the graph.

Acq*Knowledge* provides a number of options for post-acquisition analysis and transformations. These transformations allow you to perform a range of operations on your data, from digital filtering and Fourier analysis to math functions. All of these options can be found under the Transform menu, and are disabled while an acquisition is in progress. Unless otherwise noted, all of the transformations described here apply to the selected channel only. Some options (such as the expression and math functions) allow you to specify a channel (or channels) to be transformed.

It is important to remember that Acq*Knowledge* is always selecting at least one point, and the cursor will flash whenever only one point is selected. Some of the transformation functions (e.g., math function, waveform math) can operate on a single sample point, and will transform a single sample point when only one is selected.

There are two ways to apply a transformation to an entire waveform.

a) For transformations that generate a dialog, check the “transform entire waveform” box (usually located toward the bottom of each dialog). This will transform the entire waveform, regardless of whether a single point, area, or the entire waveform is selected.



b) For transformations that do not generate a dialog, use the Edit > Select all command prior to selecting the transformation. This will transform the entire waveform for all of the transformation functions.

- Edit > Select All is not necessary when only a single point is selected prior to selecting the transformation because Acq*Knowledge* will automatically apply the transformation to the entire waveform since it is not possible to perform these transformations on a single point.

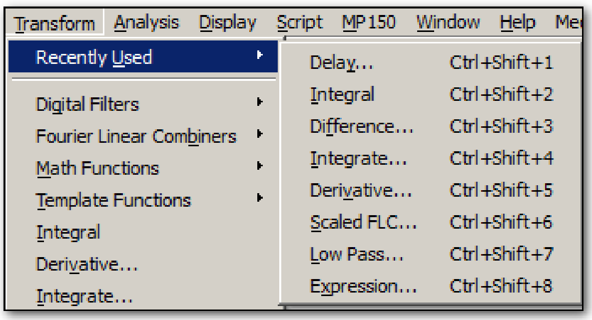
Note Transformations require Acq*Knowledge* to allocate additional memory and then load the data into memory; when transformations are executed on large data files, the application may crash.

Recently Used Transformations

The Transform > Recently Used submenu allows quick access to a user's most recently used transformations and analysis commands. The Recently Used submenu also appears at the top of the Transform submenu available from the context menus of waveforms.

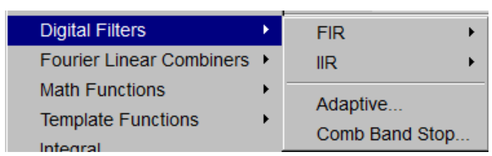
The submenu lists a default of five of the most recently used transformations, with the most recently executed at the top of the menu. To adjust the number of recent transformations displayed, select Display > Preferences.

The recently used transformation listing is saved and restored across subsequent launches of Acq*Knowledge*. It also is application wide: Executing a transformation in any graph will add that transformation onto the recently used list. The recently used list is independent for each user account.



The recently used tranformations can also be launched by the keystroke combinations appearing in the menu. (Acq*Knowledge* 4.2 and higher)

Digital Filters



FIR filters are linear phase filters, which mean that there is no phase distortion between the original signal and filtered waveforms.

IIR filters are not phase linear filters, but are much more efficient than FIR filters in processing data. The IIR filters are useful for approximating the results of standard biquadric filters of the form:

$$(as^2 + bs + c) / (xs^2 + ys + z)$$

These types of filters are commonly implemented in electronic analog circuitry. IIR filters are also used for online filtering (discussed on page 131).

- See Appendix B for more information about the differences between these types of filters.

Adaptive filtering is a signal processing technique that processes two different signals in relation to one another; see page 272 for details.

To understand how digital filters work, it is important to understand the nature of analog signals and their frequency components. All analog signals are comprised of signals of various frequencies. A commonly used analogy is that of the color spectra. Just as white light is made up of a variety of colors that have different wavelengths (frequencies), physiological signals are comprised of specific signals with unique frequency signatures.

For example, an electroencephalogram (EEG) recording is comprised of several different types of signals, each of which has a different frequency signature. Alpha waves (one of the most studied EEG signals) have a frequency range of about 8 Hz to 13 Hz. This means that alpha waves go through a complete cycle (from peak to peak or trough to trough) anywhere from eight to 13 times a second.

There are, of course, signals that have other frequency signatures in EEG data. Most types of physiological data have a number of different frequency signatures present in the overall signal. In addition, frequency components besides the signal(s) of interest are often present. In the U.S., it is not uncommon for 60 Hz electrical noise to be acquired along with physiological signals (in other countries, AC interference is present at either 60 Hz or 50 Hz).

Use digital filtering to retain only the frequency components of interest and remove other data (whether it is "noise" or merely physiological signals outside the range of interest).

It is important to note that the way in which data is filtered depends in large part on the sampling rate at which the original data was acquired. For instance, if data was collected at 50 samples per second (50 Hz), it is not possible to filter out 60 Hz signals.

In fact, data must be sampled at a rate equal to at least twice the frequency of the signal to be removed. So, if data is to be collected and the information between 80 Hz and 120 Hz is to be removed, the data must be sampled at 120 Hz*2, or 240 samples per second (or faster). Also, each channel of data is filtered separately, so removing one type of data from one channel will not affect any other channels.

Digital filters can be divided into four general classes:

low pass band pass high pass band stop

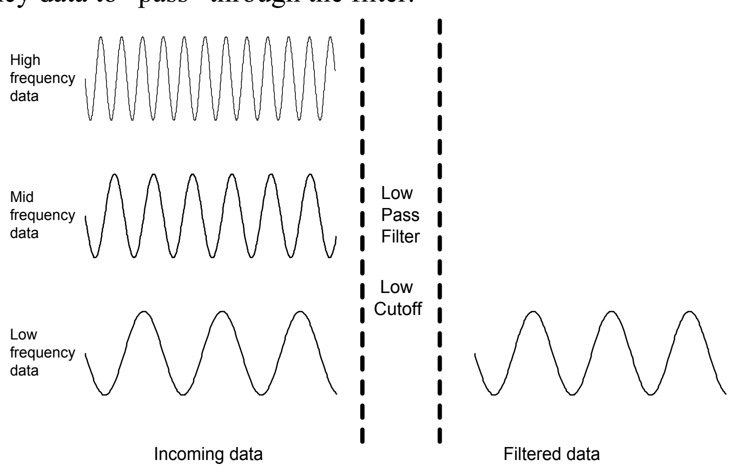
Descriptions of these four classes of filters follow, with visual examples of how these filters work. In each of the four examples, a single channel of data containing frequency components in three ranges (low frequency, mid-range, and high frequency) is acquired.

- Low frequency data, by definition, has slowly changing values, much like respiration patterns or core temperature variations.
- High frequency data, compared to low frequency data, is noticeably more "spiked," much like an EMG signal. As you can tell, the high frequency wave repeats itself about five times in the time it takes the low frequency wave to repeat once.
- Mid-range data falls somewhere in between these two extremes.

In the examples that follow, one possible way that these data could have been collected is if respiration were measured, but the measurement was contaminated with high-frequency muscle movement and mid-frequency signal coming from AC interference. The data is then passed through a filter, where some of the frequency components are removed.

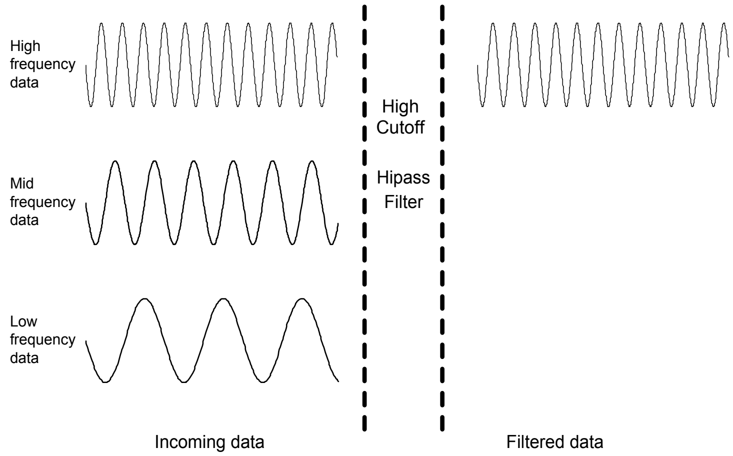
Low pass filtering

In the example below, a low pass filter attenuates the data above a given threshold, allowing only lower frequency data to "pass" through the filter.



High pass filtering

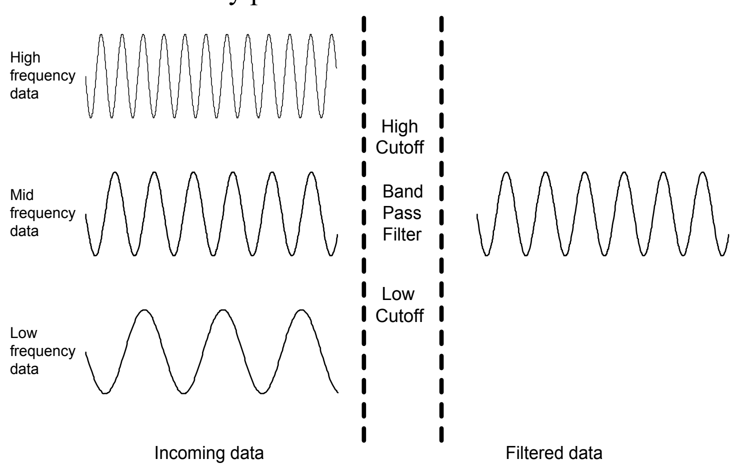
In the example below, a high pass filter removes the low and middle range data, but allows the high frequency data to pass through the filter.



Whereas the low pass and high pass filters retain data either above or below a given threshold, the next two types of filters work with a range, or band, of data.

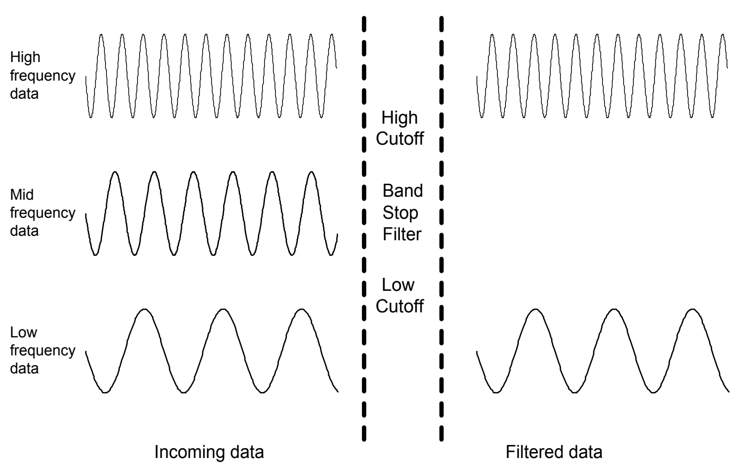
Band pass filter

The band pass filter, allows only the data within the specified range to pass through the filter. A band pass filter is useful when you want to retain only specific waves from an EEG record. For instance, to retain alpha waves, you can set the filter to only pass data between 8 Hz and 13 Hz.

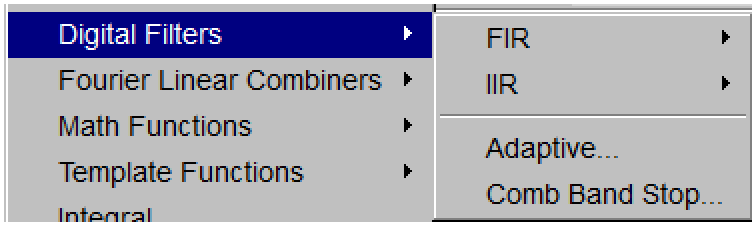


Band stop filter

The band stop filter allows data to pass above and below the specified range. This type of filter is typically applied to remove extraneous 60 Hz or 50 Hz noise from a data record.

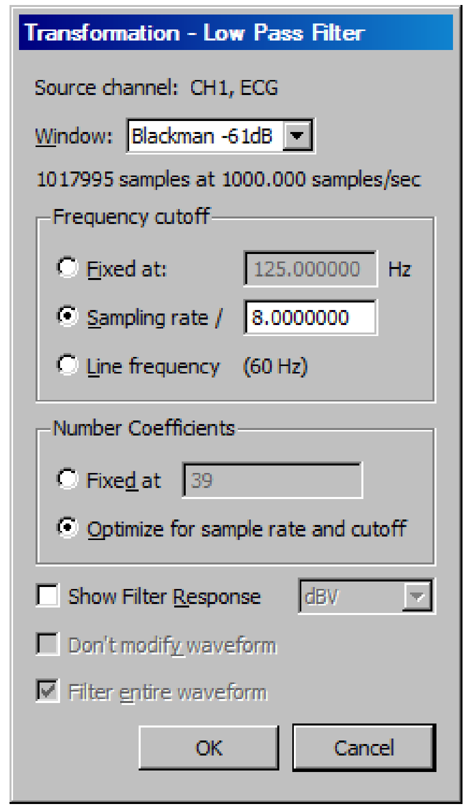


FIR Filters



Digital filter dialog

When you select an FIR filter type, the corresponding Digital Filter dialog will pop up, allowing you to specify a number of different filtering options.



1. Window. The Window popup menu allows you to choose from a variety of filtering algorithms. The filter default is set to a "Blackman" type. These different Windows (described in detail in Appendix D) allow you to "fine tune" the filter response.
2. Cutoff Frequency (Hz) (or threshold). Enter a fixed value or set to a fraction of the sampling rate or to line frequency.

   Sampling rate—frequency is set to a fraction of the sampling rate and automatically updates when the sample rate is modified.

   Line frequency—frequency is set to the line frequency at which the data was recorded.

   Fixed at —Fixed value guidelines are as follows:

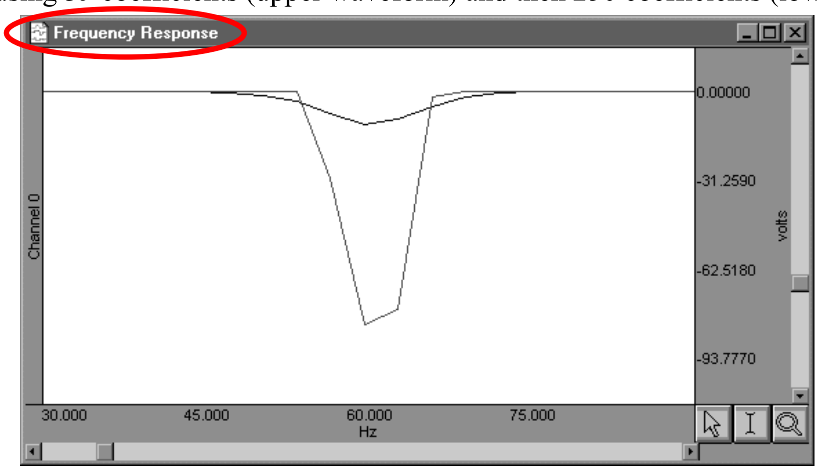
   - *Low Pass Filter*—data with frequency components below the cutoff will pass through the filter, whereas frequency components above the threshold will be removed. For low pass filters, the default cutoff frequency is the waveform sampling rate divided by eight and can be set to any value between 0.000001Hz and 0.5 times the sampling rate.
   - *High Pass Filter*—data with frequency components above the cutoff will pass through the filter, whereas frequency components below the threshold will be removed. For high pass filters, the default threshold is the waveform sampling rate divided by four and can be set to any value between 0.000001Hz and 0.5 times the sampling rate.
   - *Band-type Filters*—a low threshold and a high threshold must be specified to define the band of data (the frequency range) that is either passed or stopped, depending on whether it is a Band Pass or Band Stop filter. In either case, the default for the low threshold is the waveform sampling rate divided by eight and the default for the high threshold is the waveform sampling rate divided by four. The threshold settings can take on any value from 0.000001Hz and 0.5 times the sampling rate, but the two thresholds cannot be set to the same value and the high threshold must be greater than the low threshold.
3. Number of Coefficients. Enter a fixed value or enable the optimize option.
   - Fixed at—This determines how well the filter will match the desired cutoff frequency (or range). The minimum number of coefficients is 3 and the maximum must be less than the total number of sample points in the selected area. The software will truncate the maximum number of coefficients to the highest odd number less than the total.
   - Optimize for sample rate and cutoff—the number of coefficients is set as four times the sampling rate divided by the cutoff frequency of the filter. Optimize does not necessarily produce the best quality filter, but it takes less time.

   The recommended number of coefficients is

   4 x (waveform sampling rate/lowest frequency cutoff for the filter)

For every filter except the band pass, the lowest frequency cutoff is equal to the specified cutoff frequency for the filter; for the band pass filter, the lowest frequency cutoff is the low frequency cutoff setting. Filters that use a small number of coefficients tend to be less accurate than filters that use a large number of coefficients. Larger coefficients increase filter accuracy, but also increase the processing time required to filter the data.

To see how changing the number of coefficients affects the way data is filtered, it can be useful to examine the filter response patterns. In the example below, data was collected at 500 Hz and the band stop filter was designed to remove 60 Hz noise using a low cutoff of 55Hz and a high cutoff of 65Hz. The same data was band stop filtered using 39 coefficients (upper waveform) and then 250 coefficients (lower waveform).

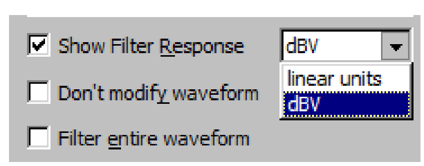


Along the horizontal axis, the units are scaled in terms of frequency, with lower frequencies at the left of the screen. The values along the vertical axis are scaled in terms of dB/V and indicate the extent to which various frequencies have been attenuated.

In both filter response waveforms, there is a downward-pointing spike that is centered on 60 Hz. The baseline of the filter response corresponds to a value of approximately 0 on the vertical axis, indicating that the signals significantly above or below 60 Hz were not attenuated to any measurable extent. As you can tell, however, the filter does not "chop" the data at either 55Hz or 65Hz, but gradually attenuates the data as it approaches 60 Hz.

For example, the upper waveform in the filter response plot represents data that was filtered using a value of 39 coefficients. The slope is relatively shallow when compared to the lower waveform, which represents a filter response performed with 250 coefficients. Although the filter that used 250 coefficients took slightly longer to transform the data, the filter response pattern indicates that the data around 60 Hz is attenuated to a greater degree. Also, the 250-coefficient filter started to attenuate data considerably closer to the 55 Hz and 65 Hz cutoffs, whereas the default filter began to attenuate data below 55 Hz and above 65 Hz.

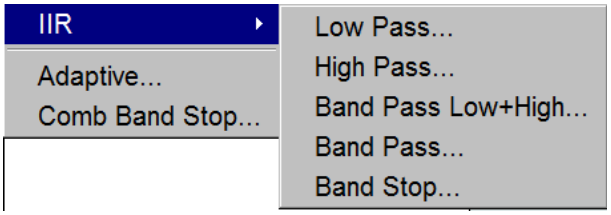
> TIP: A good rule of thumb is to use a number of coefficients greater than or equal to two times the sampling rate divided by the lowest cutoff frequency specified. For example, if running a low pass filter at 1 Hz on data sampled at 100 Hz, choose at least (2 x 100/1) or 200 coefficients in the filter. Additional coefficients will improve the response.

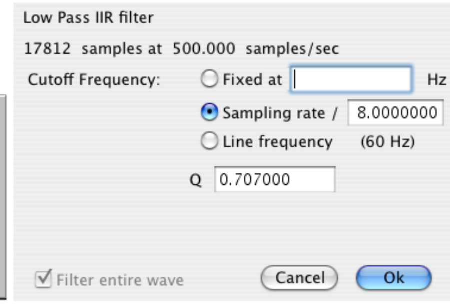


4. Show Filter Response. When checked, this option generates a plot of the filter response in a new window, labeled "Frequency Response" (see example above).
   - Units: Select linear units or dBV.
5. Don't modify waveform. This option is useful in conjunction with the "Show Filter Response" option. When both boxes are checked, Acq*Knowledge* will produce a plot showing the filter response, but will not modify the waveform. This allows you to repeatedly specify different filter options (without modifying the waveform) until the desired frequency response is achieved.
6. Filter entire wave. If this option is checked, Acq*Knowledge* will filter the entire wave and replace the original. If you want to keep the original, duplicate it prior to filtering.

IIR Filters

To access the IIR filter dialog, click the Transform menu, scroll to select Digital Filters, drag right to IIR and drag right again for the filter options. For all filter types, the software will limit the frequency setting so it cannot exceed one-half the channel sampling rate. For real-time filter options, see page 131.





Low Pass and High pass
: Pass data that falls below or above the specified standard. The Low Pass default is waveform sample rate/8; the High pass default is waveform sample rate/4.

Band Pass (low + high)
: Pass a variable range of data. Specify a low frequency cutoff and a high frequency cutoff to define the range or "band" of data that will pass through the filter; frequencies outside this range are attenuated. For the Band Pass Low + High filter, the low default is waveform sample rate/8 and the high default is waveform sample rate/4.

- This filter is best suited for applications where a fairly broad range of data is to be passed through the filter. For example, apply to EEG data to retain only alpha wave activity.

Band Pass (single freq)
: Requires only a single frequency setting, which specifies the center frequency of the band to be passed through the filter. The "width" of the band is determined by the Q setting of the filter (discussed in detail below). Larger Q values result in narrower bandwidths, whereas smaller Q values are associated with a wider band of data that will be passed through the filter. This filter has a bandwidth equal to Fo/Q, so the bandwidth of this filter centered on 50 Hz (with the default Q=5) would be 10 Hz. Although functionally equivalent to the Band Pass (low + high) filter, this filter is most effective when passing a single frequency or narrow band of data, and to attenuate data around this center frequency. The Band Pass (single frequency) default is waveform sample rate/8.

Band Stop (single freq)
: Defines a range (or band) of data and attenuates data within that band (the opposite function of a band pass). This filter is implemented in much the same way as the standard Band Pass, whereby a center frequency is defined and the Q value determines the width of the band of frequencies that will be attenuated. The Band Stop (single frequency) default is waveform sample rate/8.

Q coefficient
: The online filters are implemented as IIR (Infinite Impulse Response) filters, which have a variable Q coefficient. The Q value entered in the filter setup box determines, in part, the frequency response of the filter. This value ranges from zero to infinity, and the "optimal" (critically damped) value is 0.707 for the Low Pass, High pass and Band Pass filters. A Q of .707 for any of these filters will result in a second order Butterworth response. The Q is set to a default of 5.000 for the single frequency Band Pass and Band stop filters. For more details about the Q setting, see the Appendix.

Sampling rate
: Sets the Frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.

Line frequency
: Sets the Frequency to the line frequency at which the data was recorded.

Adaptive Filtering

Adaptive filtering is a signal processing technique that processes two different signals in relation to one another and can be used for noise estimation, noise reduction, general-purpose filtering, and signal separation. Adaptive filtering creates efficient high-quality filters with a minimal number of terms, which can be very useful in blocking mains interferences or other known periodic disturbances.

- Useful for noise filtering where it is possible to acquire a signal that is correlated to the noise (similar to the way noise-cancelling headphones detect and remove outside noise). Applications include removing EMG from ECG or EOG from EEG.

➲ See the Adaptive Filtering Calculation Channel on page 146.

The weights within an adaptive filter are modified on a step-by-step basis. Acq*Knowledge* uses the N-tap FIR adaptive filter, with coefficients updated using least means squares (gradient) feedback.

Source signal

The source channel will be replaced by the adaptive filter results.

Noise signal

The noise channel is the signal that is correlated with the noise to be eliminated from the Source; it is not modified by adaptive filtering.

Source and Noise channels must have the same sampling rate.

Order

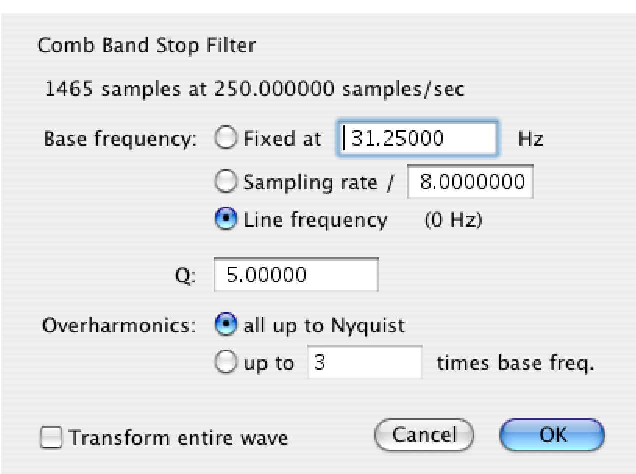
Specify a positive integer for the number of terms to be used in the internal FIR filter.

Step size

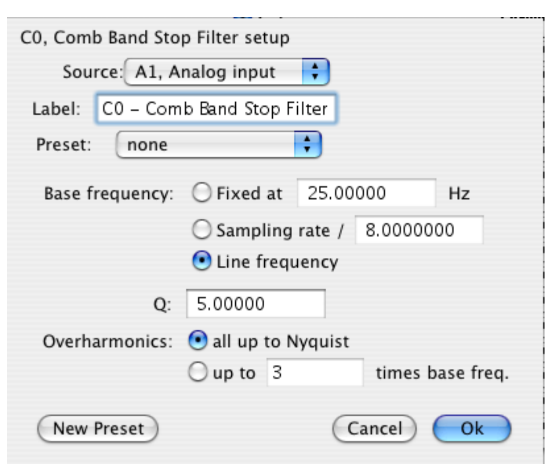
Provides *mu*, the rate of adaptation of the coefficients within the FIR filter.

Comb Band Stop Filter

Comb Band Stop filters out a fundamental frequency and its overharmonics (integer multiples of the base). Resonance, aliasing, and other effects may generate interference at multiples of a base frequency. The Comb Band Stop filter combines all the required filters instead of requiring a separate filter for each interfering overharmonicX.



Transformation Dialog



Calculation Channel Dialog

Resonance, aliasing, and other effects may generate interference at multiples of a base frequency. The Comb Band Stop filter combines all the required filters instead of requiring a separate filter for each interfering

overharmonic. Comb Band Stop filters remove a fundamental frequency and its overharmonics (e.g., integer multiples of the base frequency) from a signal, and are useful for removing noise. Acq*Knowledge* approximates a Comb Band Stop filter by cascading a series of IIR Band Stop filters, and is limited to removing frequencies and overharmonics. The number of filters used can be fixed at a particular number (e.g., limiting the number of harmonics to filter out) or configured to automatically remove all possible harmonics for any given sampling rate.

- Mac OS — Use the "Comb Band Stop Filter" Automator action to integrate Comb Band Stop filters into Workflows.

For a given base frequency ω and quality factor Q, the comb filter approximation will be given by the set of following formulas:

$$y = \left(F_{\omega} \circ F_{2\omega} \circ F_{3\omega} \cdots \circ F_{k\omega}\right)(x)$$

where $F\omega$ represents a standard two-tap IIR band stop filter for the frequency ω with coefficients computed using the quality factor Q.

The number of overharmonics of the base frequency to be removed is given by the integer value k. The maximum allowable number of overharmonics may be automatically determined given the sampling frequency f_s:

$$k_{\max} = \left\lfloor \frac{f_s}{2\omega} \right\rfloor$$

This limits the maximum overharmonic frequency to be less than the Nyquist of the sampling frequency.

After the first comb filter is performed, the most recently used settings for the comb filter will be displayed, (except for “Transform entire wave,” which will be reset each time the dialog is opened).

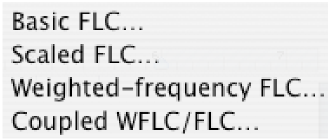
Textual export will include the source channel, base frequency, quality factor, and number of harmonics.

Comb Band Stop Filter Dialog

number of samples	Width of the selection.
@ samples/sec	Waveform sampling rate of the source channel. • The channel sampling rate of the calculation channel can not exceed the channel sampling rate of the source channel. Downsampling will be applied to the source channel prior to comb filter processing, if required, and all Nyquist frequency restrictions will be determined from the calculation channel sampling rate.
Frequency	Fixed—The comb filter will remove this base frequency and integer multiples of this frequency. • Must be positive and less than the Nyquist frequency (half the sampling rate). Sampling rate—Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified. Line frequency—Uses the line frequency at which the data was recorded.
Q	Quality factor used when computing the coefficients of the IIR notch filters. • Must be positive.
all up to Nyquist	Removes all integer multiples of the base frequency. This will include all multiples of the base frequency that are less than the Nyquist frequency.
Harmonics	Removes the base frequency and integer multiples of the base frequency up to and including the multiple contained in the edit field • Must be an integer greater than 0 and must not exceed k max • The final multiple must be less than theNyquist frequency. If it is not, the input will need to be corrected before the comb filter can be applied.
OK	If the settings are valid, executes the comb filter transformation. Verification of certain calculation channel parameters does not occur until the start of acquisition as sampling rates may be changed after calculation channels are configured. Prior to the start of acquisition, the following will be checked: • source channel to ensure it is still being acquired. • base frequency of the comb filter to ensure it is less than the Nyquist frequency of the channel sampling rate. • if the user has manually specified that a fixed number of overharmonics should be used, the number of overharmonics to ensure the highest used overharmonic does not exceed the Nyquist frequency of the channel sampling rate. If any of the parameters are invalid, a prompt will be displayed indicating which settings are incorrect and must be fixed for the acquisition to be started.
Cancel	Quits without modifying any data.
Source	All enabled analog, digital, and lower-index calculation channels.
Label	When the calculation type of a channel is changed to comb filter, the title of the channel will be replaced with the default label "C*n* –Filter" where *n* is the index of the calculation channel. • Must be 40 characters or less.
Preset	Displays the title of any Calculation Preset currently applied to the calculation channel.

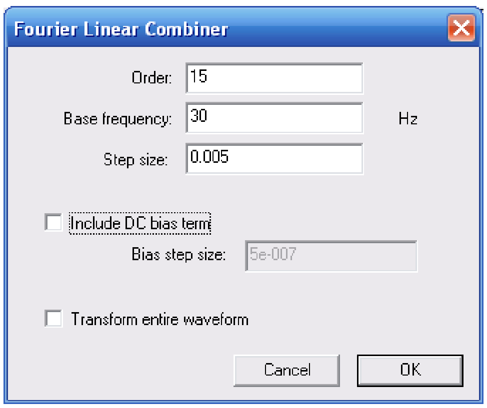
Fourier Linear Combiners

Transform > Fourier Linear Combiners:



➲ See FLC Calculation Channel options on page 145.
➲ See FLC references on page 276.

Fourier Linear Combiners are linear combinations of adaptable sinusoidal functions that are particularly well suited to processing cyclic data. Sine and cosine harmonics of a *base frequency* are summed together and the *order* is the fixed number of harmonics used in the model. *Step size* provides mu, the gain factor used to adjust the weights of the harmonics at each processing step. Step sizes must be much less than 1 for the system to converge. As step sizes decrease, relaxation time lengthens. The FLC model is adjusted based on the source data using least means square (LMS) feedback and the *bias* compensates for DC offset.



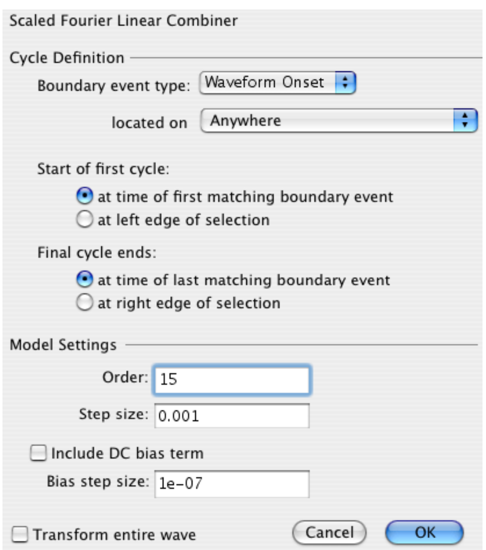
Basic FLC

Simple summation of fixed numbers of sines and cosines; uses harmonics of a fixed frequency and adjusts weighting coefficients of the mixture.

Operates on a single channel at a time.

Well suited for extracting data of a known frequency band from a signal with a stable frequency.

- Use as an adaptive noise filter to remove non-periodic and semi-periodic noise uncorrelated to the base harmonic frequency.



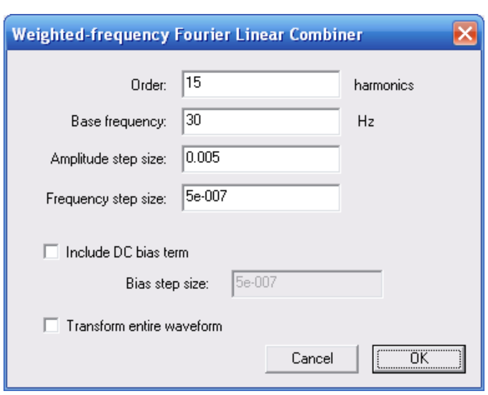
Scaled FLC

Fundamental harmonic frequency can vary on a cycle-to-cycle basis. The frequency remains fixed within a single cycle and must be known before processing.

Scales the harmonics used in each cycle based on cycle boundary events (defined through the Cycle Detector, ECG Analysis, or manually). Events from one signal can be used to drive analysis of another signal.

Well suited for signals with detectable boundaries, such as ECG.

- Use to extract information that is tightly coupled to other cyclic signals, such as extracting ICG based upon *Knowledge* of the RR cycles of the ECG.



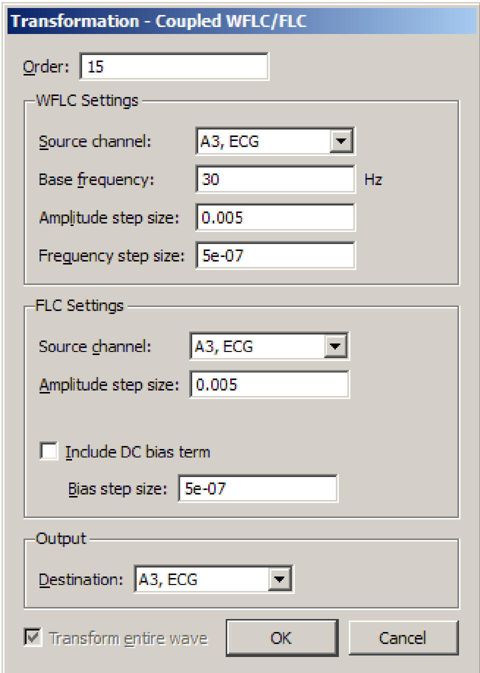
Weighted-Frequency FLC

Base frequency of the harmonics is variable; adapts the frequency in response to the input signal using LMS feedback; the frequencies are similarly adjusted to the amplitudes.

Operates on a single channel at a time.

Well suited for modeling periodic signals of an unknown and potentially varying frequency and/or amplitude.

- No cycle boundaries or frequencies need to be pre-determined.



Coupled WFLC/FLC

Runs a WFLC on the signal to determine the harmonic frequency and then runs the result through an FLC using the computed harmonic. The second FLC can be run on the same or a different channel.

The transformation will occur in the channel designated as " Output."

Well suited for real-time extraction of information from one signal based upon the frequencies contained in another signal.

- Use to remove movement noise from ECG.
- Unique configurations can be established with two input signals, one for frequency and one for amplitude.

FLC References

The basic Fourier linear combiner (FLC) is described by Vaz and Thakor.

- Christopher A. Vaz, and Nitish V. Thakor, "Adaptive Fourier Estimation of Time-Varying Evoked Potentials," *IEEE Trans. Biomed. Eng.*, VolBME-36, pp. 448-455.

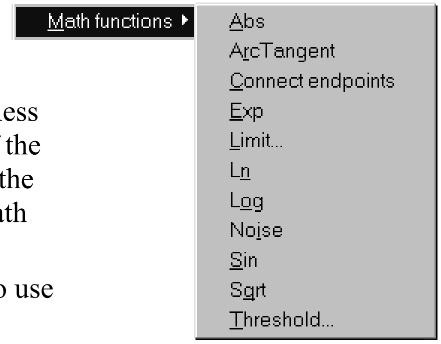
The weighted-frequency Fourier linear combiner (WFLC) and the coupled weighted-frequency Fourier linear combiner (CWFLC) are described by Riviere, Rader, and Thakor.

- Cameron N. Riviere, R. Scott Rader, and Nitish V. Thakor, "Adaptive Canceling of Physiological Tremor for Improved Precision in Microsurgery," *IEEE Trans. Biomed. Eng.*, Vol BME-45, pp. 839-846.

The scaled Fourier Linear Combiner (SFLC) is described by Barros, Yoshizawa, and Yasuda.

- Allan Kardec Barros, Makoto Yoshizawa, and Yoshifumi Yasuda, "Filtering Noncorrelated Noise in Impedance Cardiography," *IEEE Trans. Biomed. Eng.*, Vol BME-42, pp. 324-327.

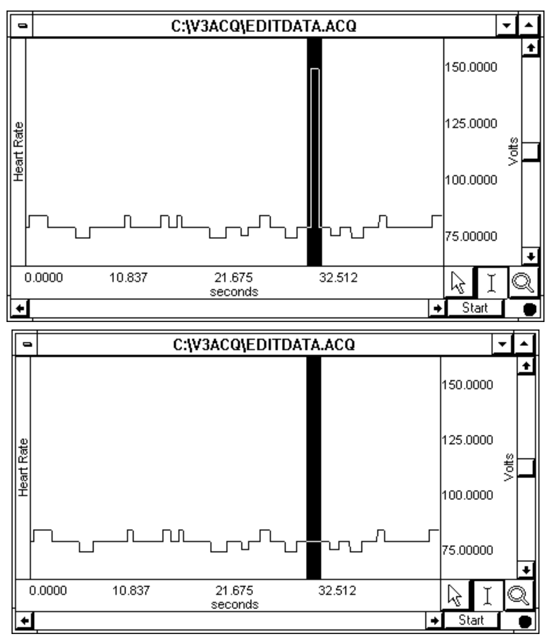
Math Functions



Acq*Knowledge* allows you to perform a wide range of mathematical and computational transformations after an acquisition has been completed. Unless otherwise noted, each of these functions applies only to the selected area of the selected channel. If no area is selected (i.e., a single data point is selected), the cursor will blink and Acq*Knowledge* will transform the entire wave. If a math function attempts to divide by zero, a zero will be returned.

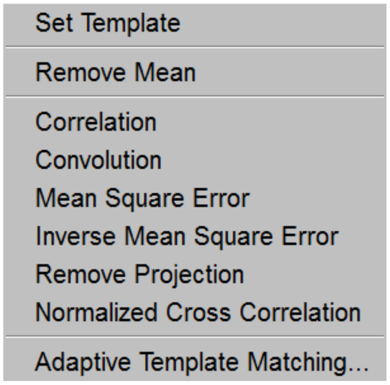
For complex transformations involving multiple functions, you may want to use the Expression/ Equation Generator (see page 293 for details).

The following table describes the commands available in the Transform > Math functions menu:

Transform > Math	**Explanation of Command**
Abs (Absolute Value)	Computes the absolute value of the data. All negative data values are made positive, with no change in magnitude. This function can be used to rectify data.
Atan (Arc Tangent)	Returns the arc tangent of each data point in radians. This rescales the data such that the range is from $-\pi/2$ to $\pi/2$.
Connect endpoints (Connect the endpoints)	Draws a line from the first selected sample point to the last selected sample point and interpolates the values on this line to replace the original data. The *connect endpoints* function is very useful for removing artifacts in the data or in generating waveforms. In the example below, the “noise spike” in the data is an undesired measurement artifact that should be removed. You could cut the section of data, but then all subsequent data points would shift left. In order to preserve the time series of the data, you could use the *connect endpoints* command to draw a straight line (although not necessarily flat) that connects the two extreme sample points of the selected area.  *Area selected before (top) and after (bottom) connect endpoints function*
Exp (Exponential)	Computes the function e^x, where x is the waveform data and e is 2.718281828. This is the base of the natural logarithms.
Limit (Limit data values)	“Clips” data outside the range specified by the set of thresholds in the limit dialog. This function will prompt you for an upper and lower limit. Any data values outside these limits will be clipped at the closer limit. Although both a high and low threshold must be entered, To limit only one extreme (high or low) while leaving the other extreme unaffected. For instance, if you wanted to limit data so that all

Transform > Math	Explanation of Command
	negative values were set to zero but the positive values were left unchanged, you would set the low threshold to zero and the high threshold to 99 (or some other large positive value that exceeds the maximum value for that channel).
Ln (Natural Logarithm)	Computes the natural logarithm of the selected section. The inverse of this function is the exponential function, *Exp*.
Log (Base 10 Logarithm)	Computes the base 10 logarithm of the selected section. In order to perform the inverse of this function, which would be 10^x, use the Waveform Math power operator with the constant k=10 as the first operand and the waveform data as the second operand.
Noise	Converts the selected section into random data values between –1.0 and +1.0. This is mainly useful for creating stimulus signals and other waveforms.
Sin (Sine)	Calculates the sine of the selected section. The data is assumed to be in radians.
Sqrt (Square Root)	Takes the square root (√) of each data point in the selected section.
Threshold (Threshold data values).	Transforms all data points above the threshold to +1 units, and converts all values below the lower threshold to 0 units. Once the data crosses a threshold it will continue to be set to +1 for the upper cutoff and 0 for the lower cutoff, until it crosses the opposite threshold. The most common application of this function is to serve as a simple peak detector, the results of which can be used in rate or phase calculations. Threshold Algorithm Assume a domain variable $t \in \{t_{start}, t_{start}+1, t_{start}+2, \ldots\}$ with t_{start} being an integer, a real-valued signal y(t) defined for all t, and two real valued levels y_{low} and y_{max} satisfying the relation $y_{low} \le y_{high}$. Define the threshold function thresh(t) function such that: $thresh(t_{start}) = \begin{cases} 1 & y(t_{start}) \ge y_{low} \\ 0 & y(t_{start}) < y_{low} \end{cases}$ $thresh(t) = \begin{cases} 0 & y(t) < y_{low} \\ 1 & y(t) > y_{high} \\ thresh(t-1) & y_{low} \le y(t) \le y_{high} \end{cases}$

Template Functions



The Template Functions are useful for comparing waveforms. Technically, the template functions provide correlation, convolution and mean square error transformations of a template waveform against another waveform. To activate the full template menu, select an area and then select set template.

> NOTE: To determine a level of comparison between two waveforms, use the Correlation function.

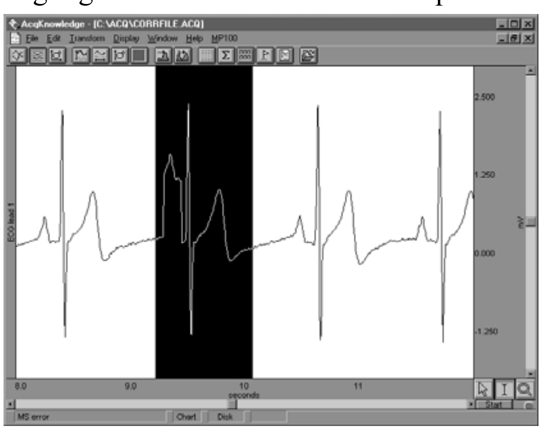
All the template functions perform a mathematical operation of the template waveform on the waveform to be compared, move one sample forward, and repeat the multiplication until the end of the longer waveform is reached.

Set Template

Use the following ECG waveform as an example. An abnormality exists in the record. After detecting an abnormality, you should find out if there are other (similar) abnormalities in the record. To do that, you need to select the pattern you'd like to search for, and then compare that pattern to other data sets in the file.

Selecting a section of a wave to be used as a template:

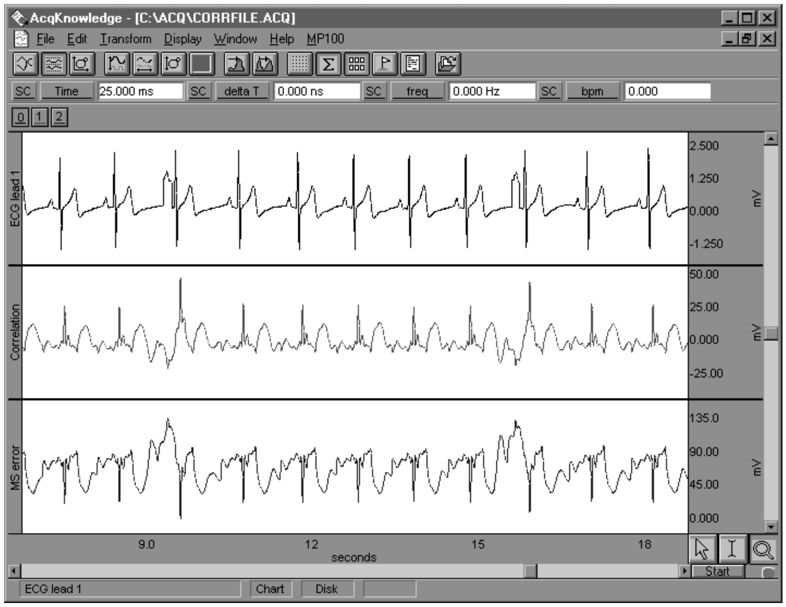
1) Highlight the section to be used as a pattern.



2) Click the Transform menu and choose Set template from the Template functions submenu. This copies the selected portion into a buffer for subsequent template functions
3) Select the waveform and position the cursor at the beginning of the data.
4) Choose Correlation from the Template functions submenu. The center waveform in the graph below shows the result of the correlation.

Note the higher amplitude peaks where the template data more closely matches the waveform. The lower waveform illustrates the mean square error function, which is similar to the correlation function.

This indicates that there are two abnormal beats in the record. The first one appears at about 3 seconds and is the one used as a template; the second one appears at about 11 seconds.



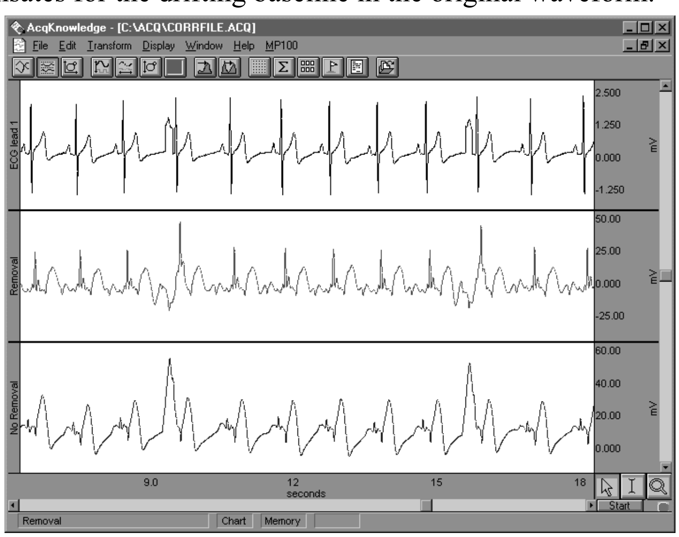
Result of correlation and mean square error functions

5) Use the zoom tool to inspect the abnormalities more closely.

Remove mean

A drifting baseline can be a problem in comparing waveforms. If you perform a Template function and the template or the waveform has a slowly moving baseline, you can increase the effectiveness of the comparison by choosing Remove mean from the submenu of the Template function. The remove mean option causes the mean amplitude value of the template and the compared section of the waveform to be subtracted from each other before the sections are compared. This way, a large baseline offset will have very little effect on the comparison. This option is toggled every time it is selected and is enabled when a check mark is present.

For example, the following graph shows the original waveform at the top, the correlated waveform with mean removal in the middle, and the same correlation without mean removal at the bottom. Note how the mean removal effectively compensates for the drifting baseline in the original waveform.



Correlation with and without mean removal

Template algorithms

The template functions are: correlation, convolution, mean square error, inverse mean square error, normalize cross correlation and adaptive template matching.

a) Correlation is a simple multiplication and sum operation (as shown in the preceding example). The template is first positioned at the cursor position in the waveform to be correlated. Each point in the template waveform is multiplied by the corresponding point in the data waveform (the waveform to be correlated) and summed to produce the resulting data point. The template is then moved one data sample forward and the operation is repeated to produce the next resulting data point. The resulting data points replace the waveform to be correlated.

The correlation function algorithm can be expressed by the following formula, where $f_{output}(n)$ is the resulting data point, $f_{template}(k)$ is the template waveform data points, and K is the number of data points in the template:

$$f_{output}(n) = \sum_{k=1}^{K} f_{template}(k) * f_{waveform}(n)$$

b) Convolution is identical to the correlation function except that the template waveform is reversed during the operation. This function is not generally useful by itself, but can be used as a building block for more sophisticated transformations. The convolution function algorithm can be expressed by the following formula, where $f_{output}(n)$ is the resulting data point, $f_{template}(k)$ is the template waveform data points, and N is the number of data points in the template:

$$f_{output}(n) = \sum_{k=-N/2}^{N/2-1} f_{template}(-k) * f_{waveform}(n+k)$$

c) Mean square error positions the template at the cursor position in the waveform to be compared. Each point in the template waveform is subtracted from the corresponding point in the waveform to be compared. The result is squared and summed to produce the resulting data point. The template is then moved one data sample forward and the operation is repeated to produce the next resulting data point. The resulting data points replace the waveform.

The mean square error function tends to amplify the error (or difference) between the template and the waveform, which makes it useful when you are looking for an extremely close match rather than a general comparison. When a match is found, the mean square error algorithm returns a value close to zero.

The mean square error function algorithm can be expressed by the following formula, where $f_{output}(n)$ is the resulting data point, $f_{template}(k)$ is the template waveform data points, and K is the number of data points in the template:

$$f_{output}(n) = \sum_{k=1}^{K} [f_{template}(k) - f_{waveform}(n)]^2$$

d) Inverse Mean square error simply inverts the result of the mean square error algorithm. Accordingly, when this algorithm finds a match between the template and the data, the algorithm returns the inverse of a value close to zero and, typically, a large positive spike will occur at the point of the match.

e) Remove Projection Template removes the projection of a reference signal from another part of a signal (whereas the other template functions revolve around the comparison of a portion of a signal against a reference signal).

Remove Projection treats the template in memory as a vector. The projection of the selected area onto the template is computed as a vector dot product. This projection is then removed from the source data. After a remove projection transformation, the remaining data consists of the part of the signal that is the most unrelated to the template.

Remove Projection can be useful for emphasizing signal differences. For example, it may be useful for exploring differences in an arrhythmia in comparison to a normal reference beat. It may also be useful as a denoising building block by removing the projection of a signal against idealized noise in the template.

The number of samples in the template should match the number of samples in the selected area of source data.

- Dot product is undefined for vectors of mismatched dimensions.
- If the template is longer than the selected source data, the template will be shortened (for that single transformation; it will be restored afterward) so its length matches the selection width.
- If the selection is longer than the template, any data occurring after the end of the template will not be transformed.

To create a Remove Projection template:

1. Highlight the portion of data to be used as the reference signal.
2. Transform > Template > Set Template.
3. Highlight the portion of the data to be analyzed.
4. Transform > Template > Remove Projection.

f) Normalized cross-correlation is useful when searching for variations in the signal. Regular cross-correlation (Transform > Template > Correlation) can exhibit large amplitude spikes when the energy of a signal varies greatly or amplitudes change suddenly, causing jumps that are not necessarily indicative of a match with the template. Normalized cross-correlation is a statistical method that can help resolve these issues by applying normalization to both the template and signal being searched. This reduces the effect of amplitude variation in the result, making normalized cross-correlation useful for template matching purposes.

This transformation computes the windowed normalized cross-correlation, and results in a value between -1 to 1, which indicates the linear fit of the data set. Normalized cross correlation is defined as:

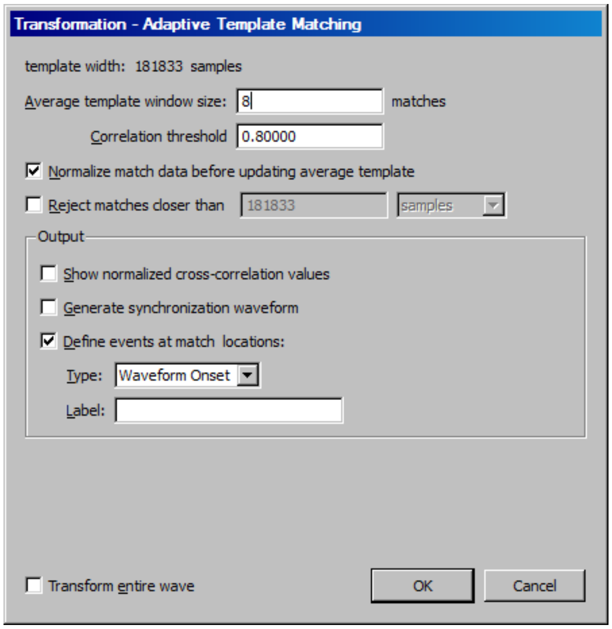
$$\gamma = \frac{\sum_{i=0}^{L}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=0}^{L}(x_i - \bar{x})^2 \sum_{i=0}^{L}(y_i - \bar{y})^2}}$$

where x = template
y = signal
L = length
$\bar{f}$ = mean value of the signal f

At the end of the transformation, the source data will be replaced with the sliding NCC values. Data outside the selected area will be left unmodified. If the selected area is zero width when the transformation is to be executed, the entire waveform will be transformed.

If selection is shorter than the template, the missing data at the right end of the selected area will be filled with zero padding until it matches the length of the template. This padding occurs in memory and will not affect the source data in the graph. The same zero padding is used when computing NCC at the end of every selected area when the template is running off the end of the data. This zero padding should trend the NCC to zero at the right edge of the transformed area, in most cases.

Adaptive Template Matching



Many different types of physiological analysis involve locating repetitive features within a signal. These may occur at regular intervals or may occur sporadically. Sometimes the features of interest may be intermingled with other results, such as occassional heartbeat arrhythmias occurring in a long-term ECG recording. Template matching is one frequently used approach for locating areas of waveforms that exhibit certain characteristics. An example feature is specified as the input template and then, using cross correlation or related methods, the areas of an arbitrary wave that most strongly match the example can be located.

Adaptive Template Matching allows the template to vary during execution to incorporate changes to the morphology of signal features. The adaptation consists of a moving average of a number of the most recent matching features. A template match will be defined as a peak in the windowed normalized cross correlation of the adapting template with the signal.

Normalized cross correlation helps to eliminate artifact due to baseline shift and changes in overall power and amplitude. This heuristic is sensitive to waveform morphology instead of amplitude.

Template width

The number of samples in the template that will be used as the initial template for the transformation, as set using Transform > Template Functions > Set Template.

Note One template is shared globally by all graphs and data views in Acq*Knowledge*.

Average template window size

Input positive integers only. Provides the number of previous matches to be used for constructing the average template estimate.

Correlation threshold

Floating point input in the range -1 to 1. Provides the threshold used for peak detection on the normalized cross correlation signal. Corresponds to r in the algorithm description.

Normalize matching data before updating average template

Toggle check box. When enabled, the reference set normalization algorithm option is used. This performs mean subtraction and unit magnitude normalization to every member of the reference set prior to constructing the average template. This option can help to compensate for unintentional weighting of the windowed average template towards larger amplitude data.

Reject matches closer than

When checked, the minimum match interval algorithm option is used. This rejects matches that are too close together and can compensate for degeneration of the algorithm into continual matching due to signal self similarity. The edit field contains the minimum width that must separate valid matches. The width must always be a positive number. The popup menu specifies the units of the separation interval. Its contents are dependent on the horizontal axis type:

Time (seconds & HH:MM:SS)	Frequency	Arbitrary
samples	samples	samples
milliseconds	Hz	arbitrary units
seconds		
minutes		
hours		

Output

Show normalized cross correlation values provides access to the sequence of correlation values that is examined by the heuristic for potential matches. Viewing the normalized cross correlation signal can provide feedback that is useful for proper threshold selection and for detecting whether the heuristic has fallen into one of its degenerate cases (e.g. NCC signal hovering around the threshold for extended periods of time). When checked, a new channel will be added into the graph containing the normalized cross-correlation values computed by the algorithm.The channel will be labeled "NCC Values."

Generate synchronization waveform allows for the generation of spike trains. The value of the wave in the graph will be zero by default. At each sample position where a match with the average template is triggered, the wave value will be set to one. A single sample position set to 1 indicates a single valid match. This synchronization wave can be used in conjunction with the cycle detector to perform further data reduction, input to the rate detector for computing match frequencies, and other analysis.

Define events at match locations output allows placement of an event on the waveform being analyzed at the location of each valid match. The event output can allow adaptive template matching to be used to construct classifiers that provide event locations for further data reduction with the cycle detector.

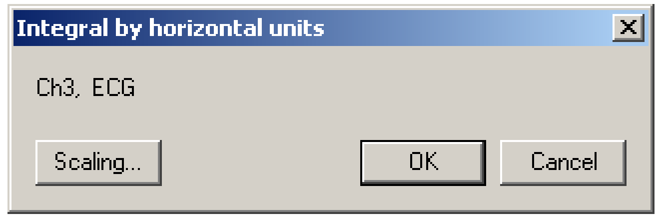
- *Type*—Used to choose the type of event that will be defined at match locations. Displays the standard hierarchical menu list of event types.
- *Label*—Label to be given to events defined at match locations.

Transform entire wave

When checked, the entire waveform will be analyzed. When unchecked, only the selected area will be transformed.

Integral

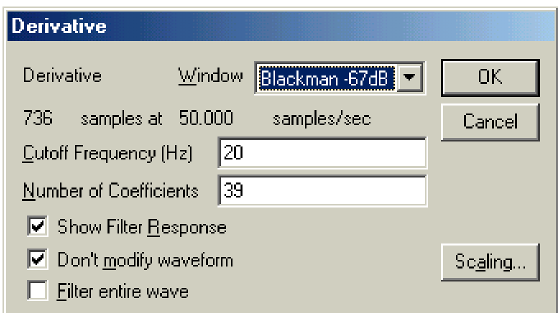
Integral is essentially a running summation of the data. Each point of the integral is equal to the sum of all the points up to that point in time, exclusive of the endpoints, which are weighted by half. The exact formula is below, where f( ) is the data values and ΔTs is the horizontal sampling interval:

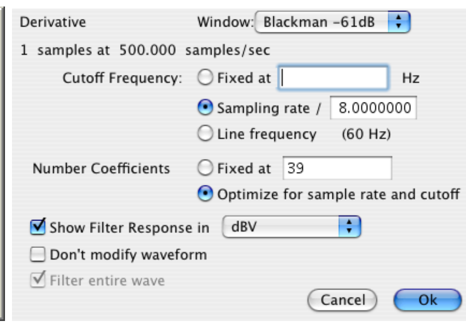


$$f_{output}(n) = \sum_{k=1}^{n-1} f_{input}(k) + [[f_{input}(n-1) + f_{input}(n)] / 2] * \Delta Ts$$

The units will be (amplitude units • horizontal units). The integral function can be used to compute the area under the curve in a continuous fashion. For instance, if you had data acquired by an accelerometer, the integral of the data would be the velocity, and the integral of the velocity would be the distance. As with all transformations, this function can be applied to either a selected area or to the entire waveform.

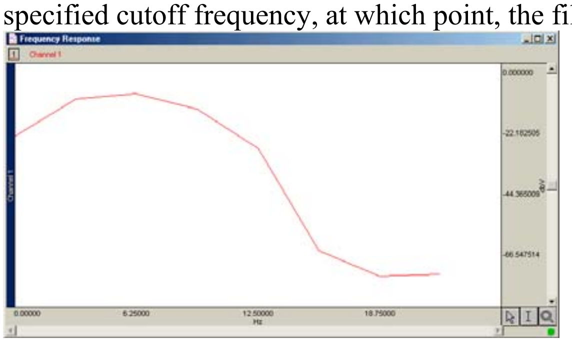
Derivative





Derivative calculates the derivative of the selected area of a waveform. Since high frequency components return nonsensical results in a derivative, a low pass filtering function is included in the Derivative function (see page 267 for more information on low pass filters). Derivative is based on an FIR filter implementation.

The Filter Response for a Derivative transformation will be displayed as a linear graph, not in (log). The Derivative FIR filter frequency response will appear as a linearly increasing magnitude up to the point of the specified cutoff frequency, at which point, the filter magnitude will drop off sharply.



Derivative can provide a more meaningful result than Difference (which often has a higher than required frequency response, thus processing potentially undesirable data). However, if your data is already "well behaved" (i.e., low pass filtered or contains little or no high frequency information), you can use Difference with a 2-sample interval to quickly generate results very similar to Derivative.

Cutoff Frequency

The value entered in the cutoff frequency box should be roughly equivalent to the highest frequency component of interest present in the time series data. The default cutoff frequency is 0.125 times the waveform sampling rate.

Sampling rate—Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.

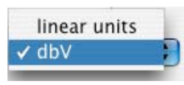
Line frequency—Uses the line frequency at which the data was recorded.

# of Coefficients

Fixed—The default number of coefficients is (4 x waveform sampling rate)/Cutoff Frequency. As the number of coefficients (Q) increases, the Derivative becomes more accurate. Fixed can produce better filters but may take longer to execute.

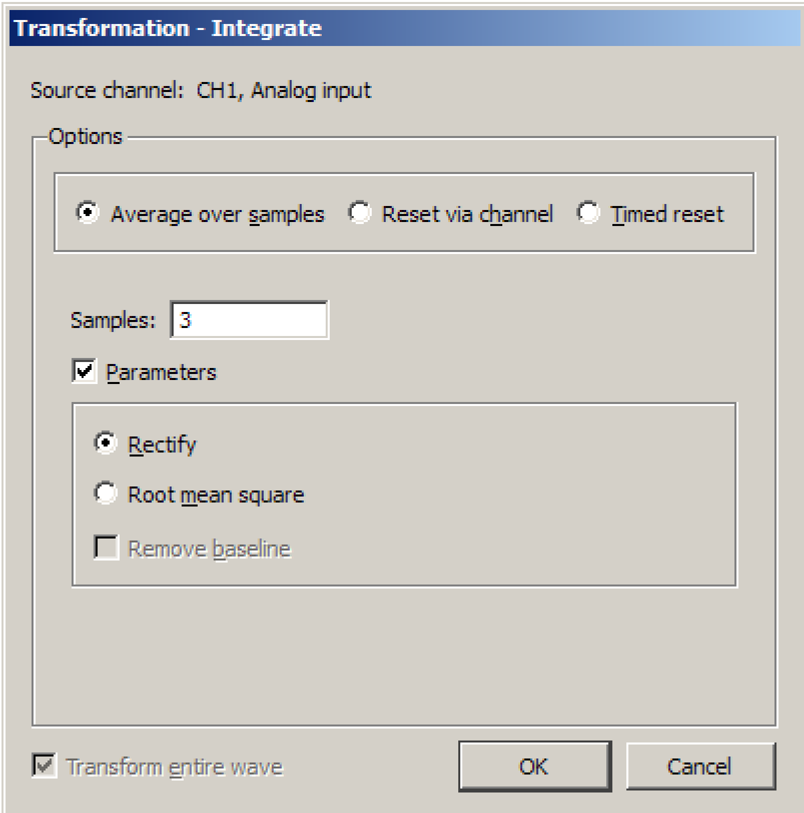
Optimize for sample rate and cutoff—Estimate the number of coefficients as four times the sampling rate divided by the cutoff frequency of the filter. Optimize does not necessarily produce the best quality filter, but takes less time.

Units

Select linear units or dbV. 

TIP: A good rule of thumb is to use a number of coefficients greater than or equal to two times the sampling rate divided by the lowest cutoff frequency specified. For example, if running a low pass filter at 1Hz on data sampled at 100 Hz, choose at least (2 x 100/1) or 200 coefficients in the filter. Additional coefficients will improve the response.

Integrate



The Integrate transformation operates the same as the Integrate calculation—see page 119, except it does not have a Max Cycle option, which is not relevant post-acquisition, and Reset via channel with mean subtraction enabled functions differently online and offline.

Root mean square is implemented as:

Sqrt(sum(x^2)/(n))

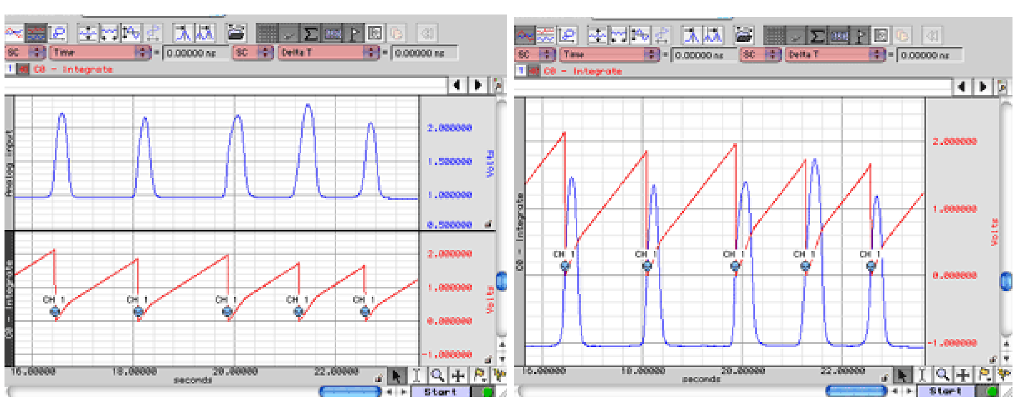
Reset

Online — Mean subtraction causes the online version to be delayed by the mean cycle length. It waits for that period of time to pass so it can determine a mean value for the initial cycle, and it then tries to re-compute this mean for each cycle. If the resets are too short or too long, the window expires and the processing halts again until a new mean can be recomputed. Online processing may reset from threshold crossing in the control channel or window expiration when it loses mean tracking.

Offline — Since all the data is available, the mean is computed from the data in the channel and doesn't delay the signal. Also, since it isn't doing windowed means, there are no window expiration events that are inserted. Offline processing may reset from threshold crossing in the control channel.

Output Reset

Enable the checkbox option to create an Event at each signal reset.

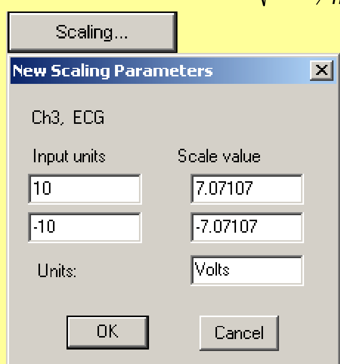


The Integrate formula is the same in the calculation (online, real-time) mode and the transformation (off-line, post-processing) mode; it varies only based on the parameters selected.

Notes

- For the first points, value of index *"i"* will be *less than or equal to zero;* it means that for summation you have only values beginning with $f(x_1)$.
  - For the first point for summation you have: $f(x_{-1})$, $f(x_0)$, $f(x_1)$.
    $f(x_{-1})$ and $f(x_0)$ - don't exist, so you have only $f(x_1)$.
  - For the second point for summation you have: $f(x_0)$, $f(x_1)$, $f(x_2)$.
    $f(x_0)$ - doesn't exist, so you have only $f(x_1) + f(x_2)$.
- The Integrate formula is implemented as a Standard Deviation formula (see mathworld.wolffram.com > Wolfram Research > equation 5 at http://mathworld.wolfram.com/StandardDeviation.html).
- The Root Mean Square formula is identical to the Standard Deviation formula, but without mean removal; this is the *n-1* definition.
  - For an explanation of *n-1* verus *n* in the formula, see notes as a pdf or http://www.uic.edu/classes/mba/mba503/971/503nts3.htm.
  - For a window size *n*, to convert from the *n-1* definition to the *n* definition, use $\sqrt{(n-1)/n}$
- The formulas to calculate RMS are optimal for data with a zero mean (typical for biopotential data). For data with a non-zero mean, scaling can be applied. Click the "Scaling" button in the Integrate dialog (or click the channel's vertical scale to generate the Vertical Scale dialog and then click the "Scaling" button), and then enter the following parameters:

Input value	Map (Scale) value
10	7.07107
-10	-7.07107



1. Via samples, no extra parameters selected

$$F(x_j) = \sum_{i=j-s+1}^{j} f(x_i) * \Delta x$$

<u>*Where:*</u>
i - index for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;
x_i, x_j - values of points at horizontal axis;
$f(x_i)$- values of points of a curve;
$F(x_j)$- integrated values of points of a curve;
s – number of samples to average across;
$\Delta x = \frac{x_n - x_1}{n-1}$ - horizontal sample interval;
x_n, x_1 - values at horizontal axis at the endpoints of selected area.

Integrate formulas, continued… See *Notes* on page 288

2. Via samples, rectify

$$F(x_j) = \sum_{i=j-s+1}^{j} ABS(f(x_i)) * \Delta x$$

Where:
i - index for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;
x_i, x_j - values of points at horizontal axis;
$f(x_i)$ - values of points of a curve;
$F(x_j)$ - integrated values of points of a curve;
s - number of samples to average across;
$\Delta x = \frac{x_n - x_1}{n-1}$ - horizontal sample interval;
x_n, x_1 - values at horizontal axis at the endpoints of selected area.

3. Via Samples, root mean square (RMS)

$$F(x_j) = \sqrt{\frac{\sum_{i=j-s+1}^{j} (f(x_i))^2}{s-1}}$$

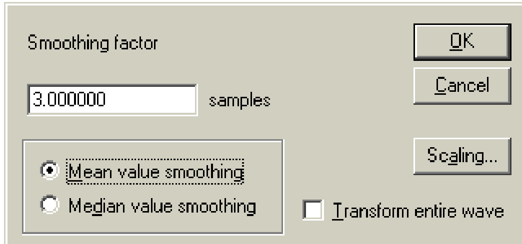
Where:
i - index for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;
x_i, x_j - values of points at horizontal axis;
$f(x_i)$ - values of points of a curve;
$F(x_j)$ - integrated values of points of a curve;
s - number of samples to average across.

4. Via samples, root mean square, remove baseline

$$F(x_j) = \sqrt{\frac{\sum_{i=j-s+1}^{j} \left[f(x_i) - \frac{\sum_{m=j-s+1}^{j} f(x_m)}{k} \right]^2}{s-1}}$$

Where:
i and m- indexes for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;
x_i, x_j - values of points at horizontal axis;
$f(x_i)$ - values of points of a curve;
$F(x_j)$ - integrate values of points of a curve;
s - number of samples to average across.
k - coefficient: for the first few points that have index j < s k=j,
for the other points with j > =s k=s

Smoothing



The smoothing function is a transformation that computes the moving average of a series of data points and replaces each value with the mean value of the moving average "window." This has the same effect as a crude low pass filter, with the advantage being that smoothing is typically faster than digital filtering.

Samples

Acq*Knowledge* allows you to set the width of the moving average window (the number of sample points used to compute the mean) to any value larger than three. By default, this is set to three samples, meaning that Acq*Knowledge* will compute the average of three adjacent samples and replace the value of each sample with the mean before moving on to the next sample. For data acquired at relatively high sampling rates, you will probably want to set the smoothing factor to a higher value, since smoothing three sample points when data is collected at 1000 Hz will only average across three milliseconds of data, and will typically do little to filter out noise. To set the size of the window, enter a value in the Transform > Smoothing dialog.

This function is most effective on data with slowly changing values (e.g., respiration, heart rate, GSR) when there is noise apparent in the data record.

Mean value

Mean value smoothing is the default and should be uses when noise appears in a Gaussian distribution around the mean of the signal. The Mean value smoothing formula is shown below, where "m" is the number of points in the window and "n" is the sample number:

$$f_{output}(n) = \sum_{k=n-(m/2)}^{k=n+[m-1)/2]} f_{input}(k) / m$$

Median value

Use Median value smoothing if some data points appear completely aberrant and seem to be "wild flyers" in the data set.

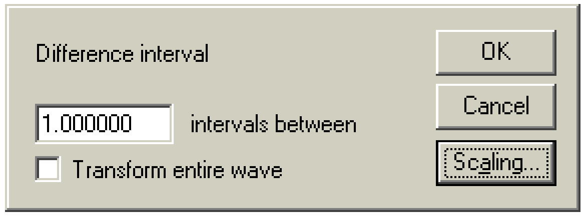
The Median value smoothing formula is shown below, where "m" is the number of points in the window and "n" is the sample number:

$$f_{output}(n) = \text{median}\,(n - [m/2]; n + [m/2])$$

Scaling

Generates the Scaling Parameters dialog.

Difference



The Difference function measures the difference (in amplitude) of two sample points separated by an arbitrary number of intervals. The difference is then divided by the total interval between the first selected sample and the last selected sample.

When you select the difference transformation, a difference interval dialog will be generated and you can enter the number of intervals between samples (default of 1).

For data with no high frequency components, a 1-interval difference transformation approximates a differentiator.

Since it is not implemented as a convolution, Difference is much faster than the derivative function.

The formula for the difference transformation is shown below, where "m" is the number of intervals difference, [ ] rounds the integer down, "n" is the sample number, and ΔTs is the horizontal sampling interval:

$$f_{output}(n) = \frac{f_{input}(n + [m/2]) — f_{input}(n — [(m+1)/2])}{(\Delta Ts * m)}$$

Example for boundary values when m = 3:

$$f_{output}(0) = (f_{input}(1) — f_{input}(0)) / (\Delta Ts * m)$$
$$f_{output}(1) = (f_{input}(2) — f_{input}(0)) / (\Delta Ts * m)$$
$$f_{output}(2) = (f_{input}(3) — f_{input}(0)) / (\Delta Ts * m)$$

If you enter an odd number (K = odd):

$$f_{output}(K) = (f_{input}(K+1) — f_{input}(K - 2)) / (\Delta Ts * m)$$

If you enter an even number (K = even):

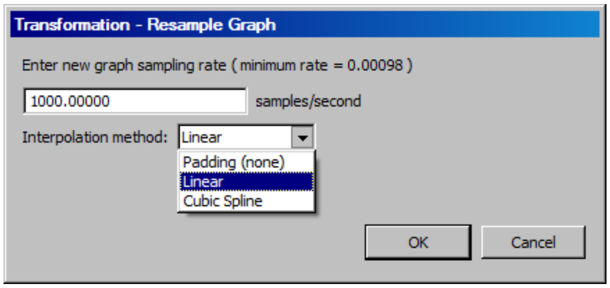
$$f_{output}(K) = (f_{input}(K+2) — f_{input}(K - 2)) / (\Delta Ts * m)$$

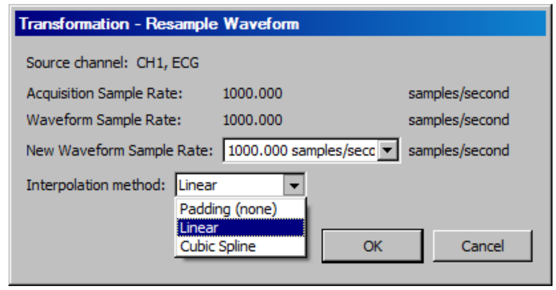
Note: The online (real-time) Difference calculation is calculated differently because projected values are not available. The online Difference formula is:

$$f_{output}(n) = f_{input}(n - m) — f_{input}(n) / (\Delta Ts * m)$$

Using the default difference setting of 1 interval will produce a "ΔP/ΔT" waveform when the transformation is applied to a blood pressure or similar waveform.

Resample





TIP A good rule of thumb is to sample from two to ten times the highest frequency component of interest.

Variable sampling rate and the flexible acquisition speeds of MP150 units can create data sets that are at different sampling rates. For some types of data analysis, the data must be resampled to a common sampling rate. Acq*Knowledge* has resampling facilities with Transform > Resample Graph; Transform > Resample Waveform, and Pasting between graph windows of different sample rates when the "Interpolate pastings between graphs" Preference is enabled (via Display > Preferences, page 424).

Acq*Knowledge* provides three interpolation methods for resampling data. Any changes made to the interpolated pastings between windows Preference and the interpolation method used in the Preferences dialog will be retained across launches of the software.

Padding—Padding will use the closest original value of the waveform to the left of the new sample position for the value, constructing a padded square save as the data is resampled. Padding is desirable when it is imperative no new data or data approximations get introduced into an analysis.

Linear—Linear interpolation is the default; previous software versions generated any missing data via linear interpolation. This method uses the sample points of the old waveform as the endpoints of a line. Missing data points are approximated from points lying on this linear segment.

Cubic spline—Cubic spline interpolation will construct a spline for the entire data set and use the values of this spline as the new waveform values. A natural fit spline is used that keeps zero second derivative at the endpoints of the fit. Cubic splines are useful when the analysis requires data with a smooth derivative.

Resample Graph

Apply an arbitrary, user-defined sample rate to all graphs in the file.

- The highest rate you can enter is the Acquisition Sample Rate.
- This option will adjust as necessary to maintain the established channel rate/acquisition rate proportion.
- You can create channel-specific rates by changing the channel sample rate after Resampling.

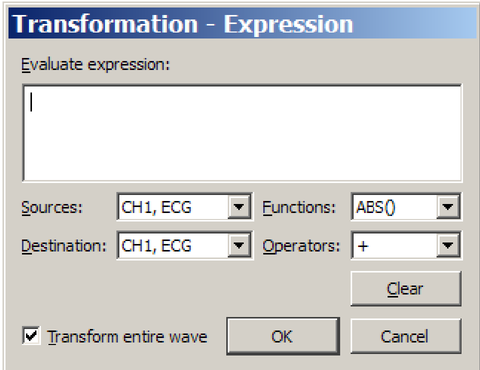
Resample Waveform

Resamples the active channel to a different rate. Resampling data maintains the same time scale but changes the number of samples per second. You can also use Resample to increase the number of sample points per interval (usually samples per second). When this is done, Acq*Knowledge* will interpolate between sample points to adjust to the new rate. This will add data points, although not necessarily more information.

- Resampling to a a lower sampling rate will "compress" a data file and information will be lost.
  - For instance, a 4-channel data file sampled at 250 samples per second for 15 minutes takes up about 1.8 MB of disk space. If these channels are resampled to 100 samples per second, the size of the file on disk is about 720 KB, a considerable reduction
- The highest rate a channel can be resampled to is the file acquisition rate (MP150 menu > Set Up Acquisition).
- If data is resampled to a lower rate and then resampled again at a higher rate, the waveform will maintain the resolution of the lower sampling rate, only with more data points.

The alpha component of an EEG signal has a frequency signature of 8-13Hz, so (assuming you have isolated the alpha component using a band pass filter) you would probably want to sample the data (in this case, isolated alpha waves) at a rate of at least 26Hz and probably no more than 130 Hz.

Equation Generator (Expression)



See the tables starting on page 85 for descriptions of sources, operators and functions for the Equation Generator/Expression dialog.

The post-acquisition Equation Generator (Expression trasnformation) is available for performing computations more complex than available with the Math and Function calculations. The post-acquisition version of the Equation Generator (Expression transformation) includes all the same features as the online version described on page 133. The Equation Generator (Expression transformation) will symbolically evaluate complex equations involving multiple channels and multiple operations. Unlike the Math and Function calculations, which can only operate on one or two channels at a time, the Equation Generator (Expression transformation) can combine data from multiple analog channels, or specify other calculation channels as input channels. Also, computations performed by the Equation Generator (Expression transformation) eliminate the need for "chaining" multiple channels together to produce a single output channel.

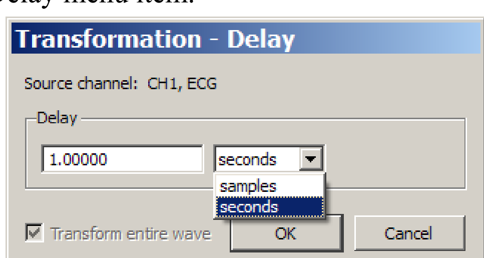
To have Acq*Knowledge* solve an equation/expression and save the result to a new channel, choose Transform > Expression (Equation Generator). A dialog will be generated. For each equation/expression, specify a source channel (or channels), the function(s) to be performed, any operators to be used, and a destination for the result. The different components of each equation/expression can be entered either by double-clicking items from the pop-up menus (sources, functions, and operators) in the setup dialog, or by typing commands directly into the box using standard mathematical notation.

You can divide a complex equation into several steps and perform each part of the equation with a separate channel. With up to 60 channels, almost any calculation can be performed.

The Equation Generator (Expression transformation) can reference past and future points.

Delay

The Delay transformation allows the addition of time delays in postprocessing (similar to the Delay calculation channel that can be used to add time delays to signals). The time delay can be added by introducing zero-valued samples at the start of the area to be delayed. The length of the waveform will remain the same; an amount of data at the end of the wave prior to the delay will be lost, with the length equal to the delay. The delay can be applied by using the Transform > Delay menu item.



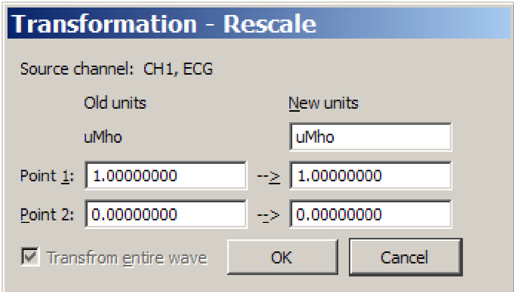
When inputting the delay amount, the units can be changed between **seconds** and **samples**.

- **Delay by samples** is applied according to the acquisition sampling rate, not the channel sampling rate. Delay specifies the units of acquisition and graph sampling rate for samples. For Delay calculation channels, the units of "samples" need to be kept constant under changes to the channel sampling rate as there is no opportunity to adjust them. As a result, acquisition sampling rate is used to determine "samples" for calculation channels. This same logic is applied to the transformation.

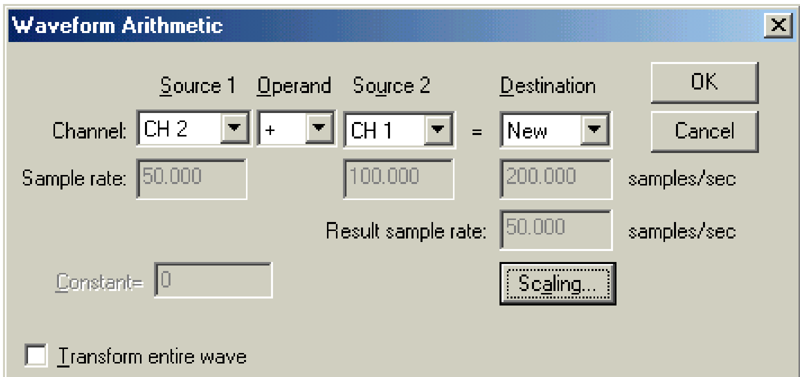
The Automator action allows Delay to be used in Automator workflows. See page 25.

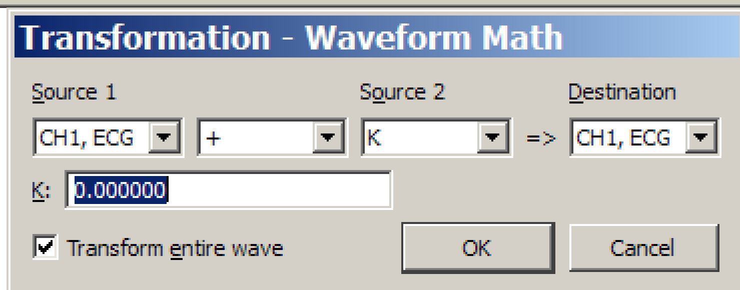
Rescale

The Rescale transformation operates the same as the Rescale calculation—see page 147.



Waveform math





The Waveform math transformation allows arithmetic manipulation of waveforms. Waveforms can be added together, subtracted, multiplied, divided or raised to a power. These operations can be performed using either two waveforms or one waveform and an arbitrarily defined constant. You can operate on the entire waveform by choosing Edit > Select all, or operate on portions of the waveform that have been selected using the cursor tool. If there is no selected area, only one sample point (the one selected by the cursor) will be transformed.

When you select Transform > Waveform Math, the Waveform Arithmetic dialog will be generated.

All of the main components of a waveform math calculation can be selected from pop-up menus in the Waveform Arithmetic dialog.

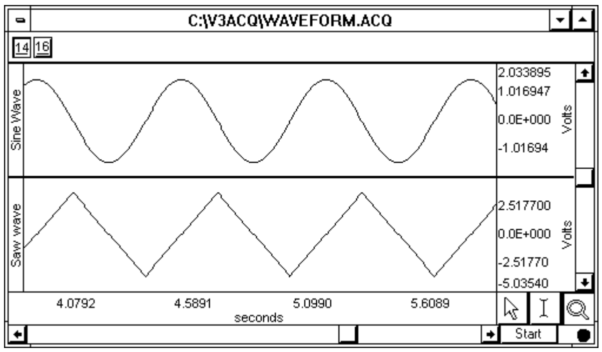
Source	The channels to be used in the transformation are referred to as source channels (Source 1 and Source 2), and can be combined using any of the operators in the pop-up menu. Source channels allow you to select any of the existing channels in the current window, or a constant (defined by K).
Constant	The “Constant =” entry box is activated when a Source is set to “K, Constant.”
Operand	The pop-up menu allows selection of addition, subtraction, multiplication, division or power functions.
Destination	You can save the results to an active channel, or create a new channel to store the results. Choose an existing channel from the pop-up menu or select the “New” option, which will create a new channel (using the next available channel).
Result sample	When using variable sample rate processing, the Equation Generator (Expression transformation) and Waveform

rate Math functions will constrain operations between waves of different rates as follows:

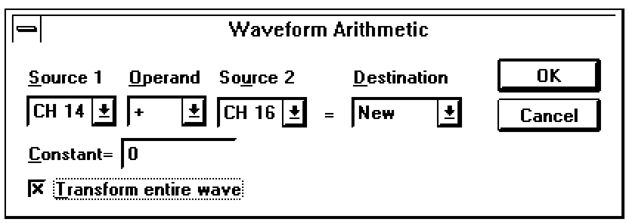
- If an equation is operating on two or more waves of different sample rates, the result of the operation will always be output at the lowest sampling rate from the waves (*F* low).
- If the destination channel for the result has an assigned rate other than (*F* low), the operation will not be permitted.
- If the destination channel is set to a new channel, the operation will always be permitted.

Scaling… Generates the scaling parameters dialog.

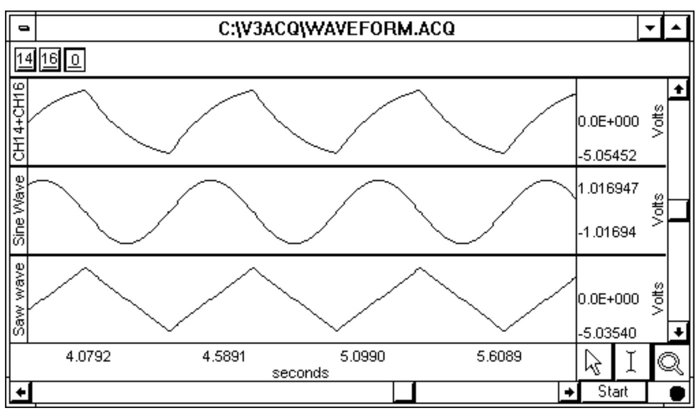
Waveform math can be used many ways. As one example, two waveforms can be added together. The following screen shows a sine wave in channel 14 and a triangle wave in channel 16.



To add these two waves, select Transform > Waveform Math and set source 1 to channel 14, the operator to addition "+", source 2 to channel 16, and destination to New as shown here:



Click OK to perform the transformation. The following screen shows the sum of CH14 and CH16 on a new channel.



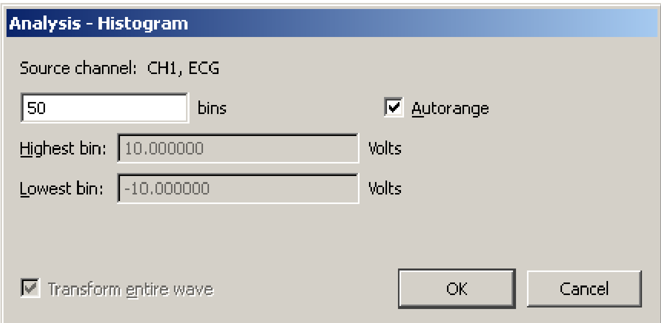
NOTE*:* If you select two waveforms of unequal length as sources, the length of the resulting waveform will be equal to that of the shortest one. Likewise, if one of the source waveforms extends only into a portion of the selected area, the resultant waveform will only be as long as the shortest source portion. If waveform math is performed on a selected area and output to an existing waveform that does not extend into the selected area, the resultant waveform is appended to the destination waveform.

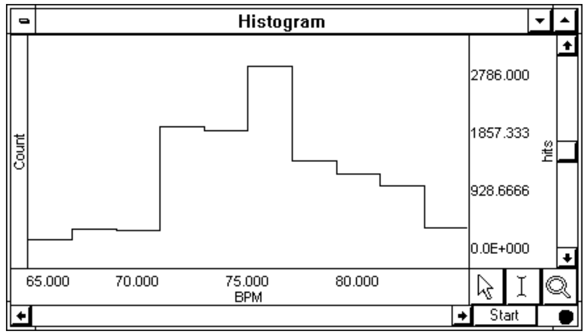
Chapter 16 Analysis Menu Commands

Overview

The Analysis menu contains operations that derive data and measurements from the graph—plus a courtesy copy of the Specialized Analysis package with classifiers and automation routines.

Histogram





The Histogram function produces a histogram plot of the selected area. When a histogram is created, the sample points are sorted into "bins" along the horizontal axis that contain ranges of amplitude values. These bins divide the range of amplitude values into equal intervals (by default, ten bins) and the individual sample points are sorted into the appropriate bin based on their amplitude value.

For instance, if a waveform had a range from 65 BPM to 85 BPM, the lowest bin would contain all data points with a value from 65 BPM to 67 BPM. The second lowest bin would hold all data points between 67 BPM and 69 BPM, and so on, until the tenth bin was created. Acq*Knowledge* then counts the number of "hits" (the number of data points) in each bin and plots this number on the vertical axis.

Analysis > Histogram Options:

bins Determines how many bins the data will be divided into; the default is ten bins.

Autorange Fits all the data selected into a bin; the bin sizes are determined by the extent of the data and the desired number of lines. Automatically sets the center of the lowest bin equal to the minimum value of the waveform (or the selected area, if a section is highlighted), and centers the highest bin on the maximum value of the waveform (or selected area, if any).

Disable to fix the bin sizes and enter values for Highest Bin and Lowest Bin.

When you click OK, a histogram plot will be generated in a new window. By default, Acq*Knowledge* displays the frequency of occurrence for each bin on the vertical axis. To calculate the cumulative frequency, select the entire histogram waveform and choose Integrate from the Transform menu.

Since the histogram function sorts sample points into a relatively small number of categories, the histogram window is likely to display a large number of "hits" in each bin, especially if data was collected at a relatively fast sampling rate. If this is the case, you may want to resample the data at a lower rate (using the Transform > Resample function). The caveat to this is that resampling the data may cause a bias, unless the data was filtered to remove all frequency components that are more than 0.5 the resampling rate.

Autoregressive Modeling

About autoregressive modeling

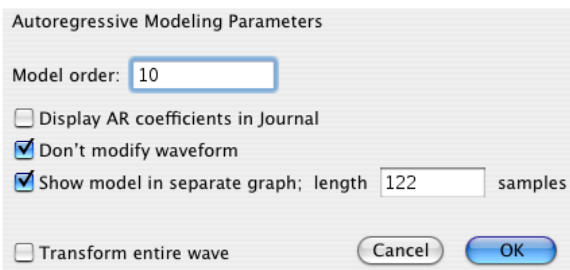
Autoregressive Modeling is a linear mathematical modeling algorithm that represents a signal as a weighted sum of its previous values combined with a noise factor. Autoregressive models are adept at capturing frequency behavior of an input signal and may be useful in generating high-resolution FFTs from undersampled data.

AR models are well suited to operation on discrete series of data and are particularly useful for expressing frequency information of a signal. Consecutive models can be used to perform advanced time series analysis, compression, denoising, arrhythmia detection, and waveform classification. AR models are commonly used on physiological data in advanced spectral analysis, and increasingly for classification of heart rhythms and gastric waves or visual detection of arrhythmias.

AR models can be used to extrapolate spectral features from waveforms at low sample rates.

- Generate high-resolution FFTs without fast acquisition sample rates (quite useful for electrogastrogram analysis).
  - An FFT from a 3,000-point AR Model provides the same result as a 42,000-point FFT.
- Examine spaces of AR parameters for feature extraction.

Since the underlying model is linear, AR modeling is not appropriate for representing signals that are inherently chaotic.



Autoregressive modeling estimates the parameters of a fixed-order autoregressive model, representing a model output value as a linear sum of previous input values. AR modeling may replace the source data with the model of equivalent length. The output length is equal to the source data, unless specified.

AR Time-Frequency Analysis is on page 300.

Output can also paste model parameters as tabular text to a journal. If "Don't modify waveform" and "Show model in separate graph" are both enabled, a new graph window will be generated to display the specified number of samples resulting from the best-fit autoregressive model.

Nonlinear Modeling

About nonlinear modeling

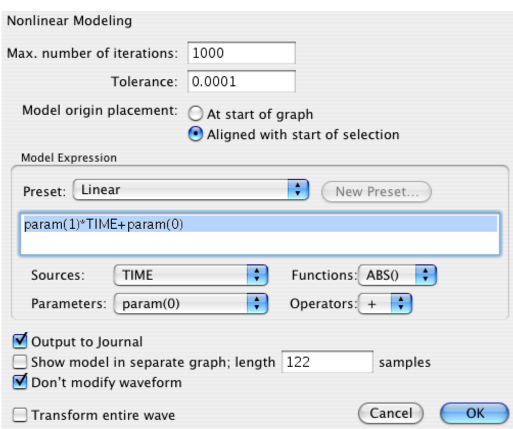
Modeling is used in physiological data to assess how well data conforms to a theoretical model. This is used to express a sampled signal in a continuous form and to perform data reduction. The nonlinear modeling features in Acq*Knowledge* support more advanced physiological analysis than is possible with the linear regression measurement, which is a rudimentary single order linear model.

Nonlinear modeling is the process of finding the best fit of a mathematical function to an arbitrary data set. Fitting the function—or model—to the data consists of choosing a set of function parameters that minimize error between the actual data points and the values generated from the model function. Nonlinear modeling functions can be arbitrarily complex. When the model is close to the shape of the data, the fits between different data sets may be good indicators of subtle variations in the data.

Most general-purpose methods of performing modeling are iterative and require an estimator for the function. A commonly used estimator is the least means squares (LMS) estimator. Nonlinear models can be estimated from data by combining LMS estimators with multidimensional function minimization algorithms.

Applications in hemodynamics

Many pressure and ECG signals exhibit regular morphologies. Fitting data to models that share these characteristics helps emphasize subtle differences in waveforms though variations in their model parameters. Nonlinear modeling is one of the most accepted methods for computing indexes for the relaxation period of left ventricular pressure. Cardiac researchers have used the time constant “tau” in various studies on cardiac function and abnormalities. Tau is determined by one of the parameters to an exponential model of the trailing end of the pressure signal. Studies have indicated that tau can be a good indicator of cardiac dysfunction, but reliable methods for its calculation have proven difficult and the effort is ongoing. The generic modeling abilities in Acq*Knowledge* allow researchers to analyze data using the tau constant and potentially develop robust algorithms for its calculation.



See the NLM measurement on page 98

Nonlinear modeling (also called “arbitrary curve fitting“) determines the “best fit” of an arbitray function to source data; the function is called a *model*.

Acq*Knowledge* uses a Nelder-Mead simplex search with a Euclidean distance function. A model must match underlying trends in the data to produce meaningful results. Also, to properly interpret the value of the best fit coefficients and any further derived results, users must consider the limitations of the simplex search method, which include: estimation only; not guaranteed to terminate; not guaranteed to find the exact solution; may get stuck in local minima.

Nonlinear modeling generates a new display and replaces source data with a model of equal (unless specified) length and also pastes model parameters as text to a journal. The sampling rate and axis units match the source graph.

Max iterations

Indicates the number of iterations after which the simplex search will be terminated if no convergence has been achieved.

Tolerance

Provides the tolerance used for termination of the algorithm. If the estimator decreases in two consecutive steps by less than this tolerance, the simplex search will halt.

Model origin placement

Controls where the zero point of the model is placed. Selection-relative placement is useful when comparing different sections of the same channel of data by looking for variations in their best fit model parameters. If channel data is used as part of the Model Expression the location from where the channel data is extracted will not be translated; regardless of the model origin setting, the channel data will be used from the selected area only.

Model Expressions

Models are defined through basic expressions, called Model Expressions. See the function tables starting on page 137 for details on Sources, Functions, and Operators.

Preset

The following presets for the most common types of models are included. Users can extend presets or create custom models if these presets are too general to achieve exact fits with simplex search. Presets are stored at Computer > Local Disk > ProgramData > BIOPAC Systems, Inc > AcqKnowledge 4.0 > Presets.

Preset	Description	Equation
Cubic	3rd order polynomial.	param(3)*(TIME^3)+param(2)*(TIME^2)+param(1)*TIME+param(0)
Gaussian	Standard Gaussian model; useful for peak fitting.	param(0)*EXP(-((TIME-param(1))/param(2))^2
Linear	Basic linear fit of the data.	param(1)*TIME+param(0)
Logarithmic	Logarithmic growth and decay; useful for initial rapid growth/decay followed by gradual decline/increase.	param(0)*LOG(TIME-param(1))+param(2)
Logistic	Logistic LVP relaxation model; T_L given by a(1).	param(0)/(1+EXP(-TIME/param(1)))+param(2)
Monoexponential	Exponential LVP relaxation model; T_e given by a(1).	param(0)*EXP(-TIME/param(1))+param(2)
Power Series	Useful for a wide variety of data, e.g. reactant analysis.	param(0)+param(1)*(TIME^param(2))
Quadratic	2^{nd} order polynomial.	param(2)*(TIME^2)+param(1)*TIME+param(0)
Weibull Distribution	Commonly used in reliability analysis.	param(0)*param(1)*TIME^(param(1)-1)*EXP(-param(0) *TIME^param(1))

Sources

All channels except the channel being modeled can be used as Sources; if the channel of data being modeled is inadvertently set as a Source, a syntax error prompt will be generated.

Parameters

Parameters are represented by *param(n)* where *n* is an integer index starting from zero. For example, in the linear model param(0)*x+param(1), *param(0)* can be interpreted as the “a” in “ax+b and *param(1)* can be interpreted as the “b” in “ax+b”.

Output to Journal displays the result of the modeling as text in the journal.

Show model in separate graph generates a separate graph to display the best fit model.

Length specifies the length of the separate model graph in samples.

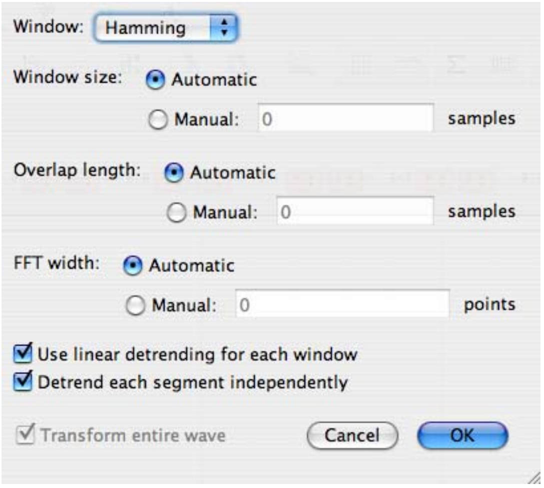
Don’t modify waveform suppresses replacement of the selected source data.

- If the model fitting does not complete successfully, the original data will be preserved regardless of the state of this selection.

Transform entire wave

Fits the entire data of the selected waveform to the model, with model origin at start of graph.

Power Spectral Density



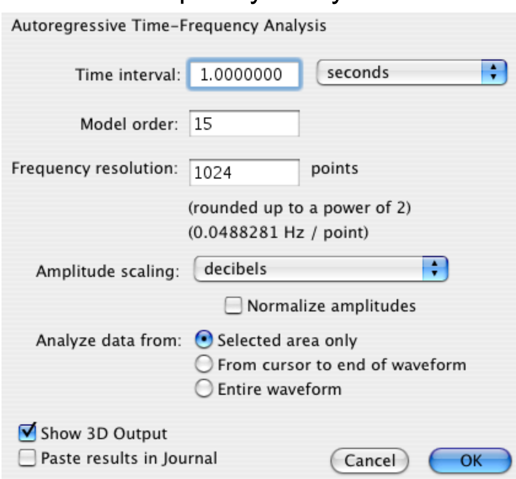
The Power Spectral Density (PSD) function extracts the power present at different frequencies within a signal and is useful for EMG analysis. The PSD transformation approximates the same result as squaring the linear FFT magnitude. PSD is not available when the horizontal units of the source graph are set to Frequency.

Acq*Knowledge* uses the Welsh approximation algorithm to average signal time-sliced portions of the signal and reduce noise effect, and generates a two dimensional graph displaying the wattage of a particular frequency component in a signal. Windowing options are Hanning, Hamming, or Blackman. The graph is plotted as horizontal frequency vs. vertical (units)^2/Hz, where *units* are the vertical axis units of the source data.

Use linear detrending for each window—when enabled, linear regression detrending is applied for each individual segment prior to the FFT computation; when disabled, windowing only is applied.

Detrend each segment independently—becomes available when "Use linear detrending" is enabled. When this option is enabled, detrending is applied independently for each segment; when disabled, detrending from the previous segment will be incorporated into the next segment.

AR Time-Frequency Analysis



The AR Time-Frequency transformation can be used to examine changes in the spectral density of a signal using enhanced frequency resolution from derived AR models. Examining frequency changes over time can be a useful tool for arrhythmia detection and rough classification of waveforms.

Autoregressive spectrum time-frequency analysis divides a waveform into equal-length time segments, calculates an AR model (see page 299) for each individual time segment, and then computes a power spectrum from the model. (To perform raw data time-frequency analysis, use the Cycle/Peak detector with the FFT 3D output option.)

Time interval—Enter a positive floating point value to specify the segment width; the source signal is split into fixed length segments of this width and a frequency spectrum is generated for each segment from a model of its data.

Model order—Enter a positive integer to specify the order of the AR model that is constructed on an interval by interval basis.

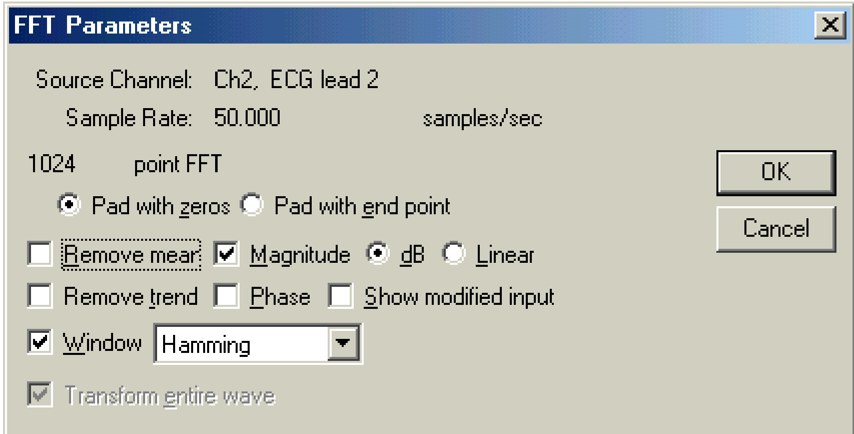
Frequency resolution—Enter a positive integer to indicate the number of points contained in the FFT of an individual time segment; it will be rounded to the closest power of 2 when analysis is performed.

Amplitude scaling—"Normalize amplitudes" scales amplitudes such that the maximum peak-peak distance is equal across time intervals.

Show 3D Output—Constructs a 3D surface plot of the time-frequency analysis with amplitude vs. frequency vs. time.

Paste results to journal—Inserts a series of tab-delimited tables representing the frequency distributions on a cycle-by-cycle basis into the Journal.

FFT Fast Fourier Transformation



The FFT algorithm requires that the length of your data be an exact power of two (i.e., 256 points, 512 points, 1024 points, and so on).

The Fast Fourier Transformation (FFT) is an algorithm that produces a description of time series data in terms of its frequency components. This is related to the *frequency spectrum*. The FFT displays the magnitude and phase of the time series data selected and displays only the DC and positive frequency components; the FFT does not display negative frequency components. To reconstruct a signal from additive sines or cosines, you need to include both the positive and negative frequency components. Since it's not physically possible to generate a negative frequency signal, you need to double the amplitude of the corresponding positive frequency component.

The output from an FFT appears in a graph window with magnitude (vertical axis) plotted against various frequencies (horizontal axis). A large component for a given frequency appears as a positive (upward-pointing) peak. The range of frequencies plotted is from 0 Hz to 1/2 the sampling frequency. Thus, if data was collected at 200 samples per seconds, Acq*Knowledge* will plot the frequency components from 0 Hz to 100 Hz.

Fourier analysis can yield important information about the frequency components in a data set, and can be useful in making determinations regarding appropriate data cleaning techniques (e.g., digital filtering). The FFT algorithm assumes that data is an infinitely repeating periodic signal with the end points wrapping around. Thus, to the extent that the amplitude of the first point differs from the last point, the resulting frequency spectrum is likely to be distorted as result of this start point to end point discontinuity. This can be overcome by "windowing" the data during the transformation. For more information on the windowing feature, see the window section that follows.

The FFT transformation cannot be performed in real time (i.e., during an acquisition). To emulate an online spectral analysis, use online filters and the Input Values window. See page 221 for more information about real-time frequency information.

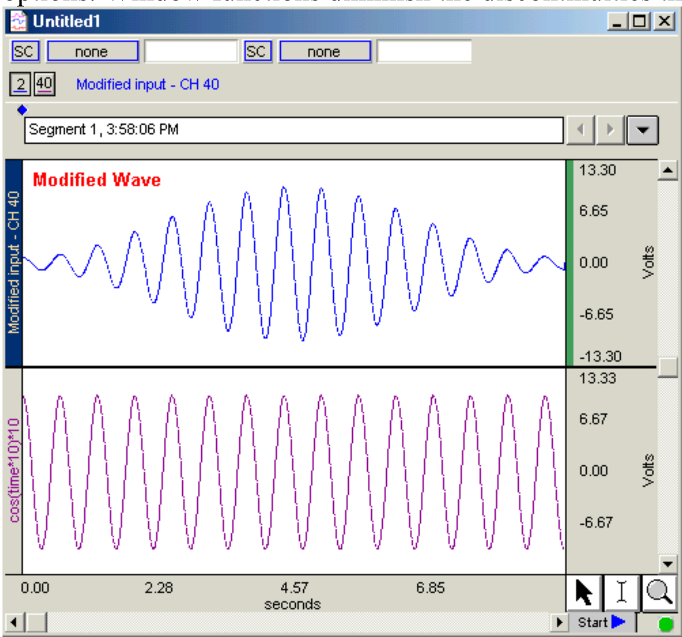
Pad If a section of data is selected that is not a power of two, Acq*Knowledge* will always "pad" data up to the next power of two, filling in the remaining data point with either

Pad with zeros: a zero

Pad with endpoint: the last data point in the selected area

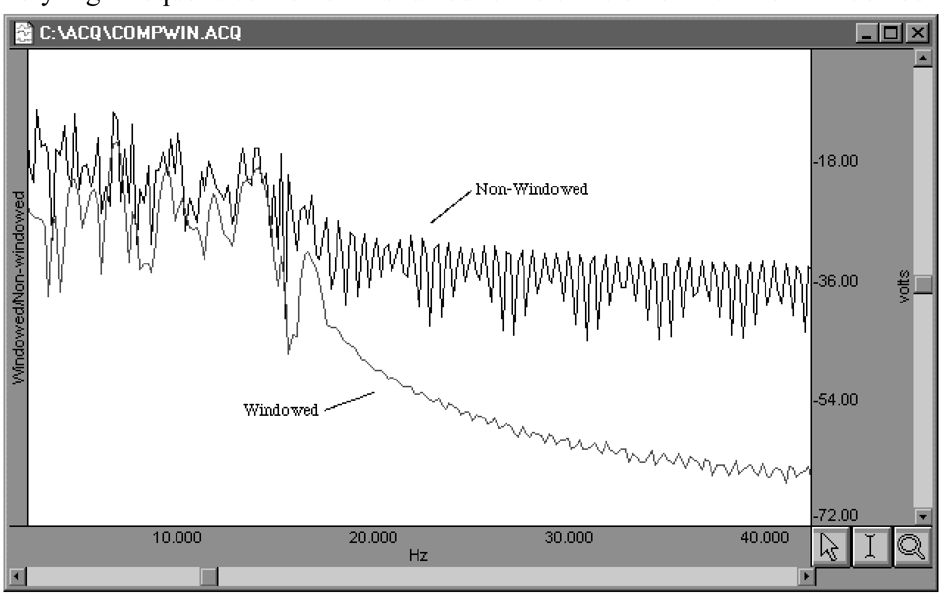
In other words, if 511 data points are selected, Acq*Knowledge* will use a modified version of the waveform as input. The modified waveform will have 512 points, and the last point in the modified wave will be either a zero or equal to the 511th point of the original data.

Show Mod. To view the modified waveform being used as input for the FFT, check the Show modified input box. Whenever possible, it is best to use an input waveform (select an area) that is an exact power of two. The waveform is modified by applying the windowing and padding options. Window functions diminish the discontinuities that occur at either end of the wave.



Window The FFT algorithm treats the data as an infinitely repeating signal with a period equal to the length of the waveform. Therefore, if the endpoint values are unequal, you will get a frequency spectrum with larger than expected high frequency components due to the discontinuity. Windowing these data minimizes this phenomenon. For example, to apply a window transformation to a sine wave whose endpoints do not match up, check the box next to Window and choose a type of window from the pop-up menu. Each of the windows has slightly different characteristics, although in practice each provides similar results within measurement error.

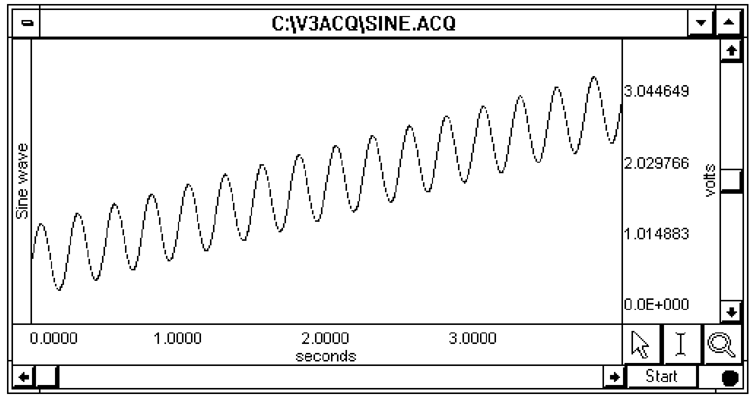
As shown below, the frequency spectra of the windowed and non-windowed data differ significantly when the endpoints are unequal. When data are not windowed, the very low and very high frequencies are not attenuated to the same extent as when windowed.

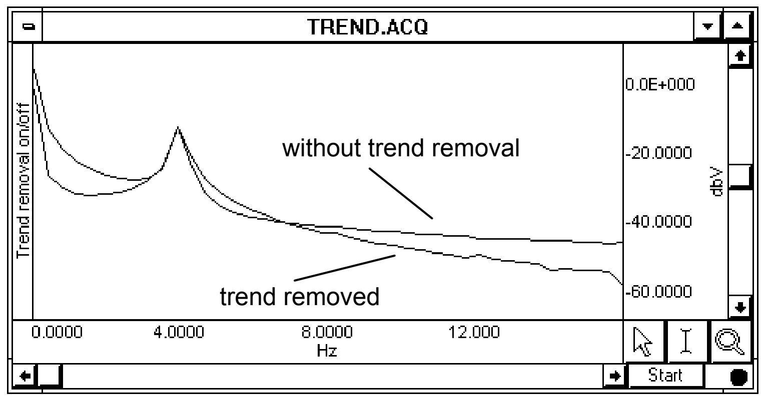


Remove Trend Sometimes, data contains a positive or negative trend that can cause extraneous frequency components to "leak" into the frequency spectrum. In this case, you could select remove trend when you perform the FFT, which will draw a line through the endpoints, and then subtract the trend from the waveform.

For example, the following sine wave has an upward trend through the data (positive trend component). The lower graph shows FFTs of the skewed sine wave data with and without the trend removed.

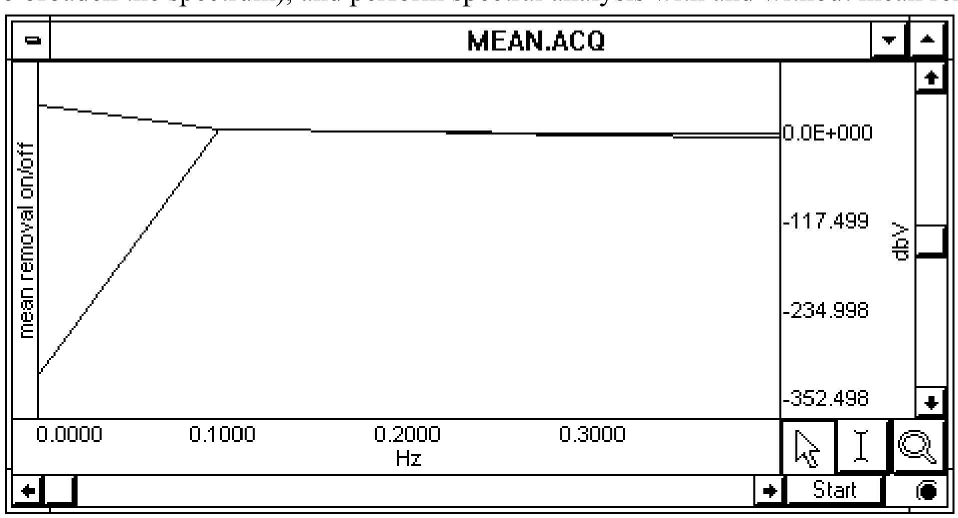
Note that the spectrum of the data without the trend removal has gradually decreasing frequency components, while the data with the trend removed has far fewer frequency components except for the single spike due to the sine wave.





Remove Mean Remove mean calculates the mean of all the points in the selected area and then subtracts it from the waveform. This is generally useful for windowing a waveform that has a large DC offset.

As an example, you might start with a sine wave with a 10-volt DC offset (with a little noise added to broaden the spectrum), and perform spectral analysis with and without mean removal:



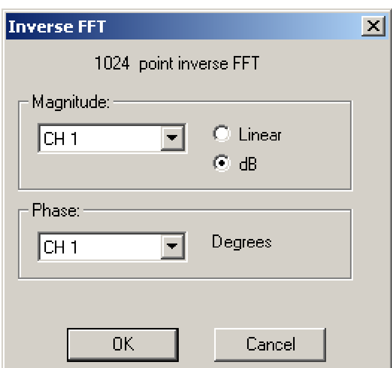
Note the large spectral components at the beginning of the top plot, without mean removal. This is due to the offset of the original data. The bottom plot is with mean removal.

Since the offset of the waveform is often an artifact of the way it was generated, the remove mean option provides a more accurate indication of the true spectral components. This is especially true for applications where low frequency components are of interest. If your data has a large DC offset and you plan on windowing the data, you will generally get a more meaningful spectrum if you remove the mean prior to windowing (which is the same order the FFT uses).

Linear
By default, the FFT output is described in terms of frequency along the horizontal axis and dBV on the vertical axis. The Bell scale (from which dB are derived) is logarithmic, and in some cases it may be useful to have the output scaled in linear units. To do this, click the button next to linear and check OK. The other options in the dialog work as they normally do when the dB scaling option is selected. The relationship between log and linear units is: dBV_{out} = 20 log VIN.

Phase
The standard FFT produces a plot with frequency on the horizontal axis and either dB/V or linear units (usually Volts) on the vertical axis. In some cases, it may be useful to obtain phase plots of the waveform (as opposed to the default magnitude plots). Phase plots display frequency along the horizontal axis, and the phase of the waveform (scaled in degrees) on the vertical axis. This option functions exclusive of the magnitude option—you can check either independently, or if you check both, two plots will be produced (a magnitude plot and a phase plot).

Inverse FFT



The Transform > IFFT menu option is generated after an FFT is performed. An Inverse FFT (Transform > IFFT) converts spectral values back to a time series waveform to reverse the FFT transformation. Any modifications to the original data (such as windowing or padding) will be shown in the resulting time series data.

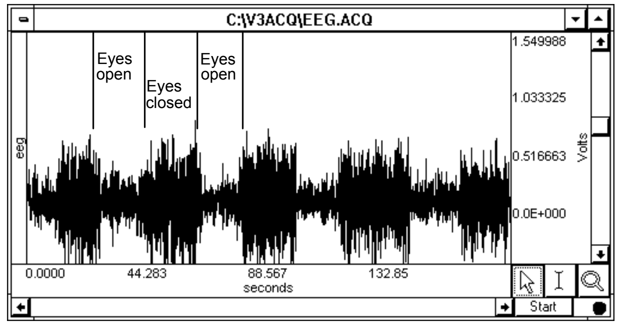
To obtain a meaningful IFFT result you must have a graph window open with at least one magnitude channel and at least one phase channel. With the window open, choose IFFT from the Transform menu to generate the Inverse FFT dialog.

To accurately recreate the time series waveform

1. Select the source channels for the inverse FFT in the Magnitude and Phase pull-down menus.
2. Select whether to express Magnitude in linear units or dB logarithmic units (decibels). To determine this setting, check the vertical axis units of the magnitude channel; this should correspond to the Magnitude scaling choice that was used when performing the forward FFT.
   - The Phase waveform must be in degrees.
3. Click OK to perform the IFFT.
   - The result is generated in a new time domain window, labeled "IFFT of Spectral…"

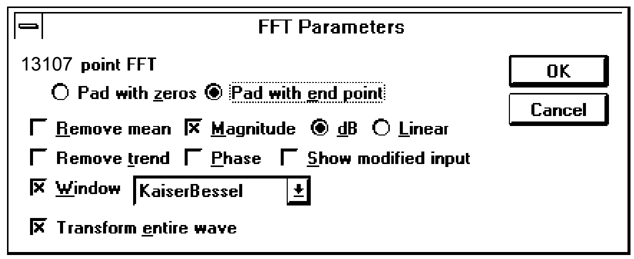
To perform an FFT, you might start with an electroencephalogram (EEG) signal acquired when the subject alternated between eyes open and eyes closed. Typical results suggest that higher levels of alpha activity (activity with frequency components between 8Hz and 13Hz) are to be expected when a subject's eyes are closed.

1. The raw data, prior to FFT, is shown here:



2. Select Transform > FFT from the menu.

   The FFT Parameters dialog will be generated; in this example, the Window function chosen is Kaiser Bessel:

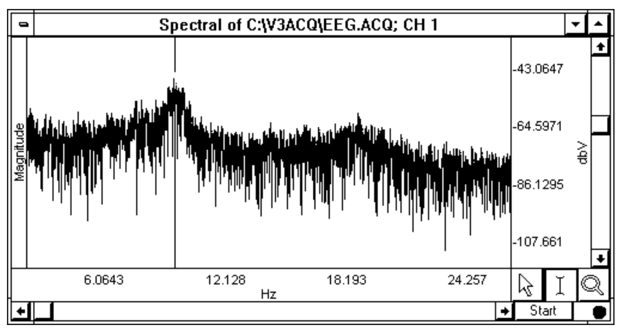


3. Click OK.

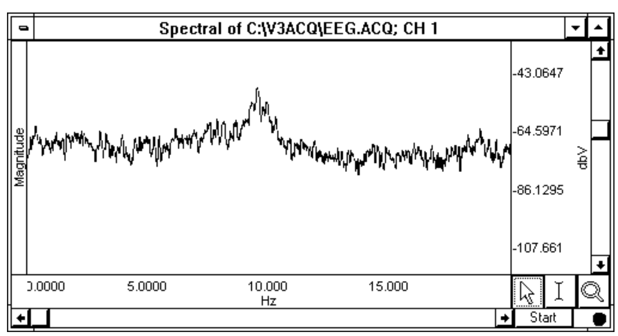
   A frequency domain window (a graph window which places frequency along the horizontal axis rather than time) will be created and displayed, showing the spectrum of the input data.

   The window is named "Spectral of (the original window name)" and ends with the channel number, as shown here:

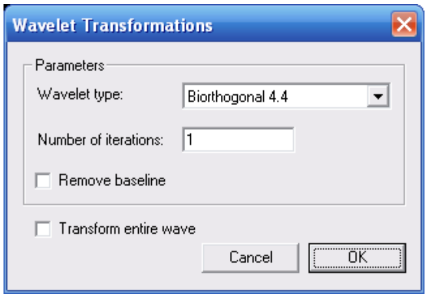
   The resulting magnitude value for each component is equal to the peak value of the sine wave contributing to that component. The entire pattern of frequency components is known as the frequency spectrum of the data. The somewhat erratic appearance of the spectrum is usually due to small-scale variations in the original waveform.



4. *Optional*—This "noise" can be removed by applying a smoothing transformation to the FFT output. In the graph shown, there is a pronounced frequency component centered on 8Hz, which corresponds to the alpha wave frequency band (8Hz—13Hz). The frequency spectrum (0-20 Hz shown) used 20-point smoothing.



DWT Discrete Wavelet Transformation



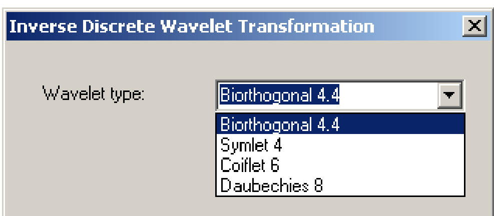
About Wavelet Transformation

Wavelet transforms are similar to Fourier transforms. Instead of projecting a signal in a space of sines and cosines, wavelet transforms project a signal into a space comprised of orthogonal functions called *wavelets*. Discontinuities are more obvious in wavelet transforms than in sines and cosine analysis, making wavelet transforms a better choice for decomposing a signal to its fundamental form. Wavelet transforms can be used for noise reduction and filtering, extracting features from signals that are not apparent in time or frequency domains, and predicting signal qualities from a small number of data points.

Discrete wavelet transforms break a source signal into high-frequency and low-frequency components. Use for ECG and EEG analysis. DWT creates a new graph with wavelet coefficients on the horizontal axis and the amplitude for each coefficient on the vertical axis, pastes acquisition settings to the graph-specific journal, and places an event at each boundary between the high- and low-frequency components produced at each iteration.

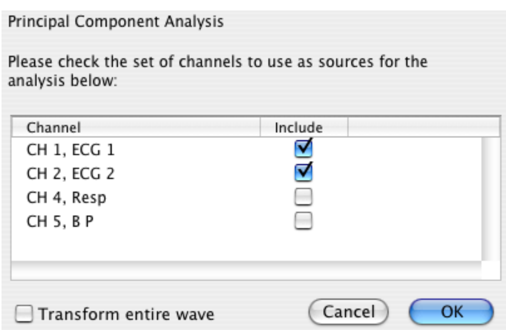
Wavelet type	Specify Biorthogonal 4.4, Symlet 4, Coiflet 6, or Daubechies 8.
Number of iterations	Specify the number of transforms to execute iteratively.

Inverse DWT



Operational on the result of a DWT. Projects data from wavelet space to time space. For correct recomposition of the source data, the wavelet type specified for the IDWT must match the wavelet type used for the DWT. Amplitudes of the wavelet coefficients may be changed, but an IDWT will fail if the horizontal units, events at DWT iteration level boundaries, or file length have been modified.

Principal Component Analysis



About Principal Component Analysis

Principal Component Analysis decomposes source signals into a new signal space (constructs an orthogonal set of vectors). PCA is useful as a feature extraction and data reduction tool.

Changes in the values of the mixing matrix may be indicative of changes in underlying signal morphologies that other methods cannot easily detect.

For example, PCA is useful for EEG analysis; where it can reduce 32 channels to the fundamental elements of signals.

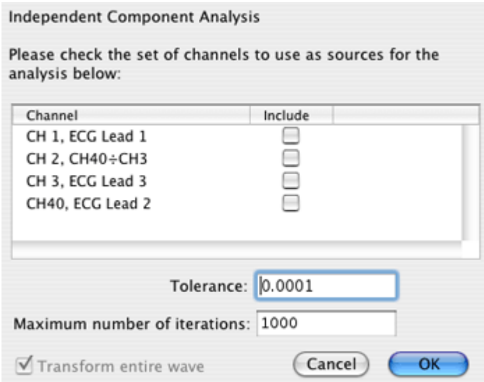
Acq*Knowledge* uses a mean-adjusted covariance matrix method to generate a new PCA graph with each component in a separate channel. The coordinates of the new space are the eigenvalues extracted from the matrix defined by the source data and are called "Principal components." The extracted eigenvectors are the "mixing matrix." Sine and cosine are orthogonal signals. The principal components are numbered in order of decreasing eigenvalues, which implies that the first principal component contains the majority of the variation of the source signals. Results are also pasted in to the journal, including the eigenvalue magnitudes and the eigenvector matrix. To determine the percentage contribution of each component, review the eigenvalue magnitudes. Select two or more channels—all of the selected channels must have the same sampling rate.

Inverse PCA

Available only for graphs produced by PCA. Reconstructs the source signals based on the components and mixing matrix of the PCA graph. The graph is reconstructed in a new window, with a list of the components used pasted to the journal.

➲ For noise reduction, use only the strongest principal components to reconstruct the source signals.

Independent Component Analysis



About Independent Component Analysis

Independent Component Analysis is useful for signal separation, denoising, and advanced EEG analysis to remove noise signals or locate approximate regions of active processing centers in the brain. ICA is a form of statistical blind separation that attempts to separate mixed (overlapped) signals based on the assumption that they are statistically independent.

- For example, if two microphones in a room record one person reciting Shakespeare and another person playing the banjo, the recordings will capture both the speaker and the banjo. After performing ICA on the two recordings, one result will have only the speaker and the other will have only the banjo.

Acq*Knowledge* uses the FastICA algorithm to generate a new ICA graph with each component in a separate channel.

Select two or more channels—all of the selected channels must have the same sampling rate.

Specify tolerance and number of iterations.

ICA limitations to consider for application and interpretation:

1. The number of mixed sources must be equal to the number of independent components (as in the example where two microphones captured two sound types).
2. Sources must be statistically independent; highly-correlated signals cannot be effectively separated.
3. Sources must have non-Gaussian probability distribution. It is not possible to separate out components like white noise through ICA.
4. Signal mixing must be a constant, linear process. Any type of non-linear signal propagation cannot be expressed in linear combinations of sources, the underlying assumption of ICA.
5. The component sources must be stationary (that is, point sources).

Inverse ICA

Available only for graphs produced by ICA. Reconstructs mixed signals based on the components and mixing matrix of the ICA graph. The statistical nature of the algorithm implies that it cannot perfectly reconstruct original source data—it estimates the most probable set of source signals. The graph is reconstructed in a new window, with a list of the components used pasted to the journal.

Find Cycle (Peak Detector)

Overview

The advanced Cycle/Peak Detector combines with the powerful new Event Marking System. Use it to perform amplitude, time, or event-based measurements. New output options for measurements, averaging, events, clustering (K-means), and 3D surface (cycle data, histogram, FFT, and DWT).

The Find Cycle detector uses three tabbed settings panels to define and automate cycle/peak detection:

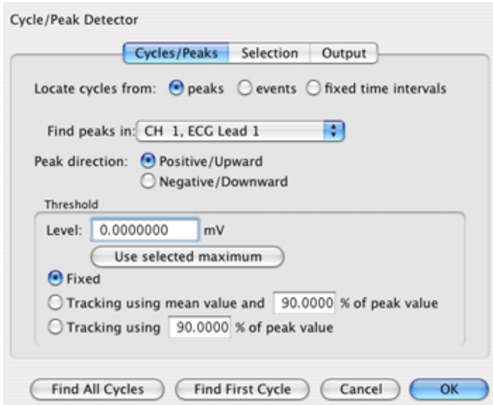
Cycles/Peaks Selection Output

Cycle detector settings are graph-independent, which means that find cycle/peak operations can be performed in multiple graphs without needing to re-enter graph-specific settings for each run. By using multiple data views, different find cycle/peak operation can be performed on the same set of data without losing settings between "Find Next Cycle/Peak" operations.

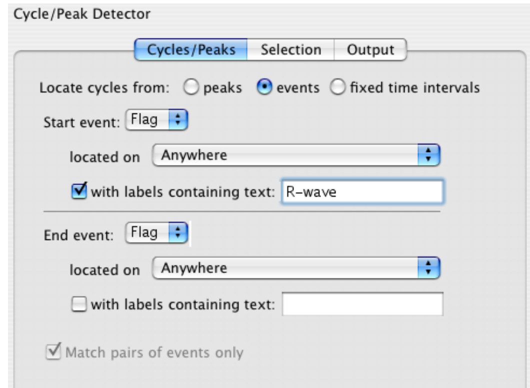
When the Cycle/Peak Detector is first opened for a graph, the dialog will be filled with the values from the last successfully executed find Cycle/Peak operation. Subsequently, changes to the settings will be applied only to that graph.

TIP If you're running the cycle/peak detector multiple times and need to put the cursor back at the beginning of the waveform for the next pass, use the keyboard shortcuts Home, End, Page Up, and Page Down to quickly change cursor location (see page 64).

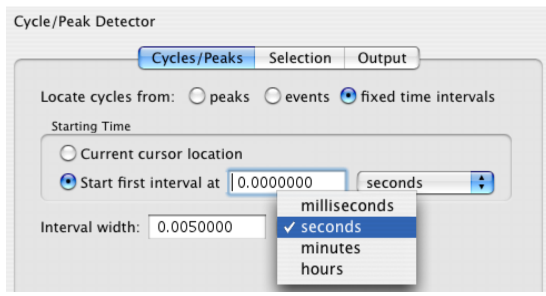
Cycles/Peaks tab



Peaks



Events



Fixed Interval

A cycle is defined as the interval between two events of user-specified types. The Cycles/Peaks tab offers three general methods for establishing cycle parameters:

- Peaks: Data driven maximum and minimum
- Events
- User-defined fixed time intervals

When the cycle location mode is switched on the "Cycles/Peaks" tab, the edge selection offsets will be checked. If they are non-zero, a prompt will generated to warn that that the edge adjustment offsets may not apply for the new cycle location mode. The user can reset the offsets to zero (default) or retain the (non-zero) settings used in the previous cycle location mode.

Peaks

Peak direction See the Peak definitions.

Level *Important usage note*—Level is not set automatically when the Cycle/Peak detector is generated. (Automatic Level is used in previous versions of Acq*Knowledge* for Mac and current version for Windows.)

Use selected... To optimize the threshold detection level for the selected area of data in the graph, click the "Use selected maximum/minimum" button underneath the level. If you change the source channel or peak direction, you can also use this button to re-compute the recommended level based upon your new settings"

Threshold Fixed—Keeps the threshold voltage level constant.

Tracking The Tracking threshold mode modifies the threshold after it finds a peak, depending upon the value of the new peak, and will compensate for a slowly drifting baseline.

Hints regarding the use of Tracking Threshold Options

- If data has a very consistent cyclical nature, either Tracking Option will work.
- If data has spurious positive or negative peak values present, the Means Reference Tracking Option is probably a better choice.
- If data has an erratic baseline, but consistently sized, positive and negative peaks, the Peaks Reference Tracking Option is probably a better choice.

Tracking using mean value and % of peak value—Adjusts the threshold voltage level after each peak based on the average of the last cycle's data and the specified percentage of the current peak voltage. The Means reference option will cause the software to determine the Mean Value of all the data, from peak to peak. This Mean Value establishes a variable reference upon which the tracking threshold operates. The software will determine the new threshold (NT) as follows:

For Positive Peaks

NT = Mean Value + (Positive Peak Value - Mean Value) x (% factor)

For Negative Peaks

NT = Mean Value - (Mean Value - Negative Peak Value) x (% factor)

Tracking using % of peak value—Adjusts the threshold voltage level dynamically based on the specified percentage of the value of the most currently found peak. The Peaks reference option will cause the software to determine the Positive Peak Value and Negative Peak Value of all the data, from peak to peak. The Positive and Negative Peak Values establish a variable reference upon which the tracking threshold operates. The software will determine the new threshold (NT) as follows:

For Positive Peaks

NT = Neg. Peak Value + (Pos. Peak Value—Neg. Peak Value) x (% factor)

For Negative Peaks

NT = Pos. Peak Value - (Pos. Peak Value—Neg. Peak Value) x (% factor)

Events

Event-based cycle location can extract information from events or define events based upon the output of the peak detector. A cycle is defined as the interval between two events of user-specified types.

Start / End Define the event; any of the predefined event types can be explicitly matched.

Match pairs "Match pairs of events only" is active when the Start event criteria are identical to the End event criteria. Toggle the checkbox to set this option. For a cycle to be located, a pair of two distinct events that match the criteria must be present. The event occurring earlier in time matches the left edge, later in time matches the right edge. This is the default search mode; this is the only search mode when the criteria are different.

When unchecked, a single event can be used as the Start event and the End event of a cycle, which will produce a zero width cycle. This is useful for adjusting a selection relative to an event, such as locating the first second prior to each event of a specific type. This single-event matching option makes it possible to hit time periods for each event since each cycle consumes two events.

Located on Specify the channel when the event must be defined, either its actual channel or "Global" for markers not associated with any channel. Select "Anywhere" to search for events of specific types across channels.

With Labels optional Toggle the "With labels containing text" checkbox to set this option.

When checked, the matching event's label must contain the text in the edit box to the right of the checkbox.

- The text search is not case sensitive. The search must be non-empty for cycles to be located properly.

When unchecked, the matching event can have any label, including none.

The Cycle detector uses the following algorithm to search for cycles in the graph:

1. From the starting point, find the first event matching the criteria of the Start event. This will be defined as the *left event*. If no event matches the Start criteria, no more cycles are in the file.
2. If the Start event criteria match the Ending event criteria and zero width cycles are allowed (e.g. "Match pairs of events only" is unchecked), define the right event as identical to the left event and go to step 5.
3. From the location of the left event, find the closest event matching the criteria of the End event. This will be defined as the *right event*. If no event matches the End criteria, no more cycles are present in the graph.
4. Within the time region between the left and right events, search for any events that match the Start criteria. If such an event occurs, redefine the left event to be this matching event and repeat the step. If no event is located, then the closest pair of events has been located.
   - This step is useful for working with data that has missing portions of the sequence, as can come out of some classifiers. For example, if two event types A and B are used as the endpoints, a sequence of three events AAB will match the last two events as the cycle. This is logical in the case of physiological data where, if B should occur periodically in the signal, AA is an indicator of an abnormality or missed classification.
5. Set the selected area to the time interval whose endpoints are the left and right events.
6. Perform selection adjustment and output as indicated by the settings on the "Selection" and "Output" tabs.
7. If "Find All Cycles" is being performed, return to step 1 and use the ending event location as the new starting point to find any remaining cycles in the graph.

Fixed Interval

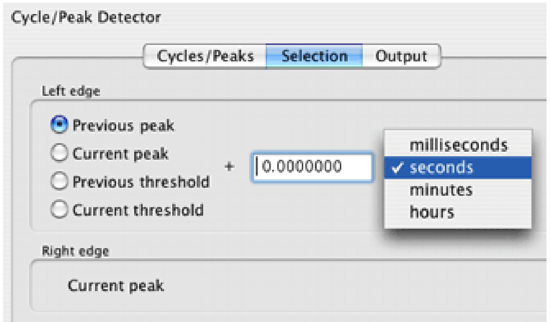
See the interval definitions.

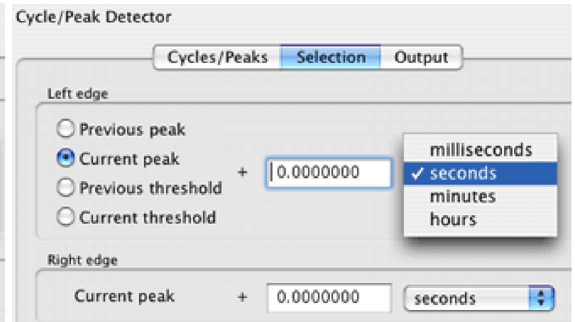
Selection tab

Use the Selection tab to adjust the range of data that will be analyzed to generate any output. By default, the data range is set to be the entire cycle as located by the settings on the Cycle/Peak tab, but it can be adjusted to analyze only specific portions of the cycle.

The controls on the Selection tab vary based on the settings on the Cycle/Peak tab

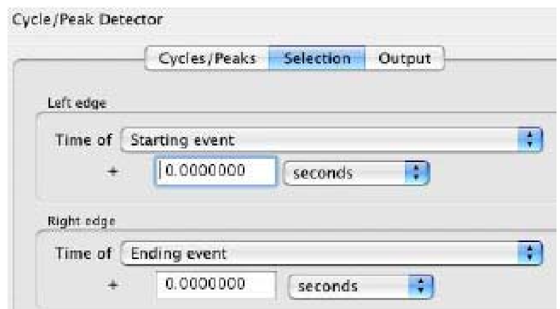
Peak — When the Cycles/Peaks location method is "Peaks," you can adjust the Selection based on the times of the peaks in the data or the times of the threshold crossings prior to the peaks.





To perform analysis on the entire data within each cycle, the selection should be from the "previous peak" to the "current peak." To examine fixed-width time windows located at each peak, use the "current peak" to "current peak" settings and adjust the two time offsets accordingly. Note that your settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.

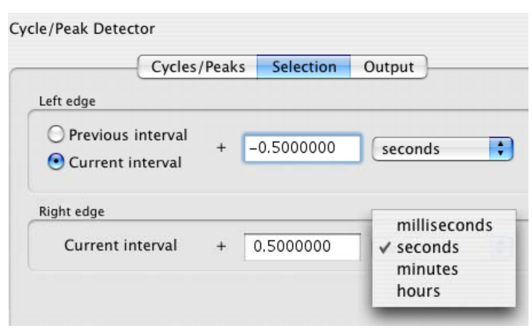
Event — When the Cycles/Peaks location method is "Events," you can adjust the Selection based on the locations of the events that define the boundaries of a cycle.



For a specific cycle, the starting event will be the event at the left boundary of the cycle and the ending event will be the event at the right boundary of the cycle. The starting event will never be located after the ending event in time.

To analyze data over each entire cycle, use the "starting event" to "ending event" setting. To examine fixed-width time windows occurring within each cycle, set the left edge and the right edge to the same event (e.g. "starting event" to "starting event" for time windows at the beginning of each cycle) and adjust the offsets accordingly. Note that your settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.

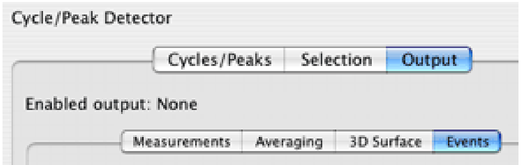
Fixed — When the Cycles/Peaks location method is "Fixed time intervals," you can adjust the Selection based on the endpoints of the time interval.



To analyze the data over each entire interval, use the "previous interval" to "current interval" setting.

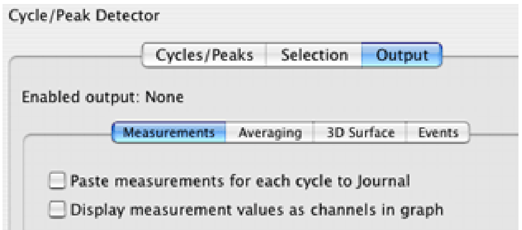
To examine fixed-width time windows within each interval or only a sub-portion of each interval, use the "current interval" to "current interval" setting and adjust the time offsets accordingly. Note that your settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.

Output tab



The Cycle/Peak Detector includes four Output options, which can be independently enabled: Measurements, Averaging, 3D Surface, and Events. The selected output, if any, is listed at the top of the Output tab as Enabled output.

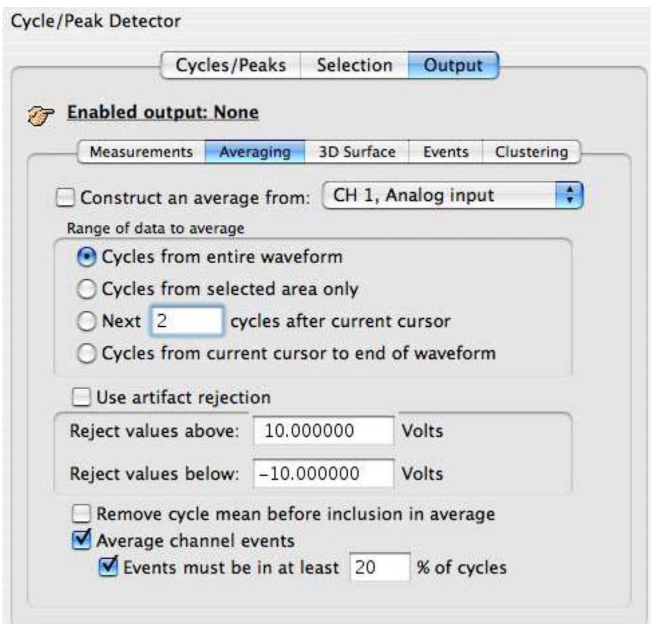
Output Measurements



Toggle each checkbox to enable/disable the option:

- Paste measurements for each cycle to the Journal
- Plot measurement results; display measurement values as channels in graph.

Output: Averaging—Offline



Use Averaging Output" to perform offline ensemble averaging of source data or ensemble averaging of event locations. Specify the channel where the cycles/peaks are to be located in the "Cycles/Peaks" tab and specify the channel whose data should be ensemble averaged in the "Average" controls on the "Output" tab.

Toggle the "Average channel events checkbox near the bottom of the tab to turn event averaging on and off.

Offline averaging can produce average locations of events within the defined cycle along with the average data. When a cycle is found, any events in that cycle will be noted. Events that are on the channel of data being averaged will be examined for inclusion in the average.

Index — For each individual cycle, each event will be given an index starting at 0 and increasing to one less than the number of occurrences of that event type within the cycle. The time offset for each event from the start of its cycle will be averaged along with the offset for events with the same index from all other cycles. When the graph of the averaged data is produced, these average time offsets from the start of the cycle will be used to define new events for the averaged data. If the events and averaging interval were correlated with the data, the average event offset will produce a reasonable representation of the appropriate event locations for the averaged cycle.

- Average events reflect the accuracy of classifiers and the consistency of data used to locate each cycle.

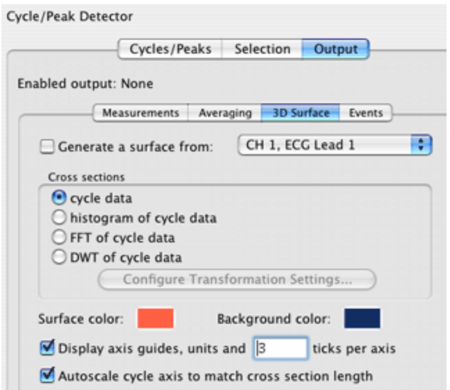
Label — Each event is labeled with the number of cycles contained in the event. Differences in the event sequence can cause spurious events to be inserted. The label helps in manual inspection for events that were only in one or two cycles.

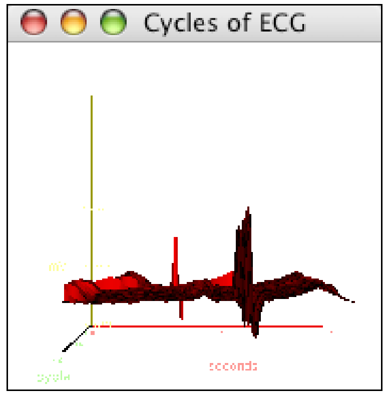
Rejection — Toggle the "Events must be in…" checkbox to turn rejection on and off, and specify a percentage for the relative number of cycles an event must appear in to be considered valid.

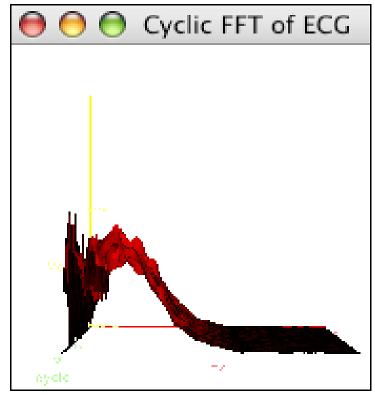
Remove… When mean removal is enabled, the mean value of the data within each cycle is subtracted prior to including it in the overall signal average. This mean removal option is useful for:

- Extracting signals that are "riding" on top of other signals with high DC offset (e.g., MRI artifact on top of skin temperature)
- Compensating for baseline drift where there are not enough cycles present in the data for the baseline variation to completely cancel itself out.

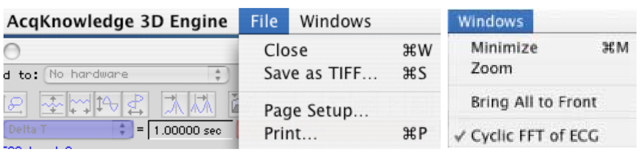
Output 3D Surface



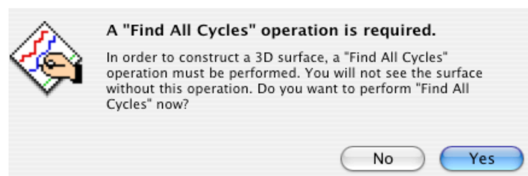


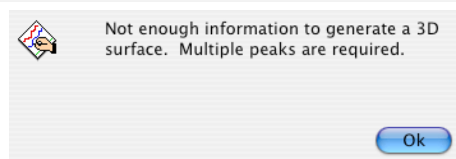


3D Engine menus and prompts



Save as TIFF Choose File > Save as TIFF when 3D output is enabled.





Toggle the "Generate a surface" checkbox at the top of the 3D tab to turn Surface Output on and off.

1) Choose a channel to generate a 3D surface from.
2) Confirm or establish the cycle period of interest on the channel.
   - Use the *Cycles/Peaks* tab and the *Selection* tab to adjust the threshold and cursor positions for the cycle period for 3D output.
3) Choose a cross-section output format for the cycle data: cycle data, histogram, FFT, or DWT.
   - For histogram, FFT, or DWT, click "Configure Transformation" to change the settings.
4) Select surface and background colors.
5) Set axis options.
6) Click OK.

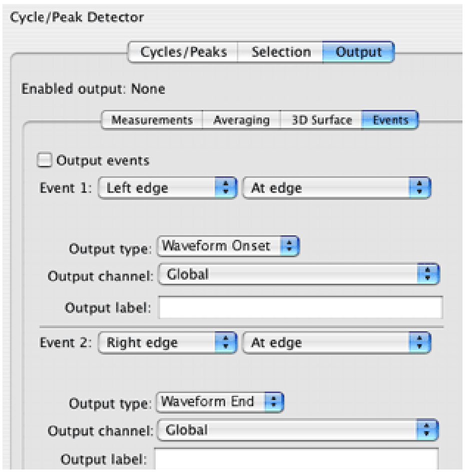
Use the cursor to rotate the 3D image; the magnitude of display response increases as you leave the center of the screen (keep cursor close to center for slow response/display control).

3D Output Example Compare ECG cycles in 3D Output. The following example shows how to Acq*Knowledge* will generate a 3D image using each cross section of ECG.

a) Cycles/Peaks tab: set the threshold level to identify each R-wave.
b) Selection tab: set the cursors to
   Current Peak
   Left edge -.5 seconds
   Right edge .5 seconds

c) On the Output tab
   Enable 3D Output
   Specify the channel to generate a surface from.
   Choose “cycle data” for the cross-section format.
d) Click Find All Cycles.

Output Events



Toggle the “Output events” checkbox at the top of the Events tab to turn Event Output on and off.

The Cycle/Peak Detector Output mode can define events at specific locations; a maximum of two events per cycle can be inserted with Event Output. After the Peak Detector has located a cycle and adjusted the selection, the data within that cycle can be analyzed and used to create new events in the graph (data-driven or time specific).

Event definition

Insertion method & channel selection

Brief definitions follow, see the Event Location table on page 317 for details:

At edge place the event directly at the specified edge (left or right). See Edge Adjustment on page 316.

Percent change looks for a crossing based on a percentage of the value of the signal at the corresponding edge and places the event when a signal increases or decreases in value from the edge.

% peak to peak looks for a point where the signal's value has changed by a percentage of the maximum peak-to-peak amplitude distance over the selected area and places the event when a signal increases or decreases in value from the edge

Minimum place events at the minimum of a specific channel's data within the selection.

Maximum place events at the minimum of a specific channel's data within the selection

The channel whose data should be examined is specified in the pull-down menu directly to the right of the insertion method pull-down menu:

Output type

For each insertion method, the “Output type” pull-down menu adjusts the event type of the inserted event.

Output channel

Sets the channel where the event is inserted, either “Global” for defining global events or specific channels.

- None—disables any insertion for that event and all of the other controls will be hidden except the insertion method pull-down menu.
- Left edge / Right edge—a pull-down menu is displayed to be used to change between the different offset methods
- Minimum / Maximum

Output label

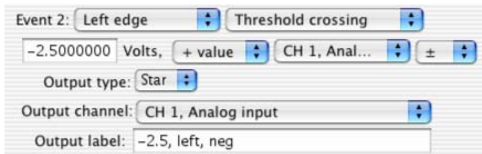
Use this edit field to type in specific label text. Each event that is inserted will have its label set to this text. By default, it is empty (inserted events will not be labeled).

Edge Adjustment

When an “at edge” location method is used, options will be generated to fine-tune event placement relative to that (right or left) edge of the selection.

Offset

Underneath the insertion method pull-down menu, a set of controls will be added that allow the user to specify the percentage, choose whether they want to search for an increase or decrease, and choose the channel whose signal should be examined.



When the offset method is “Threshold crossing,” the event will be placed when the signal on a channel crosses a threshold.

There are a number of possible ways to configure the threshold crossing:

- Fixed—The edit field may contain a specific voltage level for the threshold. In this configuration, an event will be placed if the value of the channel specified in the next pull-down menu crosses this fixed voltage value.
- \+ value—The edit field may specify an offset from the value of the channel at an edge. The threshold voltage level is the value of the chosen source channel plus the offset from the edit field. To specify a threshold lower then the value of the channel at the edge, a negative sign can be placed before the offset.

Direction of crossing

The direction of the crossing can be specified.

- \+ (positive crossing)—the signal must approach the threshold from below and cross to above the threshold before an event is inserted.
- \- (negative crossing)—the signal must approach the threshold from above and cross to below the threshold before an event is inserted.
- ± (mixed threshold)—an event will be inserted at the first positive or negative crossing that is encountered.

Event Location Table

Insertion Method	*Location Process*
Edge, at edge	Place an event at the left or right boundary of the selected area, as specified.
Edge +/- percent offset	Given a particular channel, place an event at the specified time within the selection when the signal increases or decreases by a specific percentage. Left edge + — Place at the time closest to the left boundary of the selection. The percentage is calculated from the value of the signal at the left boundary of the selected area. Right edge - — Place at the time closest to the right boundary of the selection. The distance between the event and the right edge of the selection will have an amplitude difference equal to the indicated percentage of the right edge's value. If the signal does not increase or decrease by that percentage within the selection, no event will be inserted.
Edge +/- percent peak to peak offset	Given a particular channel, place an event at the specified time within the selection when the signal increases or decreases by a specific percentage of the peak to peak delta of the selected area. Left edge + — Place at the time closest to the left boundary of the selection. The percentage is calculated from the result of subtracting the minimum value of the signal over the selected interval from its maximum. Right edge - — Place at the time closest to the right boundary. The distance between the event and the right edge of the selection will have an amplitude difference equal to the indicated percentage of the minimum value of the signal over the selected interval subtracted from its maximum. If the signal does not increase or decrease by that percentage within the selection, no event will be inserted.
Edge +/- threshold crossing	Starting at the specified boundary of the selection, determine a threshold value. This threshold voltage may be: ▪ fixed voltage level ▪ value of signal at the specified edge + offset ▪ mean value in selected area + offset Left edge + — Search for the first location where the signal on a particular channel crosses the threshold. Right edge - — Examining data from right to left, search for the rightmost location where the signal on a particular channel crosses the threshold. If the direction of the threshold crossing matches the user specified direction, then an event is inserted. If it does not, then the next threshold crossing is located and the process repeats. If the threshold is never crossed within the selected area in the user-specified direction, no event is inserted.
Minimum	The event will be placed at the time location corresponding to a specific channel's minimum value within the selected area.
Maximum	The event will be placed at the time location corresponding to a specific channel's maximum value within the selected area.

Output: Clustering

Clustering is the process of taking a set of data points and partitioning them into a fixed number of groups called clusters. Each cluster represents data points that may share some type of commonality. This can be used to assign each data point to a class of similar points. Clustering can be used for hemodynamic analysis and is one of the basic analysis tools used for spike analysis in neurophysiology.

Algorithm Overview

K-means clustering is an iterative algorithm that begins with a data set of real-valued points in an n-dimensional space. Given this data set, one then specifies how many clusters are present. The k-means clustering algorithm attempts to find the location at the center of each of these clusters. Essentially, this algorithm partitions the data set into k groups such that the sum of the differences between the centers of each group and its members is minimized.

A basic algorithm description is:

A. Given a total of k clusters, choose k potential cluster centers.

B. Assign each member of the data set to a cluster according to the closest potential cluster center using a Euclidean distance function (sum-of-squares).

C. Adjust the location of the potential center for each cluster to a more optimal value. The most basic method is to assign the new center as to match the mean value of all of the members of the set (referred to as expectation maximization).

D. Determine if the set of clusters and centers is satisfactory. If not, go to step 2 and repeat the clustering process.

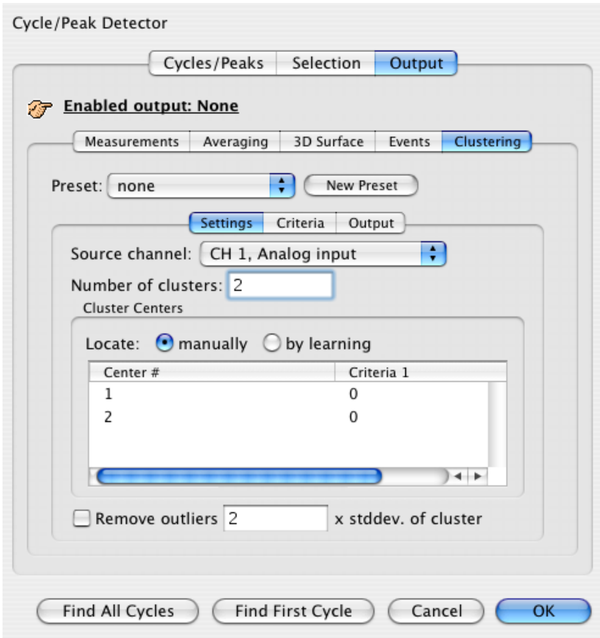
There are many different variations on what constitutes satisfactory ending conditions. The most ideal stopping criteria are when the cluster assignments do not change any longer with successive iterations. If there is no change in the centers, the solution perfectly minimizes the Euclidean distance sum for each cluster, unique up to variations in ordering of the dimensions. In practice, determining the perfect clustering of a data set is computationally intensive and may require an indefinite amount of time. Approximations of perfect clustering are quicker to compute and usually produce sufficiently accurate results.

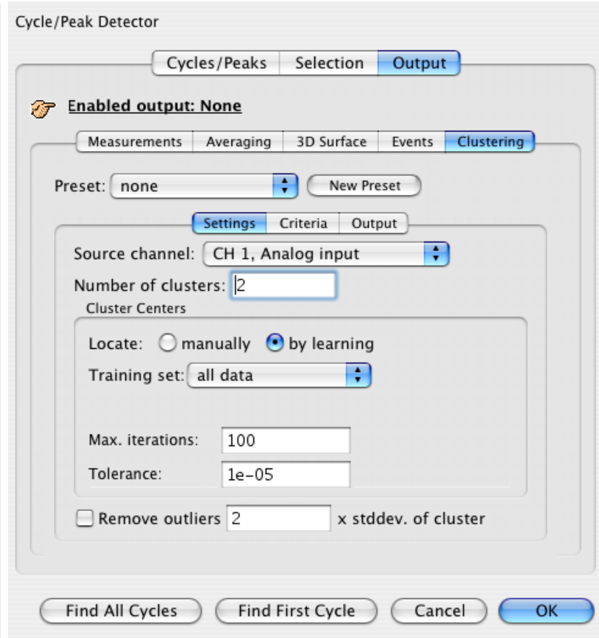
A useful termination condition for constructing approximate solutions is to place a tolerance on how much the centers are moved in successive steps. If the total distance between the centers at subsequent steps of the algorithm is less then a specific tolerance, the centers can be assumed to approximate the ideal solution. Another potential termination condition is to limit the maximum number of steps that are executed. This condition does not necessarily produce a usable approximation, but it does provide a way to halt execution. This is required because there is no way to determine if the algorithm can terminate successfully for a given data set.

Feature clustering is a very common data reduction method in use by clustering based spike sorting software. A waveform segment is reduced to a single data point by extracting numerical quantities known as *features*. Each feature is a single real-valued number extracted from the data. Examples of features are: maximum amplitude in waveform segment, minimum, time to maximum, time to minimum, peak to peak distance, sum of all values, maximum slope of peak, and so on.

A commonly used feature clustering analysis starts with two features. The features are then calculated for each waveform segment and presented on a scatter plot, allowing the user to visually determine how many clusters may be present. A k-means clustering analysis is then run on these two dimensional data points to determine the center of the clusters in feature space. With the center known, each waveform segment is then assigned to a cluster depending on the values of its features.

Clustering Settings





Number of clusters

After features have been extracted from the data, the data points constructed from the feature will be split up into a number of groups. The number of clustering groups must be provided. Clustering will always partition the data into this number of clusters. The output of a clustering analysis should be verified visually and numerically to determine if the number of clusters matches the data.

Locate Centers

Clustering has a good potential to form the basis for classifiers to score physiological data. The clustering implementation will allow for automatic learning of cluster center positions through expectation maximization or for manually specified cluster center positions.

Manually

The manual method allows the centers of each cluster to be manually typed in and edited. Instead of running a full k-means algorithm to locate centers, the k-means algorithm will simply run through the data set and assign each element to the closest cluster center and apply any outlier detection.

This simplistic clustering will allow centers as computed from a previous run to be used in subsequent clustering. Using manually specified centers is necessary to provide consistency when clustering data that may occur in different experiments or different graph files. The use of manual centers allows for the clustering implementation to be used as a classifier to compare new data sets to clusters as determined from either ideal or previously scored data sets.

By Learning

The learning method will use the full k-means clustering algorithm as described above. This consists of choosing candidate centers, computing mean distances, adjusting the candidate center positions, and repeating until termination conditions are met.

The data set used to compute the center positions can either be the full data set or a subset of the data.

Training Set Definition

The training set is the set of data that is used during the iterative portion of the clustering algorithm that learns the potential center of each cluster. Training sets are only used for learned centers. There are three ways to specify a training set for use in clustering:

- Use all of the source data when searching for the centers.Allow the training set to be a specific percentage of the total source data set with members of the training set chosen at random.
- Manually identify the training set with events located in the data.

Partial clustering refers to running the k-means clustering algorithm on only a subset of the source data, referred to as a *training set*. The clustering algorithm outputs the centers of the clusters as determined from the training set, and other data points that are not members of the training set are subsequently added to the cluster whose center is closest to them. This approach assumes that the training set is a good approximation of the characteristics of each cluster in the entire data set.

There are a number of reasons to perform partial clustering. One is computational efficiency. K-means clustering can be a time intensive procedure, as each iteration of the algorithm must recompute all of the distances to reclassify the entire data set. By performing partial clustering, it is possible to reduce the complexity of the k-means clustering step by limiting the amount of source data that needs to be processed in each step. This may be acceptable in situations where perfect partitions are not required.

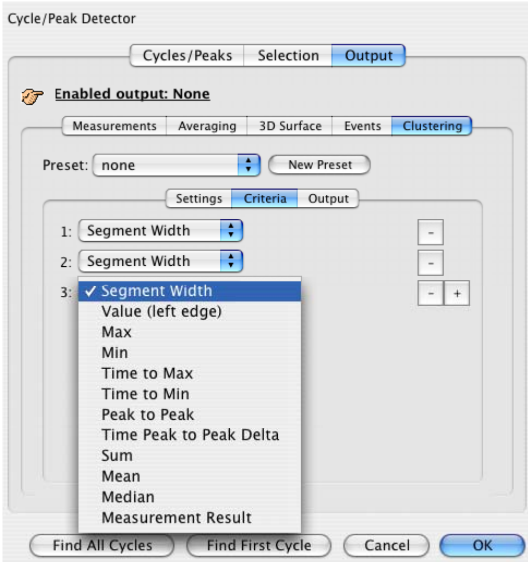
Another use of partial clustering is to construct a *classifier*. A classifier is some method for assigning a particular data point to a specific class. To construct a classifier using k-means clustering a k-means algorithm is run on a training set that has known desirable data properties for splitting data into a number of classes. Once the centers of this training set are known, they can be used to perform another clustering analysis on a set of unknown data and determine how well that data exhibits the properties of the training set.

Remove Outliers

One of the deficiencies of k-means clustering is that it is a total partition of the data set. Basic clustering assumes the original data set is ideal and that each cycle belongs to one of the clusters. Rejection of spurious data points is useful in real-world applications, particularly with physiological signals where noise and artifacts are to be expected.

The clustering analysis allows for optional removal of outliers, or spurious data points. When enabled, each cluster is assigned a boundary. After each data point has been assigned to the cluster, the standard deviation of the distance of each point from the center of the cluster is computed. When outlier rejection is enabled, any data point that is farther away from the center than a specific number of standard deviations will be removed from the cluster. Enabling outlier removal retains only the points in a cluster that have the strongest association with each other.

Clustering Criteria



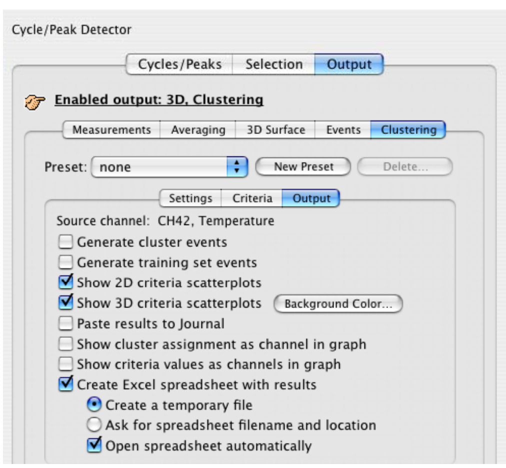
Acq*Knowledge* can perform feature clustering. For a particular segment of a waveform, features are extracted based upon user-specified criteria.

Segment Width	Peak to Peak
Value (left edge)	Time peak to Peak Delta
Max	Sum
Min	Median
Time to Max	Mean
Time to Min	Measurement Result

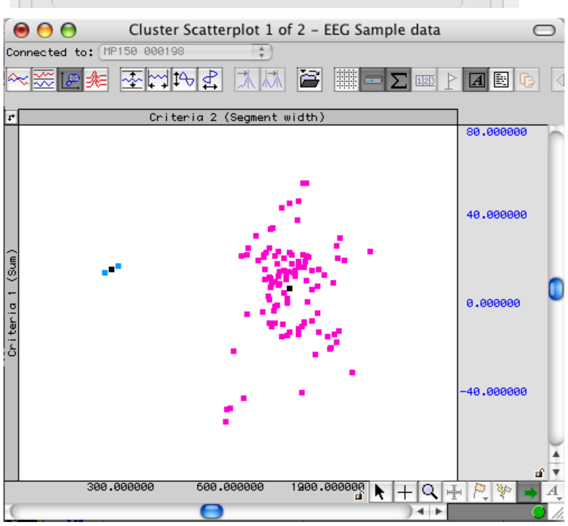
Multiple segments are located using the Find Cycle/Peak functionality. After the criteria have been computed for each segment, clustering is then performed on these criteria. This allows segments to be partitioned based upon their features. For example, “Segment Width” criteria can be used to partition ECG cycles into two clusters of shorter segments and longer segments.

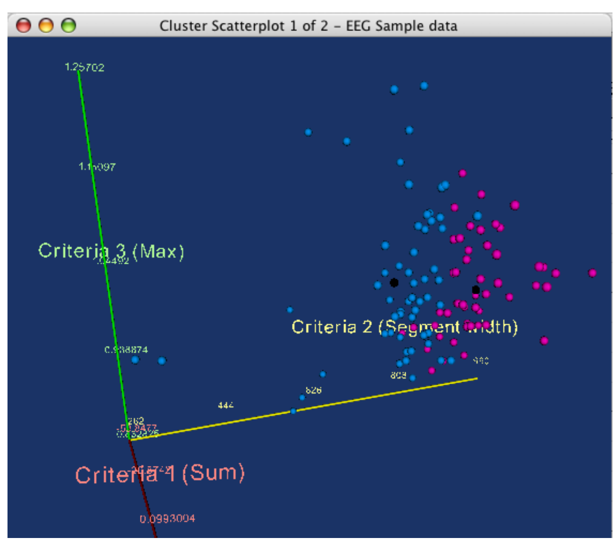
The criteria Segment Widths are reported in milliseconds for time-domain graphs, as are the other time-based criteria (Time to Max; Time to Min; and Time Peak-to-Peak Delta). If the measurements are fixed to units of milliseconds (Display > Preference), then K-Mean Criteria results will match measurement magnitude results. Clustering is defined with a hard left to right directionality for all measurements. Therefore, Delta T will have opposite signs than the same measurement pasted with Find Peak.

Clustering Output

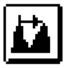


The output of a clustering analysis can be presented in multiple ways, including events, waveforms in the graph, textual tables, and visual scatterplots. These outputs allow for visual examination of the clustering results for anomalies and also provide a foundation for further data reduction using other Acq*Knowledge* tools. By examining waveform data in a reduced feature space, it may be possible to construct clustering configurations that allow for separation of neuron action potentials into different classes, detection of heart arrhythmias, and other classification tasks. To generate 3D criteria scatterplots, select at least three criteria. Includes the option to change the 3D scatterplot background color and export results to an Excel spreadsheet.



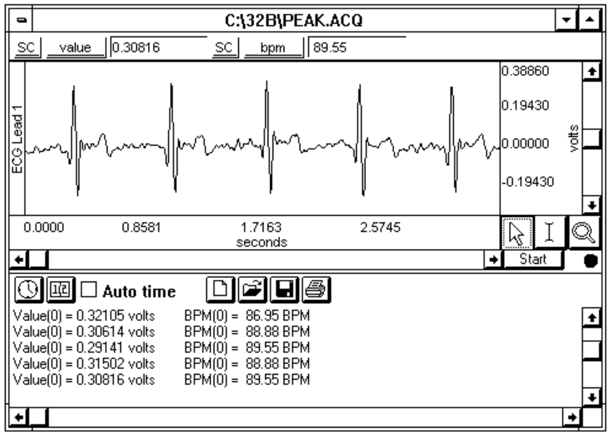


Find Next Cycle

 When you select Find next cycle from the Analysis menu (or select the toolbar icon), both cursors will move one peak to the right while staying above the threshold.

Find All Cycles

When you select Find All Cycles from the Analysis menu, the software will find all cycles/peaks through the end of the file. If your data file is very large, it may take some time to find all the cycles since Acq*Knowledge* loads data from disk while it scans for the cycles.



If the "Paste measurement to Journal" preference is set, measurement values will be pasted into the Journal each time a cycle is found, as shown above. Each column corresponds to a measurement value (in this case, Value and BPM).

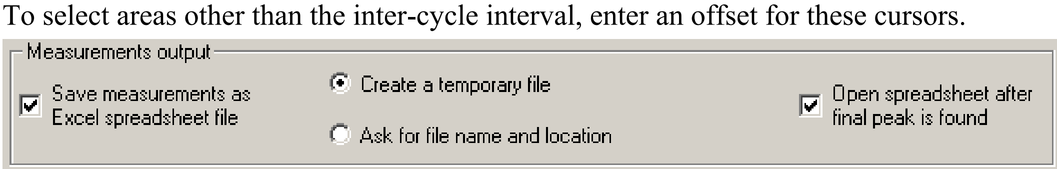
Cursor functions

The process uses the default cursor settings to select the area between two adjacent cycles. In this mode, one cursor tracks the current cycle location while the other cursor marks the location of the previous cycle (these "cursors" are internal to the software and do not appear in the graph window).

A cursor can be based on:

(a) a currently selected cycle
(b) a peak found immediately prior to the currently selected cycle
(c) the current cycle threshold
(d) the threshold used for the previously selected cycle.

To select areas other than the inter-cycle interval, enter an offset for these cursors.



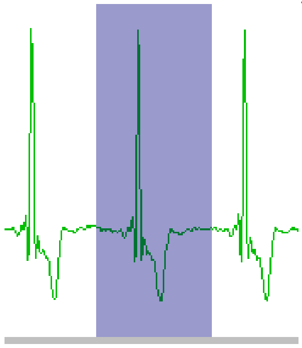
Excel Spreadsheet Export—The cycle detector has also been enhanced to allow for the direct creation of spreadsheets. The cycle-to-cycle values of the measurements can be inserted directly into an Excel spreadsheet file. Each measurement is placed into an individual column and each cycle corresponds to a single row. To generate the spreadsheet a "Find All Cycles" operation is required.

- Also available for File > Save As, File > Save Journal Text As, and Specialized Analysis tools.

The following example details how to detect the positive spike in the QRS complex—a typical use of the Find Cycle (peak detection) function.

Analysis > Find Cycle, Find next cycle, Find all cycles Icons: Find Cycle Find Next Cycle

1. Select the area around a typical peak.

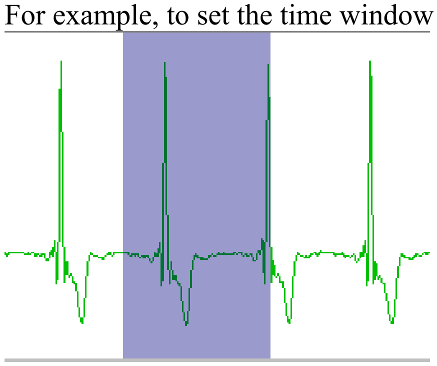


2. Select Find Cycle.
3. Enable "Use selected maximum" on the Cycles/Peaks tab to automatically set an appropriate threshold value based on the amplitude of the cycle detector.
4. Click the Output tab and choose the desired option(s), such as paste measurement controls to update the journal with the measurement values from the new peak.
5. Click a Find button.
   - Find first cycle – the cursor will blink at the first cycle point
     - To manully move through the file, click Find next
     - Or, select an area and choose Find all
     - Or, place the cursor in the data and Find all will detect cycles from that point forward.
   - Find all cycles will ocate all cycles from the current cursor location to the end of the file.

To use an offset

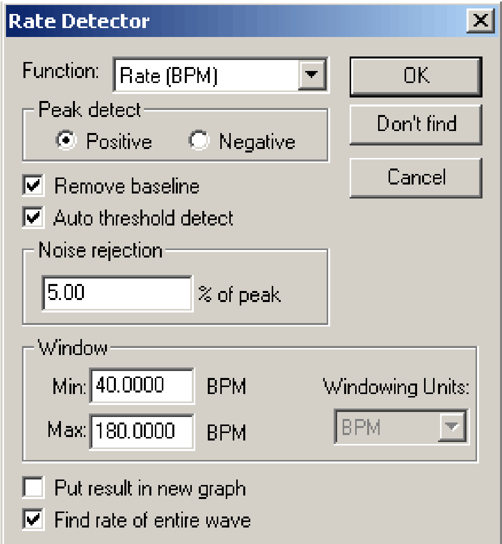
Use the Selection controls to set a time window around the selected cycle; previous peak controls the left cursor, Current peak has options to control the left and right cursors.

1. Use steps 1-4 above.
2. Click the Selection tab.
3. Set the desired cursor values.
   - For example, to set the time window 0.5 seconds *prior* to the previous peak.



To control the left and right cursors, slect currnet peak and enter the appropriate time window to define an interval around the cycle.

Find Rate



The Rate Detector is critical to Acq*Knowledge*'s ability to extract information from physiological data that has a degree of periodicity. Physiological data that can be investigated using the Acq*Knowledge* Rate Detector includes:

- ECG (e.g. Heart Rate or Inter-Beat-Interval recording)
- Blood Pressure (e.g. Systolic, Diastolic, Mean, dP/dt Max, dP/dt Min)
- Respiration (Respiration Rate measurement)
- EMG (Zero Crossing or Mean Frequency analysis)

The Find Rate function allows you to compute rate calculations (including BPM) for data that has already been collected. Although this function uses the same algorithm as the online rate detector (which uses a Calculation channel), it can be advantageous to perform rate calculations after the data has been acquired. One benefit is that off-line rate computations do not require that a separate channel (i.e., a Calculation channel) be acquired. Since the number of acquired channels is reduced, other data can be collected and/or data can be sampled at a higher rate.

Rate detector settings are graph-independent, which means that find rate operations can be performed in multiple graphs without needing to re-enter graph-specific settings for each run. By using multiple data views, different find rate operations can be performed on the same set of data without losing settings between "Find Rate" operations. When the Rate Detector is first opened for a graph, the dialog will be filled with the values from the last successfully executed Find Rate operation. Subsequently, changes to the settings will be applied only to that graph.

Modes of Operation

The Rate Detector incorporates a significant amount of flexibility to optimize performance when extracting data from periodic physiological waveforms. There are three basic modes of operation for the Rate Detector:

1) Fixed threshold detect mode
2) Auto threshold detect mode (enables Noise rejection)
3) Remove baseline and Auto threshold detect mode

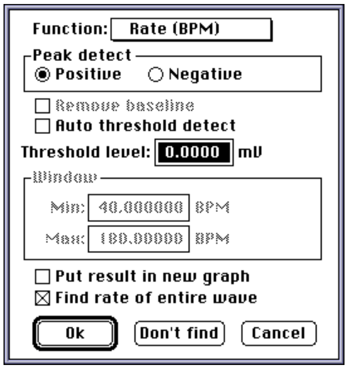
The Rate Detector will eliminate certain options when selecting different modes of operation.

- The Remove baseline function always uses the Auto threshold detect mode.
- Any cyclic measurement relating to amplitude (e.g. Peak-Peak, Maximum, Minimum, Area, Mean) automatically turns off the Remove baseline function.
- If the measurement pertains directly to time (e.g. Hz, BPM, Interval, Peak Time, Count Peaks) the Remove baseline and Auto threshold detect modes are both operational.

Generally, it's best to use the simplest Rate Detector mode that is suitable for your application. If the simplest mode doesn't work, add layers of sophistication, one at a time. For example:

- If the Fixed threshold mode can't or will not work, use the Auto threshold detect mode.
- If the Auto threshold detect mode is similarly unavailable, adjust the Noise rejection or add the Remove baseline option (if possible).

1) Fixed threshold detect mode:

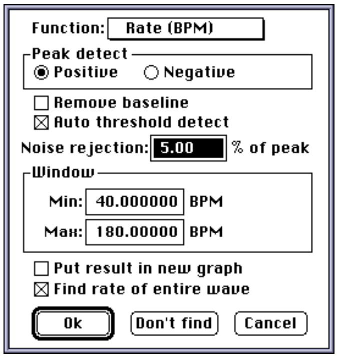


Fixed threshold detect mode is the simplest mode of operation for the Rate Detector. As shown here, the Threshold Level has been set to 0.00 Volts. If the waveform crosses 0 Volts, the Detector will begin to look for Positive or Negative peaks (based on the Peak detect setting).

<u>Not available in Fixed mode</u>:

- Noise rejection
- Windowing options
- Output reset events

2) Auto threshold detect mode:



Auto threshold detect mode is a more advanced and flexible mode of operation for the Rate Detector. In this case, the Rate Detector will create a variable threshold defined as:

Positive peak search
0.75 • (Old Peak Maximum - Old Peak Minimum)

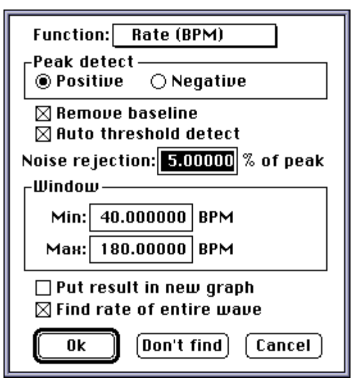
Negative peak search
0.25 • (Old Peak Maximum - Old Peak Minimum)

Furthermore, the Rate Detector will construct a moving file of data points defined by 1.5 times the number of samples that can be placed in the largest rate window size (defined by the Window settings). If the Rate Detector loses sync (no trigger event inside the window), the threshold is changed to the mean value of the moving file of data points. This operation permits successful recovery in the event of spurious waveform data values.

The Noise rejection setting creates Hysteresis around the variable threshold. The Hysteresis level is defined as:

Hysteresis = Noise rejection (%) • (Old Peak Maximum - Old Peak Minimum)

3) Remove baseline and Auto threshold detect mode:



Remove baseline and Auto threshold detect mode is an advanced and flexible mode of operation for the Rate Detector. Primarily, the Rate Detector performs an automatic (and hidden) moving difference function on the waveform data. The difference function is performed over a variable number of samples defined by:

# of points over which difference is performed =
0.025 • Sampling Rate

This difference waveform is then passed through the variable threshold:

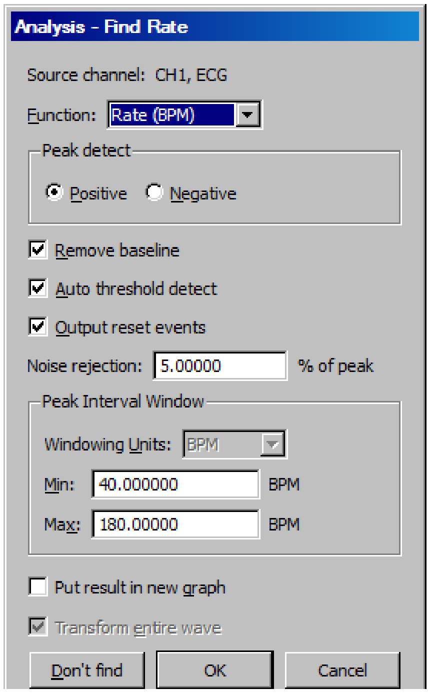
Positive peak search = *Negative peak search =*

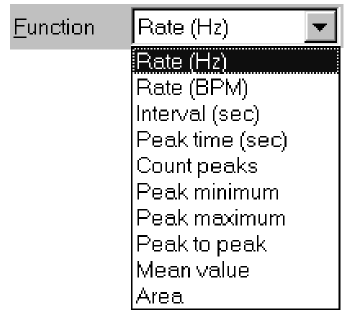
0.75 • (Old Peak Maximum - Old Peak Minimum) 0.25 • (Old Peak Max - Old Peak Min)

Furthermore, the Rate Detector will construct a moving file of data points defined by 1.5 times the number of samples that can be placed in the largest rate window size (defined by the Window settings). If the Rate Detector loses sync (no trigger event inside the window), the threshold is changed to the mean value of the moving file of data points. This operation permits successful recovery in the event of spurious waveform data values.

FIND RATE OPERATIONAL SUGGESTIONS	
Option	Waveform Characteristics
Fixed threshold option	• waveform data has clearly defined positive or negative peaks (like respiratory or air flow data), which are consistently higher (in magnitude) than the rest of the waveform. • waveform data has clearly defined zero-crossings (like EMG), and you wish to determine the rate of these crossings
Auto threshold detect option	• waveform data has a moving baseline, but the peaks are otherwise larger in magnitude than other parts of the waveform (blood pressure). *You may need to adjust the Noise rejection (Hysteresis) to optimize performance.*
Remove baseline *and* Auto threshold detect options	• waveform data has high narrow peaks (like most ECG leads), which may or may not be larger in magnitude than other (slow moving) parts of the waveform. *You may need to adjust the Noise rejection (Hysteresis) to optimize performance.*

Find Rate Dialog Settings





Function

The Rate Detector Function menu lists a variety of calculations, which are discussed below.

Rate (Hz), Rate (BPM), Interval (sec)

The most commonly used function is the Rate (BPM) option, which calculates a rate in terms of beats per minute or BPM. Rate calculations can also be performed that return a rate value scaled in terms of frequency (Hz) or time interval (sec). When rate is reflected in terms of a time interval, the time difference (delta T) between the two peaks is returned. This is sometimes referred to as the *inter-beat interval* (IBI). The frequency calculation returns the rate in Hertz (Hz), which is computed by dividing 1 by delta T. These measurements are perfectly correlated with the BPM calculation, since BPM is equal to 60 times the frequency calculation, or 60 divided by delta T.

Peak time

Returns the time (in seconds) at which the peak occurred. Like the other Rate functions (e.g., BPM and Hz), the value of the last peak time will be plotted until a subsequent peak is detected. The resulting plot will resemble a monotonically increasing "staircase" plot.

Count peaks

Produces a plot of the number of peaks (on the vertical axis) vs. time on the horizontal axis. When used with the delta measurements (in the measurement windows), this is a convenient way to calculate how many peaks occur within a selected area.

Peak maximum/minimum

Tracks the maximum value of the peak (the ECG R-wave). This correlates to the systolic pressure in blood pressure readings. To search for minimum peak values, select negative from the Peak detect section of the dialog.

Peak-to-peak

Looks at the vertical difference between the maximum and minimum values of the waveform on a cyclical basis—useful when you want to determine the amplitude of your pulsatile signal.

Mean value

Computes the mean of a pulsatile signal on a cycle-by-cycle basis between two peaks; produces a staircase plot.

Area

Computes the area of the signal between two peaks, on a cycle-by-cycle basis.

Peak Detect

By default, the Peak Detector searches for Positive peaks (upward pointing, such as the R-wave of an ECG signal) to calculate the rate of a waveform. In some instances, however, you may have to base the rate calculation on negative peaks (downward pointing). To do this, select Negative peak.

Remove baseline

The Remove baseline option applies the optimal high pass filter based on the other settings. This option is useful when signals have a slowly fluctuating baseline.

Auto Threshold Detect

When the Auto threshold detect box is selected in the Find Rate dialog, Acq*Knowledge* automatically computes the threshold value using an algorithm that accentuates peaks and uses information about the previous peak to estimate when and where the next peak is likely to occur. This threshold detector is typically more accurate than a simple absolute value rate calculation function, and is able to compute a rate from data with a drifting baseline and when noise is present in the signal. (For a detailed description of how the calculation is performed, contact BIOPAC Systems, Inc. for the complete Application Note.)

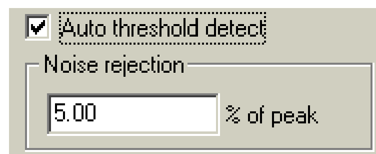
- When Auto threshold detect is enabled, the Noise rejection and Window options are enabled.

Threshold level

This option (activated when "Auto threshold detect" is *not* selected) lets you enter a threshold level to be used for a simple absolute value rate calculation function.

- The Auto threshold detect option is typically more accurate.

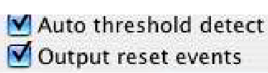
Noise Rejection



Noise rejection (activated when "Auto threshold detect" is enabled) constructs an interval around the threshold level. The size of the interval is equal to the value in the "Noise rejection" text box. Checking this option helps prevent noise "spikes" from being counted as peaks.

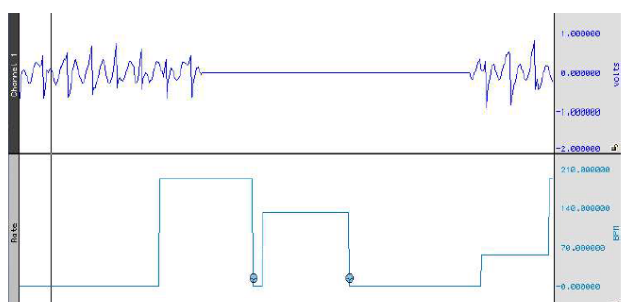
- The default is equal to 5% of the peak-to-peak range.

Output reset events



This option is activated when "Auto threshold detect" is enabled and controls the definition of reset event insertion into the graph.

If no thresholds are found within the user-specified window width, the automatically detected threshold level will "reset" and tracking will start anew; the output of the rate detector function may also drop to zero. When "Output reset events" is enabled, a reset event will be added to the channel whenever the threshold is reset due to window expiration

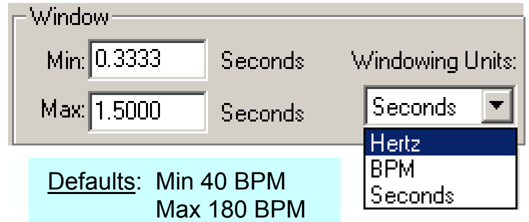


- This helps distinguish zero-valued output due to window resetting and true zero-value output.

In the sample shown, the signal drops to zero during a period of analysis (e.g., due to lead clip falling off). Reset events indicate automatic threshold tracking was lost in this interval and the points where the search for a new level begins.

Window (Peak Interval)

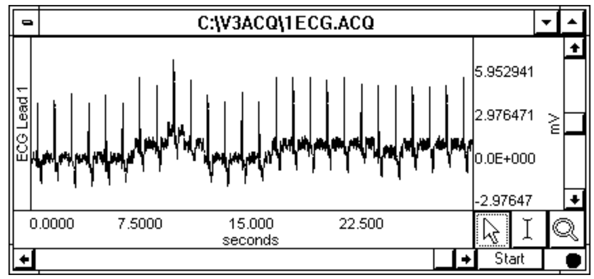
Window is used to specify an upper and lower limit for the Rate calculation. Window is activated when "Auto threshold detect" is enabled; the Windowing Units pull-down menu is only activated when the selected Function can have variable units.



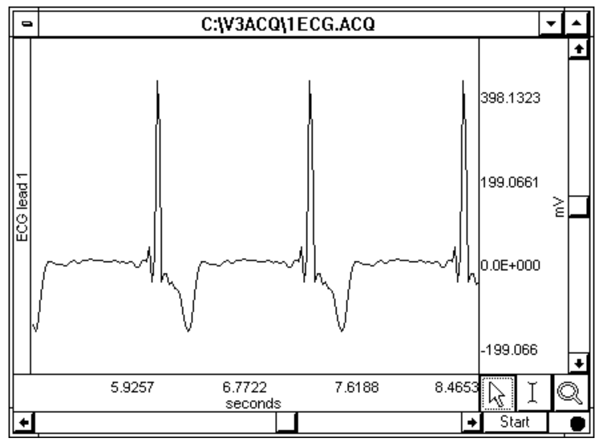
Defaults: Min 40 BPM
Max 180 BPM

Setting the upper and lower bounds for the "window" tells Acq*Knowledge* when to start looking for a peak.

Acq*Knowledge* will try to locate a peak that matches the automatic threshold criteria within the specified window. If no peak is found, the area outside the envelope will be searched and the criteria (in terms of peak value) will be relaxed until the next peak is found.



For instance, once the first peak is found, Acq*Knowledge* will look for the next peak in an interval that corresponds to the range set by the upper and lower bounds of the window. The interval associated with the upper band of 180 BPM is 0.33 seconds (60 seconds ÷ 180 BPM), and the interval for the lower band is 1.5 seconds (1 minute ÷ 40 BPM). If a second peak is not found between .33 seconds and 1.5 seconds after the first peak, then Acq*Knowledge* will look in the area after 1.5 seconds for a "smaller" peak (i.e., one of lesser amplitude).



For those rate functions that require a window interval in seconds, you will probably want to enter numbers like .33 seconds and 1.5 seconds (which correspond to the BPM defaults of 40 and 180). These numbers will be suitable for detecting the heart rate of an average subject.

A simple peak detector uses what is called a *threshold-crossing algorithm*, whereby each time the amplitude (vertical scale) value exceeds a given value, the peak detector "remembers" that point and begins searching for the next event where the channel crosses the threshold. The interval between the two occurrences is then computed and usually rescaled in terms of BPM or Hz. This is how the Acq*Knowledge* rate Calculation functions when all options are unchecked.

In the sample waveform shown here, the threshold was set to 390 mV to detect the peaks of the waveform and provide an accurate rate calculation. Since it only recognizes signals greater than 390 mV as a peak, this 390-mV threshold is referred to as an "absolute threshold." Most waveforms are not so well behaved, however, and artifact can be introduced as a result of movement, electrical interference, and so forth. Combined with actual variability in the signal of interest, this can result in "noise" being included with the signal, as well as baseline "drift" which can render absolute threshold algorithms useless.

Put Result in New Graph

When this option is checked, the results from the find rate calculation are plotted in a new graph window with data displayed in X/Y format, with time on the horizontal axis. By default, this option is unchecked and the resulting transformation is placed in the lowest available channel of the current graph.

NOTE: When put into a new waveform or used as a calculation channel, the output rate function uses padding to generate a signal at a continuous sampling rate. The extracted value is used for padding until the next cycle is detected. This padding can cause unsuitable weighting for statistical analysis. For accurate statistical analysis with only one value for each cycle, use the offline rate detector "show output in new window" to produce a "value" waveform with one output point for each cycle. This output is suitable for export to Excel or other software for statistical analysis.

Find Rate of Entire Wave

When this option is checked, the rate (or other function from the Find rate command) will be calculated for the entire wave (other than the selected area, if any).

Don't Find

Saves dialog settings so you can close out of the dialog and select an area. When you reopen the dialog, the settings will be established as before you closed out, and you can click the OK button to perform the Find Rate function. This is useful for setting parameters using an area of a waveform and then repositioning the cursor at another point in the record.

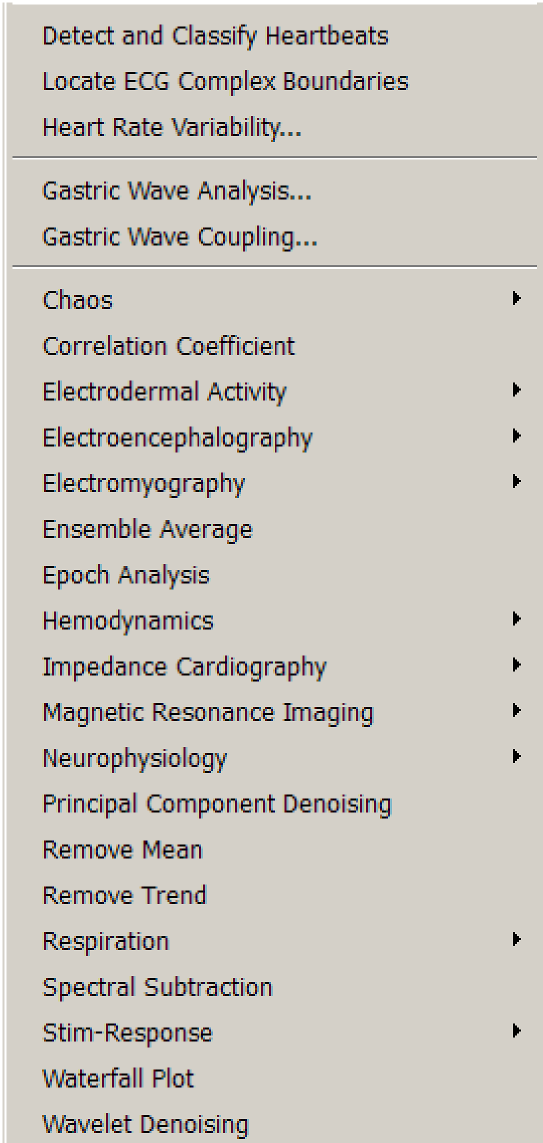
Specialized Analysis

The Specialized Analysis package includes tools to automate analysis to save hours (or days!) of processing time and standardize interpretation of results.

A courtesy copy of the Specialized Analysis package is installed under the Analysis menu with Acq*Knowledge*™ 4.

See the next chapter for full details.

Chapter 17 Specialized Analysis



The Specialized Analysis package includes comprehensive analysis tools to automate analysis to save hours (or days!) of processing time and standardize interpretation of results.

- Acq*Knowledge*™ 4 includes a courtesy copy of the Specialized Analysis Package under the Analysis menu.

Specialized Analysis provides extensive post-acquisition analysis options similar to modules from Mindware Technologies, PONEMAH Physiology Platform, EMKA Technologies, SA and other advanced analysis applications. If you need still more analysis options, save the data as MatLab, Igor Pro, PhysioNet, raw, or text format—or compress the file to reduce file size by about 60%.

Analyze data collected on MP Systems with Windows OS or Mac OS X.

*See the **Analysis** menu on page 296 for other operations that derive data and measurements from the graph*:

Histogram
Autoregressive Modeling
Nonlinear Modeling
Power Spectral Density
AR Time-Freq Analysis
FFT
DWT
Principal Component Analysis
Independent Component Analysis
Find Cycle
Find Next Cycle
Find All Cycles
Find Rate

The Specialized Analysis package includes the following Analysis Packages and Classifiers:

Analysis package—bundle of transformations created to assist with analysis in a specific area of research.

Classifier—special-purpose transformation that defines events at well-known points of interest on standard waveforms, such as the ECG wave boundary classifier and the QRS beat detector and arrhythmia detector.

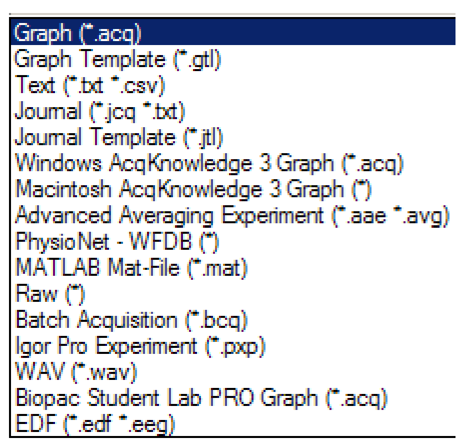
Detect and Classify Heartbeats
Locate ECG Complex Boundaries
Heart Rate Variability
Gastric Wave Analysis
Gastric Wave Coupling
Chaos Analysis
  Detrended Fluctuation Analysis
  Optimal Embedding Dimension
  Optimal Time Delay
  Plot Attractor
Correlation Coefficient
Electrodermal Activity
  Derive Phasic EDA from Tonic
  Event-related EDA Analysis
  Locate SCRs
  Preferences: Output Display Format; Phasic EDA Construction Method: Smoothing Baseline Removal or High Pass Filter
Electroencephalography
  Compute Approximate Entropy
  Delta Power Analysis
  Derive Alpha-RMS
  Derive EEG Frequency Bands
  EEG Frequency Analysis
  Remove EOG Artifacts
  Preferences: Output Display Format
Electromyography
  Derive Average Rectified EMG
  Derive Integrated EMG
  Derive Root Mean Square EMG
  EMG Frequency & Power Analysis
  Locate Muscle Activation
  Preferences: Output Display Format
Ensemble Average
Epoch Analysis
Hemodynamic Analysis
  Classifiers: ABP; LVP; MAP
  Arterial Blood Pressure
  ECG Interval Extraction
  HRV Poincare Plot
  Left Ventricular Blood Pressure
  Monophasic Action Potential
  Respiratory Sinus Arrhythmia
  Preferences: Output Display Format; LVEDP Location Method; dP/dt pk-pk %; MAP Plateau Location Method; dP/dt MAP pk-pk %
Impedance Cardiography Analysis
  Body Surface Area
  Ideal Body Weight
  ICG Analysis
  VEPT
  PEP Pre-ejection Period
  dZ/dt Derive from Raw Z
  dZ/dt Classifier: B, C, X, Y, and O Points
  dZ/dt Remove Motion Artifacts
  Preferences: Output Display Format; C-, B-, and X-Point Location; Stroke Volume Calculation Method; Body Measurement Units; Body Surface Area Method; Ideal Weight Estimation Method; dZ/dt Max Method
Magnetic Resonance Imaging
  Artifact Frequency Removal
  Signal Blanking
  Artifact Projection Removal
  Slew Rate LImiter
  Median Filter Artifact Removal
Neurophysiology
  Amplitude Histograms
  Classify Spikes
  Average Action Potentials
  Dwell Time Histograms
  Generate Spike Trains
  Locate Spike Episodes
  Find Overlapping Spike Episodes
  Set Episode Width and Offset
  Preferences: Detect Spike; Default Episode Width; Default Episode Offset; Default # of Spike Classes
Principal Component Denoising
Remove Trend
Respiration
  Compliance and Resistance
  Penh Analysis
  Pulmonary Airflow
Spectral Subtraction
Stim-Response
  Digital Input to Stim Events
  Stim-Response Analysis
Waterfall Plot
Wavelet Denoising

Acq*Knowledge* File Portability Windows←→Mac OS 10.3 or higher

Use Specialized Analysis to analyze Acq*Knowledge* data files collected on MP Systems running on Windows/PC or Mac OS X. Open/save the following file formats:

Opening files for Specialized Analysis

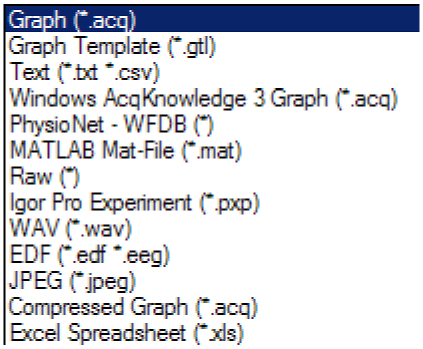
The default file formats (Graph and .ACQ) are referred to as "Acq*Knowledge*" files. The Acq*Knowledge* file format is the standard way of displaying waveforms in Acq*Knowledge*. These files are stored in a compact format that retains information about how the data was collected (i.e., for how long and at what rate) and takes relatively little time to read in (compared to text files, for instance). Acq*Knowledge* files are editable and can be modified and saved, or exported to other formats using the Save as command.



File Compatibility

- Mac Acq*Knowledge* 3.9and above can open and create PC-compatible Graph (*.acq) and Graph Template (*.gtl) files. Variable sampling rate information and hardware settings are retained, and Journals can be read from and written to PC files. Files must end on a multiple of the lowest channel sampling rate to be fully PC compatible.

Saving files after Specialized Analysis



Saving Files Acq*Knowledge* 4.1

The default file format for the File>Save as command is to save files as an Acq*Knowledge* file. Selecting Graph (MPWS) or .ACQ (MPWSW) from the popup menu in the Save As dialog will save a file as an Acq*Knowledge* file, which is designed to be as compact as possible. These files can only be opened by Acq*Knowledge*, but data can be exported to other formats.

File > Save Selection As allows you to save only a portion of your file. When this option is enabled, only the data that has been selected with the I-beam tool will be saved. This option saves the selected area to another file and does not affect the current file that you are working in.

File Compatibility

Windows Acq*Knowledge* 3.9 and above files can be opened with MacAcq*Knowledge* 3.9 and above, but some advanced features may not transfer.

Mac Acq*Knowledge* 3.9 and above can save as "Graph (Windows)" files, but it saves in Windows Acq*Knowledge* 3.7.1 format. In this earlier format, all data is retained, but newer Acq*Knowledge* features (like dual stimulation, data views, embedded archives, etc.) are lost along with any settings specific to Mac Acq*Knowledge* (like events, adaptive scaling settings, etc.).

- Mac Acq*Knowledge* 3.9 and above can save PC-compatible Graph (*.acq) and Graph Template (*.gtl) files. Variable sampling rate information and hardware settings are retained, and Journals can be read from and written to PC files. Choose the format "Graph (Windows)" to create PC-compatible files.

The Mac version does not save PC GLP files or compressed PC files.

Files must end on a multiple of the lowest channel sampling rate to be fully PC compatible.

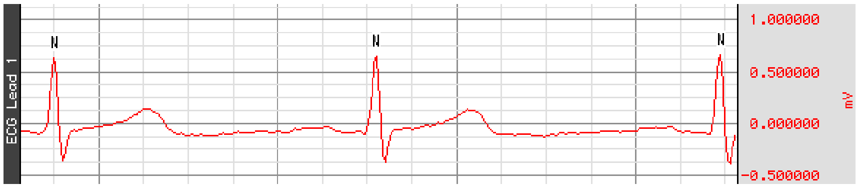
Excel Spreadsheet Export—The Specialized Analysis tools have been updated to automatically export their results to an Excel spreadsheet if desired. The spreadsheet contents mirror the tabular Journal text output. All the spreadsheets are saved as temporary files, so they need to be re-saved in order to be saved permanently.

- Also available for File > Save As, File > Save Journal Text As, and Find All Cycles journal.

Note Specialized Analysis scripts are complex and undo may not function for all steps.

Some of the specialized algorithms are very complex and processor intensive, so they may take a long (even *very* long) time to return a result.

Detect and Classify Heartbeats

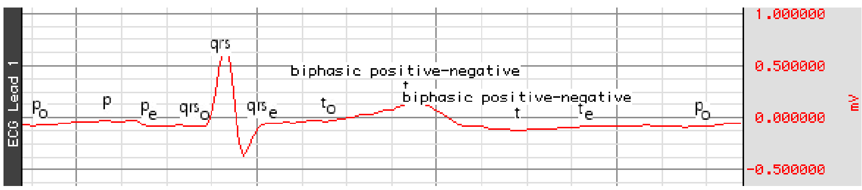


This robust QRS detector is tuned for human ECG Lead II signals. It attempts to locate QRS complexes and places an event near the center of each QRS complex to identify the type of heartbeat event:

- Normal The beat was recognizable as a valid heartbeat falling in a human heartbeat rate.
- PVC The beat was shorter than the beats around it and may be a pre-ventricular contraction. These events can be found in the "Hemodynamic > Beats" submenu of the event type listing.
- Unknown The beat wasn't recognizable as a valid heartbeat. This may occur on the first beat prior to the QRS detector locking onto the signal. It may also occur if tracking is lost due to changes in signal quality.

The Cycle/Peak detector may be used with these events to perform further cardiac analysis.

Locate ECG Complex Boundaries



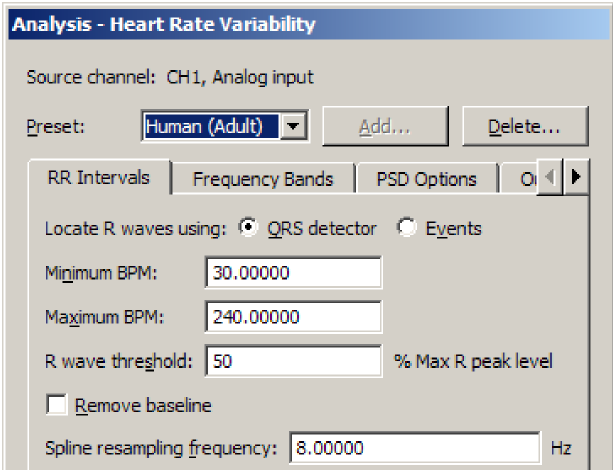
Locate ECG Complex Boundaries performs ECG waveform boundary detection for human ECG Lead II signals; ECG signals must be sampled at 5 kHz or below to be analyzed with this classifier. It will attempt to locate the boundaries of the QRS, T, and P wave and will define events for each individual complex. It will attempt to insert the following events; all of these complex boundaries can be found in the "Hemodynamic > ECG Complexes" submenu of the Event Type listing.

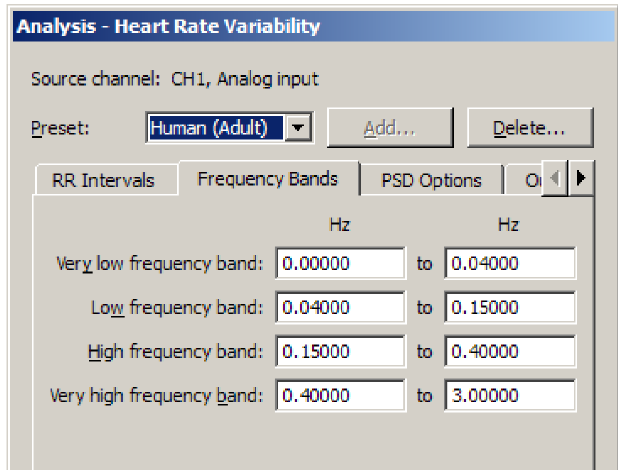
Wave	Type	Event Placement & Description
QRS	Onset Peak End	Before the beginning of the Q wave At the top of the R wave After the end of the S wave
T-wave	Onset Peak End	At the onset of T At the peak of the T wave *Note:* This may not be a positive peak if the T-wave is inverted. If the T-wave seems to be bi-phasic, two T-wave events will be inserted and the event description will indicate that the T-wave is bi-phasic. At the end of T
P-wave	Onset Peak End	At the onset of P At the top of the P wave *Note*: This may not be the absolute maximum, but rather the likely center of P. At the end of P

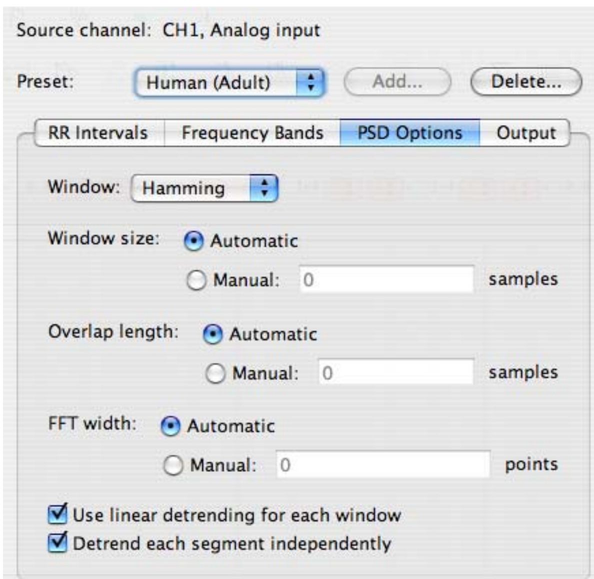
The Cycle/Peak detector may be used with these events to perform further cardiac analysis.

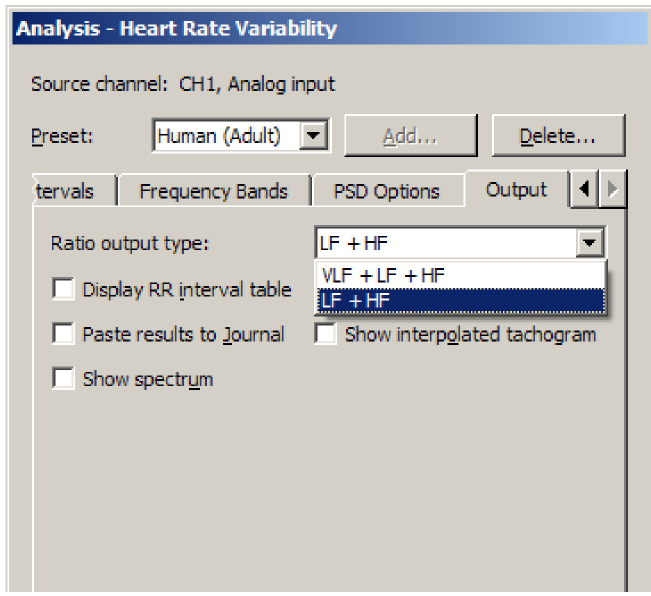
Heart Rate Variability

New parameter settings for the HRV algorithm function better on shorter ECG signals and correspond more closely with other implementations.









Heart rate variability is the examination of physiological rythms that exist in the beat-to-beat interval of a cardiac signal. Heart rate variability assists in performing frequency domain analysis of human ECG Lead II data to extract standard HRV measures. The HRV algorithm in Acq*Knowledge* 3.9 and above conforms to the frequency domain algorithm guidelines as published by the European Heart Journal. HRV processing in Acq*Knowledge* consists of three stages:

1. The RR intervals are extracted for the ECG signal.
   - A modified Pan-Tompkins QRS detector is used.
2. The RR intervals are re-sampled to a continuous sampling rate in order to extract frequency information.
   - Cubic-spline interpolation is used to generate this continuous time-domain representation of the RR intervals.
3. The frequency information is extracted from the RR intervals and analyzed to produce standard ratios. Power sums are reported in units of sec^2.
   - A Welch periodogram is used to generate the Power Spectral Density (equivalent to Transform > Power Spectral Density).

The initial implementation of the HRV algorithm was primarily for use with long duration recordings. HRV algorithm improvements allow for further customizations to the algorithm:

- Windowing type for FFTs used to construct the PSD may be changed between Hamming, Hanning, and Blackman
- Overall window length for segmenting source data for individual FFTs to include in PSD average may be modified
- Length of the individual FFTs in the average can be manually specified
- Scaling has been changed for PSDs, which are now scaled relative to the sampling frequency
- Summary of power in individual frequency bands has been changed
- Instead of a straight sum, an average power value is now reported
- Power at endpoints is halved (e.g. divided by 2)
- Sympathetic/Vagal ratios may optionally include the very low frequency band in the total power estimate
- The modifications to the HRV algorithms that affect its power spectrum estimation have also been applied to the PSD transformation.

After selecting Analysis > Heart Rate Variability, choose the appropriate tab(s) and establish settings.

Preset controls, Transform entire wave checkbox, and OK/Cancel buttons apply across all of the tabs.

Preset—The preset menu can be used to save a variety of HRV settings, including: beat detection parameters, spline resampling frequency, and frequency band ranges. Choose a preset from the popup menu to apply its settings. To construct a new preset with the currently displayed settings, choose Add New Preset. A default preset for adult human subjects is supplied.

IMPORTANT—Recording good data is essential for performing HRV analysis. The protocol for data acquisition, filtering, artifact detection and correction in Application Note 233 results in great improvements in HRV analysis.

> “Results reveal that even a single heart period artifact, occurring within a 2-min recording epoch, can lead to errors of estimate heart period variability that are considerably larger than typical effect sizes in psychophysiological studies.” —Berntson & Stowell, 199

- See **Application Note 233 Heart Rate Variability—Preparing Data for Analysis Using Acq*Knowledge* (online at www.biopac.com)**

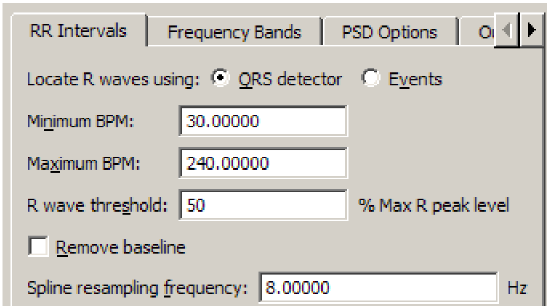
The note explains how to optimize ECG R-R interval data for Heart Rate Variability studies by using a template matching approach. It also explains how to identify erroneous R-R interval values caused by signal artifact and shows methods for correcting the errors by using the tools in the Acq*Knowledge* software. The note explains how to:

A. Record good ECG data
B. Prepare data for the tachogram
   1. Filter the ECG data
   2. Transform the data using Template Correlation function
C. Create a tachogram
D. Identify problems with the tachogram data
E. Correct tachogram data

RR intervals

Select a method to locate R waves: QRS Detector or Events.

QRS detector

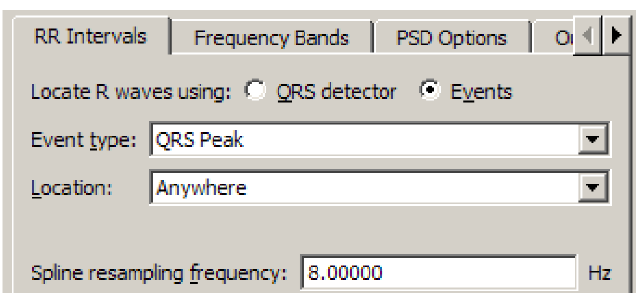


The heart rate variability implementation has a built-in QRS detector. The detector does not run on raw source data; it uses a modified Pan-Tompkins algorithm to normalize the ECG data to 1, whereby the peak amplitude of the highest R-wave represents 1. Use the tachogram output to examine the output of the QRS detector.

- *R wave threshold*—Starting with Acq*Knowledge* 4.1, the detection threshold must be specified in terms of percentage of maximum R peak level; this helps to clarify the units in which this threshold is expressed. The default threshold level of .5 should place the threshold in the middle of the R-wave, which should function on a wide range of data sets. If the R-wave amplitude varies a lot, it might be necessary to adjust the threshold level.
  - R wave threshold is expressed in normalized units, which are in the range (-1, 1): positive for positive R wave peaks. The maximum voltage in the signal maps to 1.0 and the minimum voltage in the signal maps to -1.0.

    Pan J and Tompkins WJ. A Real-Time QRS Detection Algorithm. *IEEE Transactions on Biomedical Engineering* ***32***(3):230-236, 1985.

Events



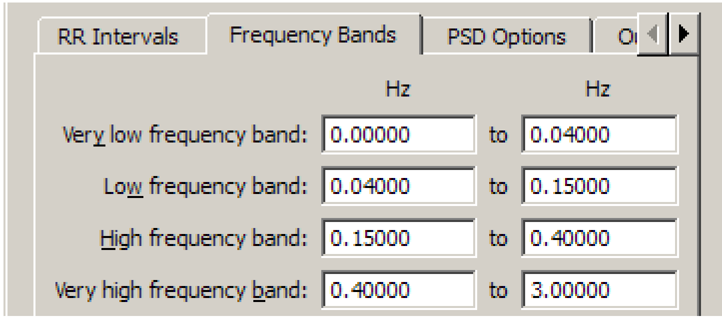
R-wave peaks will be located using events already in the graph of the channel of data to be analyzed. This assumes a single event is placed at each R-wave peak and that all of the R-peak events are of the same event type. When using events, the buit-in QRS detector is not used; the exact positioning between the events on the channel is used to extract the RR intervals.

By using events, it is possible to use other QRS detectors within Acq*Knowledge* for performing HRV analysis. It is also possible to apply spectral HRV-style analysis to data in other domains as long as intervals can be reduced to events.

Spline resampling frequency

For highest accuracy, set to no less than twice the topmost frequency of the very high frequency band.

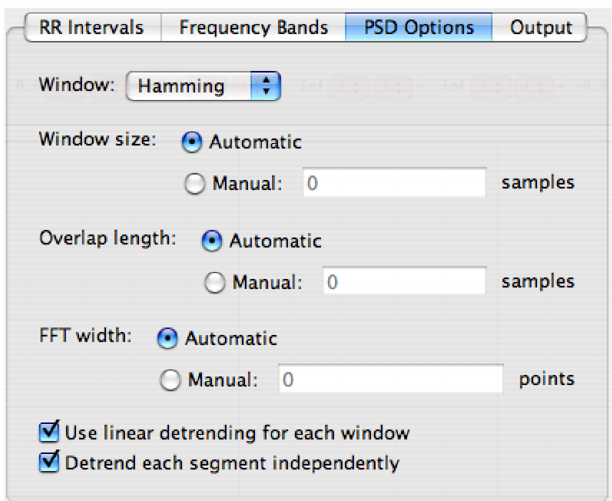
Frequency Bands



Enter the start and end of each specified frequency band to adjust the boundaries of the frequency analysis. They are preset to the frequency ranges recommended by the *European Heart Journal*. Output of derived parameters is presented in a dialog and may also be pasted as text to the Journal.

- Very high frequency band, usually used in rat studies, is disabled if the spline resampling frequency is less than the upper bound of the very high frequency range.

PSD Options



PSD Options establish parameters for the power spectral density transformation used to compute the spectrum from the interpolated tachogram; the options contained in this tab mirror the controls of the Analyis > Power Spectral Density transformation.

The use of linear detrending in each individual segment of source data prior to the windowed periodogram analysis can be enabled or disabled. When disabled, the algorithm may be tuned to correspond to implementations that do not apply linear trending, such as MATLAB, which uses windowing only. The same PSD options are available via Analysis > Power Spectral Density so users can regenerate the spectrum from either the raw or interpolated tachogram output as necessary.

After the user modifies the parameters for the PSD transformation, those parameters will become the new default values each time the dialog is displayed. When the application is relaunched, the default settings will be used (user changes are not persistent).

Window Used to change the window that is applied to each segment of the source data prior to computing the PSD to be included in the average. Includes the following options:

Hamming Hanning Blackman

Window size The specified number of samples must be a power of two. Note that the window function is applied to the entire window width of the data; using a subset of the windowed data will not include the final portion of the windowed data.

- If the FFT size is less than the window size, only a subset of the windowed sample data will be used.

Automatic If selected, the window size is selected automatically depending on the size of the source data. For a data length of *n* samples, choosing this radio button will use the window size:

$$L = \frac{n}{4.5}$$

Manual If selected, the window size will be input manually by the user in the associated edit field. The window size must be greater than three and must be less than the length of the data selection. Users will be warned on invalid window sizes when attempting to click OK.

Overlap length After each individual FFT, the window of source samples is shifted over by a certain amount to compute the next FFT, so there is an overlap of source samples in successive windows of source for the next FFT in the average.

Automatic If selected, the number of samples to overlap successive windows will be computed automatically. Given a window length *L* computed according to the window width choices, choosing this radio button will use an overlap number of samples:

$$\frac{L}{2}$$

Manual If selected, the number of samples to overlap successive windows of source data. Overlapping reduces windowing artifacts The overlap length must be positive and must be less than the window size. Users will be warned on invalid overlap lengths when attempting to click OK

FFT width Automatic If selected, the number of points to use for each individual FFT will be computed automatically. Given a window length *L* computing according to the window width choices, the number of points in the FFT will be set to:

$$N_{fft} = \left\{ \begin{array}{c} 256, L < 256 \\ 2^{\left\lceil \frac{\log(L)}{\log(2)} \right\rceil}, L \geq 256 \end{array} \right\}$$

- The number of points in the FFT is set to 256 if the window width is less than 256. Otherwise the length is set to the next power of two higher than the window width.

Manual If selected, the number of points in the FFT will be specified manually in the edit box to the right of the radio. The number of points in the FFT will be required to be a positive power of two. It is recommended that the FFT length be set larger than the window size. If longer than the window size, zero point padding is used. Users will be warned on invalid FFT number of points when attempting to click OK. If the user inputs a number of points for the FFT that is shorter than the window width, a confirmation dialog will be displayed to the user warning that the windowing is shorter than the requested FFT width and asked if they want to continue.

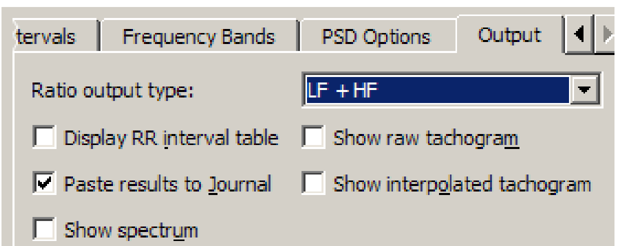
Use linear detrending for each window When enabled, linear regression detrending is applied for each individual segment prior to the FFT computation. When disabled, windowing only is applied.

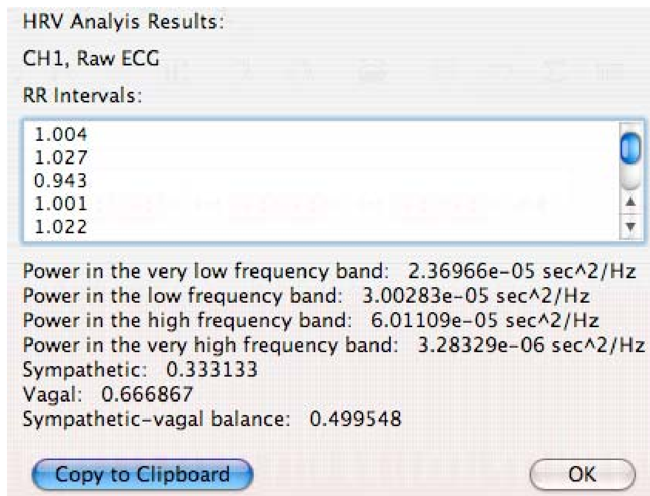
Detrend each segment independently *This option is only available when "Use linear detrending" is enabled.* When this option is enabled, detrending is applied independently for each segment; when disabled, detrending from the previous segment will be incorporated into the next segment.

Transform entire wave When enabled, the entire waveform is delayed. When unchecked, only the selected area is delayed.

- If there is no selection in the graph, the checkbox is enabled and dimmed.
- As the selection changes in the graph with the selection palette, the state of this checkbox is updated.

Output





Create standard result presentation graphs or assess performance of the HRV algorithm. Output options allow access to intermediate computation data for algorithm validation and/or measurements.

RR Interval table

- If the combined output formula is selected, the analysis output will contain an additional line of text: "VLF Ratio" with the corresponding percentage.

Spectrum

Displays the power spectrum density (PSD) estimation from which the PSD summations and sympathetic/vagal ratios are computed.

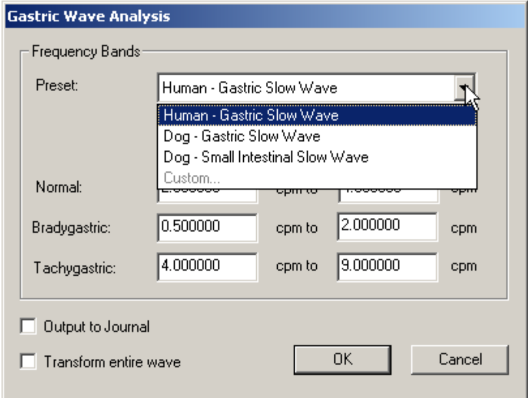
Raw tachogram

Plots the raw R-R intervals found by the QRS detector. Perform statistical HRV measures on the R-R intervals without exporting the textual R-R table to excel.

Interpolated tachogram

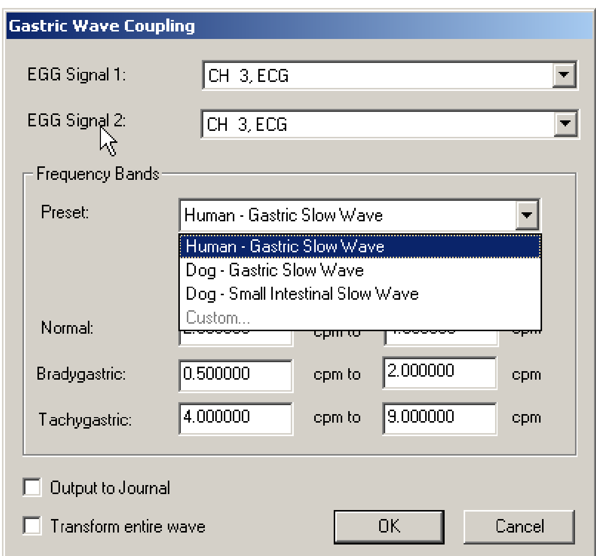
Plots the resampled R-R intervals after cubic spline interpolation is applied and extracts the PSD from this data.

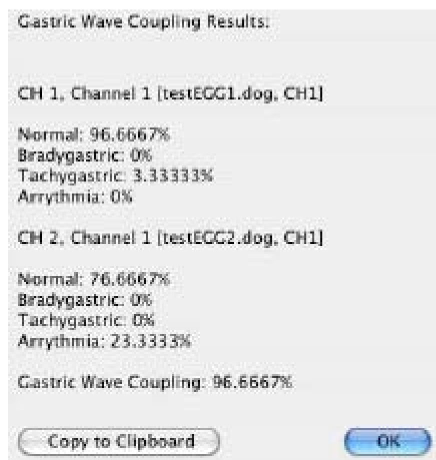
Gastric Wave Analysis



Gastric Wave Analysis uses autoregressive time-frequency analysis to determine the classifications of gastric waves present in an EGG signal. The single wave analysis determines the percentage of gastric waves that fall within the frequency bands corresponding to normal, bradygastric, and tachygastric waves. The analysis also indicates the percentage of waves that fall outside of these boundaries and are arrhythmias. The frequency bands are expressed in units of "contractions per minute" and may be adjusted by the user. Presets for commonly used subject and wave types are predefined; you may extend these presets with your own.

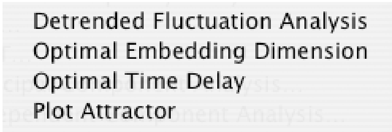
Gastric Wave Coupling





Gastric Wave Coupling takes two EGG signals and uses autoregressive techniques to classify the contractions in those signals according to user-configurable frequency bands (similar to single channel Gastric Wave Analysis). In addition to providing classification information for the two signals, Gastric Wave Coupling provides a measure of the percentage of coupling between the two signals—this measure that can be used to determine the amount of slow-wave propagation across the stomach.

Chaos Analysis



The "Chaos" analysis package assists the user in exploring the chaotic nature of data, including measurement selection and visualization of time domain attractors in the data.

Detrended Fluctuation Analysis

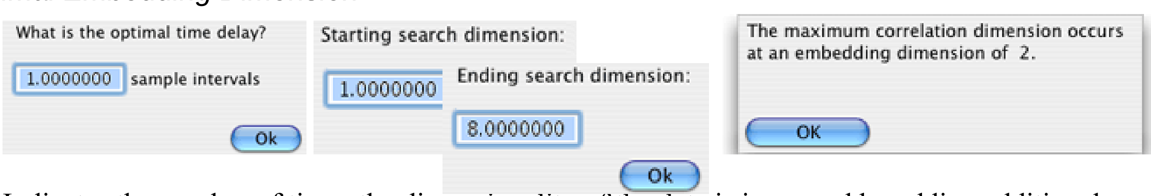
Modified root mean square analysis, useful for evaluating self-similarity in a long-term, non-stationary data series. Source data is mean-adjusted and then integrated; it is then split up into *n* segments of equal length, and in each segment, via linear regression, the best fit least squares line is computed. For a particular value of *n* and a number of samples *N*, the characteristic fluctuation of the piecewise linear fit y_n. is defined as:

$$F(n)=\sqrt{\frac{1}{N}\sum_{k=1}^{N}[y(k)-y_n(k)]^2}$$

F(n) is evaluated over a user-specified range for the number of divisions. *n* will equal the total length divided by the number of divisions. A log-log plot of the interval width *n* in samples versus the corresponding value of *F(n)* will be created. If a linear relationship appears to exist in this graph, then the source signal displays some form of self-similarity. The slope of the line in this graph is related to the scaling exponent.

➲ For more information on Detrended Fluctuation Analysis, see http://www.physionet.org/physiotools/dfa/

Optimal Embedding Dimension

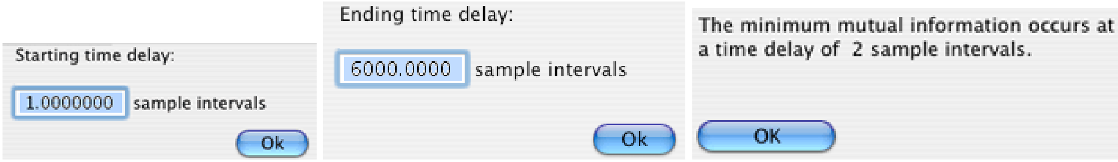


Indicates the number of times the dimensionality of the data is increased by adding additional copies of the data. Many of the fractal measurements take an embedding dimension parameter. Increasing the dimensionality of the data may improve the quality of the results. In general, embedding dimensions should always be less than 8.

After the most relevant time delay for the data has been selected, Optimal Embedding Dimension assists in choosing the embedding dimension that appears to give the most accurate results. The embedding dimension is chosen to be the earliest dimension in the search range where the fractal correlation dimension measure reaches a local maximum. This indicates the lowest dimension where the data has the potential to exhibit the most self-similarity.

- Since real data may not be fractal in nature, there may be no local maximum for the embedding dimension. In this case, it is not possible to determine the optimal dimension.

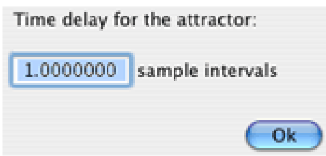
Optimal Time Delay

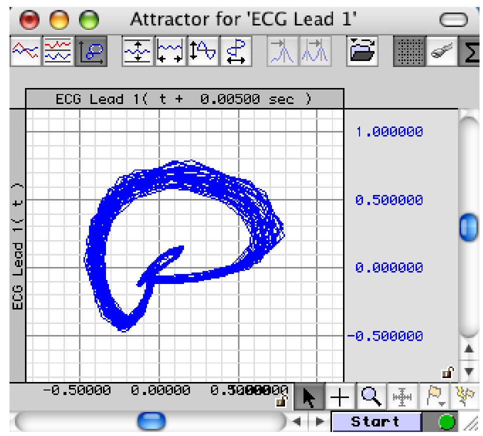


Assists in picking a time delay that is most relevant for the data. It runs through and locates the earliest time delay in the specified interval range where the mutual information measurement reaches a local minimum. Optimizing the time delay in this fashion picks the shortest delay where the signal exhibits the most independence with respect to its time-delayed version.

The fractal dimension and other chaos-related measurements operate on a single channel of data. In the process of extracting these measures, a signal is compared with a time-delayed version of itself to examine the patterns in dynamics of the data. These measures take a fixed time delay setting. The Optimal Time Delay transformation can be used to choose the best value for the parameter.

Plot Attractor

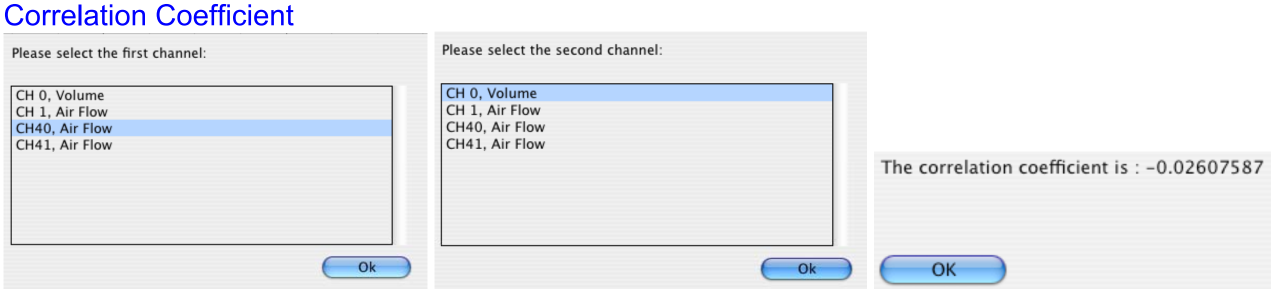




Assists in constructing X/Y plots for the attractors of time delayed data. By visually examining the shape of the attractor at a given time delay, To develop an intuitive sense for the underlying nature of the data and the dynamics of the system.

Plot Attractor functions on the active channel of the graph. It prompts the user for a time delay and then constructs a new graph window with an X/Y plot of the attractor of the original signal against the time delayed version of the signal. It does not perform any additional computation aside from assisting in the setup and configuration of the attractor plot.

Correlation Coefficient



The *correlation coefficient* is a statistical measure related to the degree of variance or covariance between two data series. Given two data series *x* and *y* of length *n*, the correlation coefficient *r* is given by the formula:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{\left[n\sum x^2 - \left(\sum x\right)^2\right]\left[n\sum y^2 - \left(\sum y\right)^2\right]}}$$

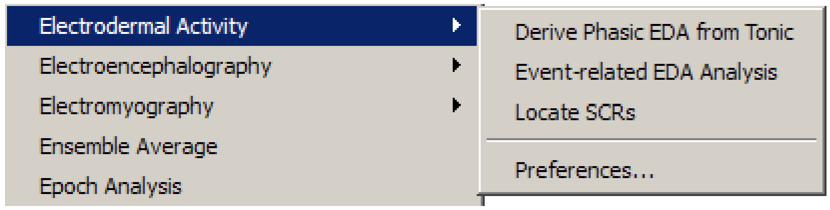
(see http://mathworld.wolfram.com/CorrelationCoefficient.html)

The square of the correlation coefficient can be used to determine the proportion of variance in common between the two signals. As the square gets closer to 1, the signals are a better statistical match for each other.

To derive the correlation coefficient, two channels of data are compared against each other.

- the channels must have the same length
- the channels must have the same waveform sampling rate
- all of the data of the entire graph for the two channels will be used to compute the correlation coefficient.

Electrodermal Activity



Overview

The **Electrodermal Activity** analysis routines are separated into three menu options that transform the tonic EDA signal to create a phasic waveform, locate and score skin conductance responses, or perform a detailed event-related EDA analysis by combining marker information from the Stim-Response: Digital Input to Stim Events routine (see page 397) to the event-related EDA Analysis routine. The Event-related routine will automatically derive the phasic waveform and locate SCRs.

The routines employ a scoring system that marks the waveform and the point of stimulus delivery. It's easy to manually adjust the automated scoring by relocating the event onset/peak/end before rerunning the analysis. The event-related analysis provides a variety of measures from the SCR data, including classification of specific and non-specific responses. The results are pasted into the journal file or Excel for further analysis.

Preferences must be established for each routine and can be adjusted at any time via the Preferences option (page 351). The time to complete the analysis routine will vary based on the number of SCR reposnes and the sample rate of the data.

Definitions

The prompts and results of the Electrodermal Activity analysis package use the following terminology and units:

µmho—the unit abbreviation for micromhos, used in channel labels and analysis results; micromho is equivalent to microsiemens.

EDA (Electrodermal Activity)—the general area of skin conductance signals. Sometimes referred to by the older term "galvanic skin response."

Tonic EDA—continuous data acquired from an EDA electrode that includes all baseline offset. Sometimes referred to as "skin conductance level." Averaging the tonic EDA over a specific period of time results in the average skin conductance level over an interval. Tonic EDA is recorded using BIOPAC equipment with the high pass filtering set to off (DC mode).

Phasic EDA—a continuous signal indicative of localized changes in the tonic EDA signal. Sometimes referred to as "continuous skin conductance response." Phasic EDA can be thought of as AC coupled tonic EDA. The EDA analysis package offers multiple ways of constructing phasic EDA including smoothing and high pass filtering. The EDA analysis package performs the majority of its analysis on tonic EDA signals, so if phasic EDA is being recorded directly it is recommended that a second channel be used to record tonic EDA.

Skin Conductance Response (SCR)—an individual localized change in the tonic EDA signal. An SCR may occur in response to a stimulus or may occur spontaneously. In general, there are multiple SCRs present in a tonic EDA signal and they can be detected as deflections from the localized baseline.

Reference

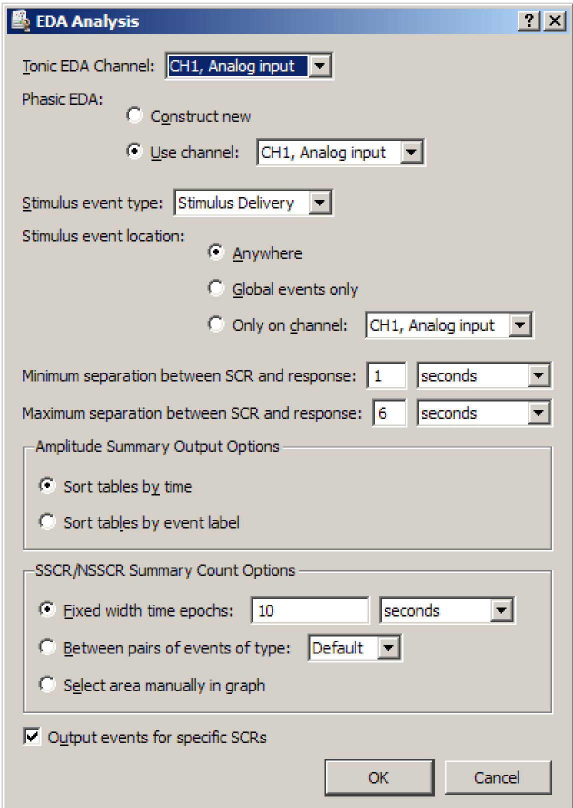
The Electrodermal Activity analysis package was developed to support the parameters established in:

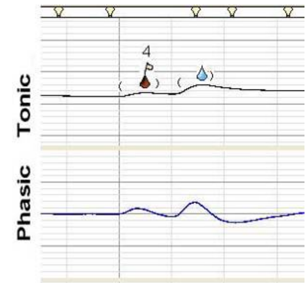
M. E. Dawson, A. M. Schell, and D. L. Filion. The electrodermal system. In J. T. Cacioppo, L. G. Tassinary, and G.B. Bernston, editors, Handbook of Psychophysiology: second edition, pages 200–223. Cambridge Press, Cambridge, 2000.

Derive Phasic EDA from Tonic

Given a tonic EDA signal, this transformation uses baseline smoothing or high pass filtering (the method currently set in Preferences) to construct a new Phasic EDA channel in the graph containing the estimate of the phasic EDA. This routine is automatically included in both the locate SCR and Event-related EDA routines.

Event-related EDA Analysis





Sample EDA Analysis Output

All SCR events are marked on the tonic waveform as follows:

(*open paren.*	The point at which the phasic signal crosses the SCR threshold level established in EDA Preferences; see page 291
blue waterdrop	blue marks the peak response of a nonspecific, event-related SCR
red waterdrop	marks a specific SCR “SRR” with a flag numbered with the stimulus event type
) *close paren.*	The point at which the phasic signal crosses the zero threshold level

The Event-related EDA Analysis transformation routine assists in the extraction of EDA measures that are linked to specific stimuli. The stimulus event marks must be included in the file BEFORE using this analysis.

This analysis routine requires four elements:

1. Tonic and Phasic waveforms.

   Tonic EDA Channel: A Tonic EDA signal must be present in the graph.

   Phasic EDA:

   Construct new: Given a tonic EDA signal, a phasic EDA will be automatically constructed using baseline smoothing or high pass filtering (the method currently set in Preferences).

   Use Channel: If the graph contains a phasic waveform, select the appropriate channel.

2. Stimulus delivery events.

   Digital markers with a common event type must be located BEFORE using this analysis.

   The Event-related EDA Analysis requires that an event be defined in the graph at the location of the delivery of each stimulus. This event may be defined using the Event Tool, hotkey insertion during acquisition, or any other method of defining events. All of the stimulus delivery locations to be extracted must have the same event type (e.g. “Flag”). To analyze multiple different event types, the transformation script must be executed multiple times.

   - If you are using E-Prime, SuperLab, or some other stimulus delivery system and have the digital events captured in the Acq*Knowledge* file, we recommend that you use the Stim-Response: Digital Input to Stim Events routine (see page 397). This routine will automatically classify and label the digital markers for use by the Event-related EDA analysis.

   Stimulus event type: If using the Digital Input to Stim Events, select Stim/Response > Stimulus Delivery. Stimulus delivery events are located by event type or by specific channel of the graph.

Stimulus event location: Specify the location as anywhere, global only, or on a specified channel. See the Events section for details.

3. Skin conductance responses.

   If the tonic EDA signal does not already have SCR events defined on it, SCR events will be automatically constructed on the channel using the Locate SCRs transformation routine.

4. Specified time window between the stimulus event and the skin conductance response.

   The transformation takes a maximum allowable separation window between the stimulus event and SCR response. Each stimulus delivery event is paired with the closest SCR event. SCRs that correspond to a stimulus delivery are known as specific SCRs (abbreviated “SRR”). SCRs generally occur within a certain timeframe after stimuli. The time window allows responses too close to stimuli to be rejected and classified as non-specific.

   Minimum separation: specify in relation to the stimulus event (includes time unit options).

   Maximum separation: specify in relation to the stimulus event (includes time unit options).

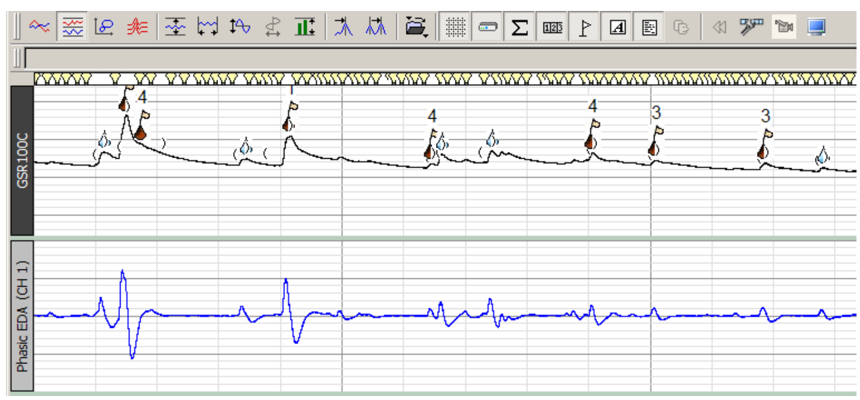
   Given a response time window $[res_{min}, res_{max}]$, for each stimulus delivery event at a time t, SCR onset events that are not presently matched as SRRs will be searched for in the window $[t+ res_{min}, t+ res_{max}]$. The SCR onset event within this window closest in time to $[t+ res_{min}]$ will be paired with the stimulus event and considered a SRR.

SRR are marked as a red waterdrop icon with a flag numbered with the corresponding stimulus event type when “Output events for specific SCRs” is enabled.

Each SRR will be matched to only one stimulus delivery event. If the closest SCR to a stimulus is farther away than this time interval, it is not assumed to be a response to the stimulus. It may be a response to a later stimulus or it may be a non-specific SCR that occurred spontaneously.

Output Events for Specific SCR

Enable this option to mark specific skin conductance events as a red waterdrop icon with a flag numbered with the corresponding stimulus event type.



Event-related EDA Analysis Output Options

Enhancements provide more options for multiple stimulus event types and unmatched events, including:

- Labels and additional measures are available in the specific stimulus and SCR analysis table
- Text and Excel tables may be optionally sorted either by time or grouped by stimulus label
- A new table has been added listing stimulus events that were not paired with an SCR
- The SRR/NS.SSR Rate analysis, which counts frequencies of SCRs in specific time periods, may now be driven by time periods defined using pairs of events or a selection in the graph
- A table has been added listing amplitude/frequency percentage statistics for all matched and unmatched stimuli events (e.g. total stimulus count, percentage of stimuli that were pared with an SCR, etc.)
- Additional optional Specific-SCR events may be defined on the tonic EDA waveform at the positions of specific SCRs with labels matching the stimulus to which they were responses. This allows for further peak-detector based runs to perform additional data reduction.

Amplitude Summary Output Options

For each specific SCR that is paired with a stimulus delivery event, the following measures are extracted in table format and can be sorted by **Time** or by **Event label**. If text output is enabled in EDA Preferences, the average value of SCL, Latency, SCR Amplitude, and SCR Rise Time will be included as the final row of the table.

Name	Abbrev.	Description	Units
Stimulus Delivery Time	Stim Time	The time within the recording where the stimulus delivery event was located.	seconds
Skin Conductance Level	SCL	Amplitude of the tonic EDA signal at the time when the stimulus was delivered.	µmho
Response Latency	Latency	Time separating the stimulus delivery from the onset time of the corresponding SCR. This latency will always be less than the maximum allowable latency specified as a parameter for the analysis.	seconds
SCR Amplitude	SCR Amplitude	Height of the corresponding SCR as determined by the change in the tonic EDA amplitude from the time of SCR onset to the maximum tonic EDA amplitude achieved during the SCR: $[EDA(t_{max}) - EDA(t_{onset})]$	µmho
SCR Rise Time	SCR Rise Time	Time taken for the tonic EDA to reach its maximum value within the SCR: $[t_{max} - t_{onset}]$	seconds

SSCR/NSSCR Summary Count Options

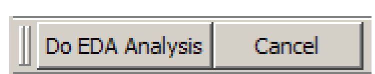
In addition to the above measures extracted for each specific SCR, the analysis performs rate extractions for specific and non-specific SCRs. By examining how the rate of SCR occurrences changes, long-term experimental trends can be investigated. This analysis is placed into a second set of waveforms (or a second table for text and Excel output).

Fixed width: fixed width window is specified as the "SCR count interval width" when performing the analysis. The entire recording is split up into fixed-width epochs of this granularity with the first epoch aligned at the start of the recording. For each fixed-width epoch, the following are extracted:

Name	Abbrev.	Description	Units
Epoch Start Time	Start Time	Time location in the recording of the start of the epoch being examined.	seconds
Specific SCR Rate	SRR	Frequency of the occurrences of specific SCRs within the epoch. Specific SCRs are those SCRs that were successfully matched to a corresponding stimulus delivery event.	Hz
Non-specific SCR Rate	NS.SRR	Frequency of the occurrences of non-specific SCRs within the epoch. These are SCRs that occur spontaneously and are not paired with any known stimulus.	Hz

Between event pairs: Select an event type from the pull-down menu. The software will locate the event markers at the beginning and end of the region of interest and perform the analysis between the two points This option is useful if the recording is broken into defined periods—such as baseline, event, and response—using the event hotkeys..

Manually selected area: Highlight the area where NSSCR/SSCR rates should be computed and then click "Do EDA Analysis" in the graph window.



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Amplitude/Frequency Percent Summary

The "Stimulus Matching Summary" table for Textual and Spreadsheet output provides overall summaries for each unique event label. The table has one line for each unique event label.

Assume we have a set S of all events of an identical label, with an indexed event defined by s_i.

This will be split into two subsets: $S_{matched}$ consisting of all of the specific stimulus events that have an associated SCR with them, and S_{ns} consisting of the non-specific stimulus events that do not have an associated SCR with them. Given these sets, the following definition holds:

$$S_{matched} \cup S_{ns} = S$$

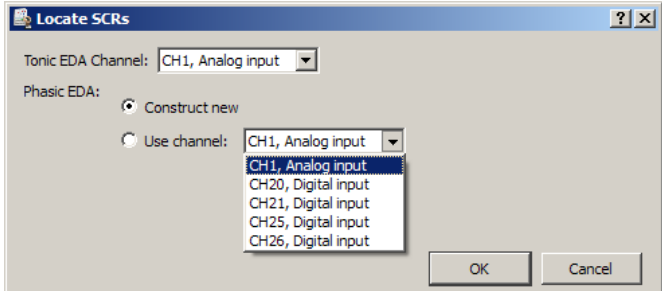
For an individual event, define the SCR Amplitude function:

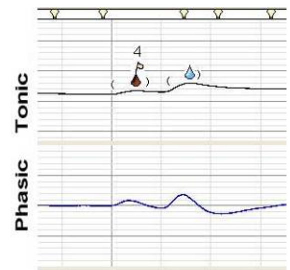
$$a(s) = |EDA(t_{max}) - EDA(t_{onset})|$$

The following are the definitions of measures that will be included in the table:

Name	Description	Units
Amplitude	Average value of the SCR amplitude of all of the specific SCR events. Defined by the following formula: $$Amplitude = \frac{\sum_{s_i \in S_{matched}} a(s_i)}{\lvert S_{matched} \rvert}$$	µmho
Magnitude	Weighted average of the SCR amplitude of all of the specific SCR events over the entire set of specific and non-specific events. Defined by the following formula: $$Magnitude = \frac{\sum_{s_i \in S_{matched}} a(s_i)}{\lvert S \rvert}$$	µmho
Matched	Total count of specific SCRs. Defined by the following formula: $$Matched = \lvert S_{matched} \rvert$$	
Non-matched	Total count of non-specific SCRs. Defined by the following formula: $$Non - matched = \lvert S_{ns} \rvert$$	
Total	Total count of events. Defined by the following formula: $$Total = \lvert S \rvert$$	
Frequency (%)	Percentage of stimulus events that were paired with an SCR. Defined by the following formula: $$Freq = \frac{\lvert S_{matched} \rvert}{\lvert S \rvert} * 100$$	
Label	Textual label of the events that are included in S. One row per unique event label will be included in the table. All events with empty labels will be consolidated into a single row of the table. All stimulus label types are case sensitive, similar to the sorting options in the other output tables.	

Locate SCRs





The Locate SCRs routine will identify skin conductance response and score the waveform. This analysis is useful for analyzing spontaneously occurring skin conductance responses. The routine is automatically included in the Event-related EDA routine. All SCR events are marked on the tonic waveform as follows:

(	*open paren.*	The point at which the phasic signal crosses the SCR threshold level established in EDA Preferences; see page 351
	blue *waterdrop*	The peak response point of a nonspecific, event-related SCR
)	*close paren.*	The point at which the phasic signal crosses the zero threshold level

This transformation requires a tonic EDA signal. If a phasic EDA has already been constructed for this tonic EDA, it may be used; otherwise, the transformation will create a phasic EDA automatically according to the settings in the Preferences.

Given a tonic EDA, the Locate SCRs transformation defines an event for each skin conductive response in the tonic EDA. SCR location is a two stage process. First, all potential SCR occurrences are located on the signal. Second, all potential SCR occurrences that are not large enough are rejected.

Potential SCR occurrences are detected by performing thresholding positive peak detection on the phasic EDA signal (using H and P as set via Preferences):

1. Given a detection threshold H (expressed in μmho), search for a positive threshold crossing in the phasic EDA signal. This position is recorded as the start of the potential SCR.
2. Continue examining the phasic EDA until the first negative threshold crossing of 0 μmho occurs. This position is recorded as the end of the potential SCR.
3. Return to step 1 to continue searching for more potential SCRs.

After all of the potential SCRs have been located, the set of valid SCRs is constructed as follows:

1. Determine the overall maximum amplitude of the phasic EDA signal within all potential SCRs.
2. Given a percentage P, construct a threshold level T of P percent of the overall maximum phasic EDA signal value located in step 1.
3. Examine each potential SCR. Find the maximum phasic EDA. If $m < t$, discard the potential SCR. Mark the potential SCR as a valid SCR.

If the tonic EDA channel chosen for analysis already has SCR events defined on it, the SCR events will be replaced with the newly detected SCR events. No existing SCR events will be erased without a confirmation.

Once SCR events have been defined, they can be used in conjunction with the Cycle Detector for performing further data reduction. The "event count" measurement can be used to estimate SCR frequency during individual time ranges of the experiment.

Events on Tonic EDA

After valid SCRs are located using the algorithm above, events are inserted into the graph that can allow for further data analysis around the SCR positions. Three events are defined on the tonic EDA waveform for each individual valid SCR:

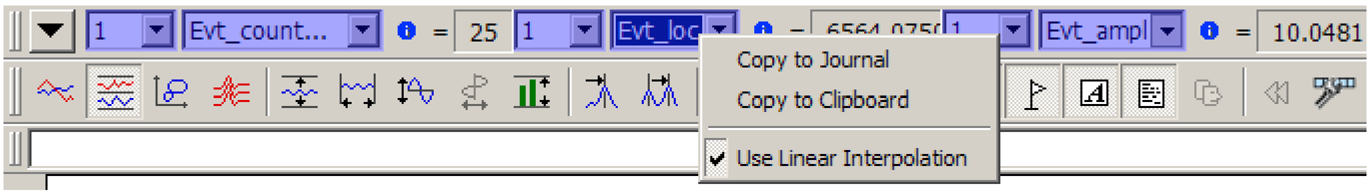
1. "General > Waveform onset" event at the SCR onset time. This is the point where the threshold H was crossed in the phasic EDA.
2. "EDA > Skin conductance response" event at the time where the tonic EDA reaches its maximum value within the SCR (max in time range).
3. "General > Waveform end" event at the ending SCR time. This is the point where the zero threshold was crossed in the phasic EDA.

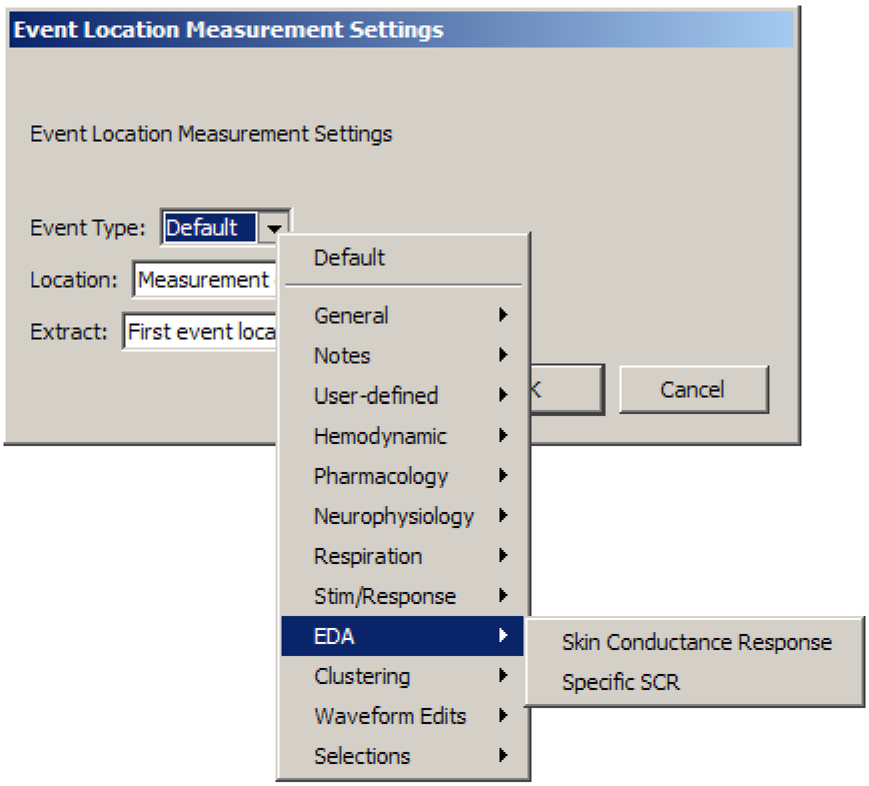
Events for SCRs will always occur as described above, in the order shown.

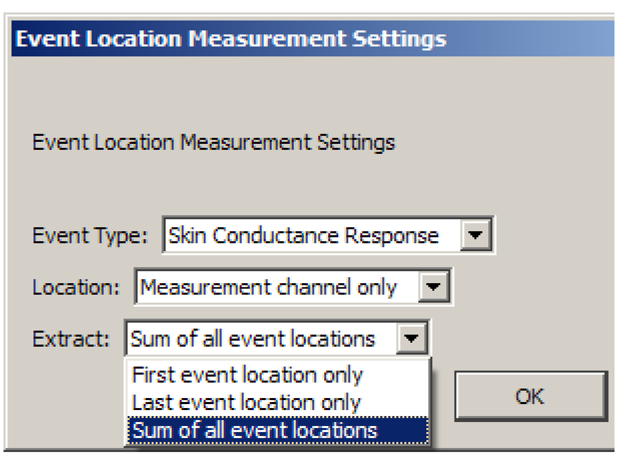
EDA Measurements

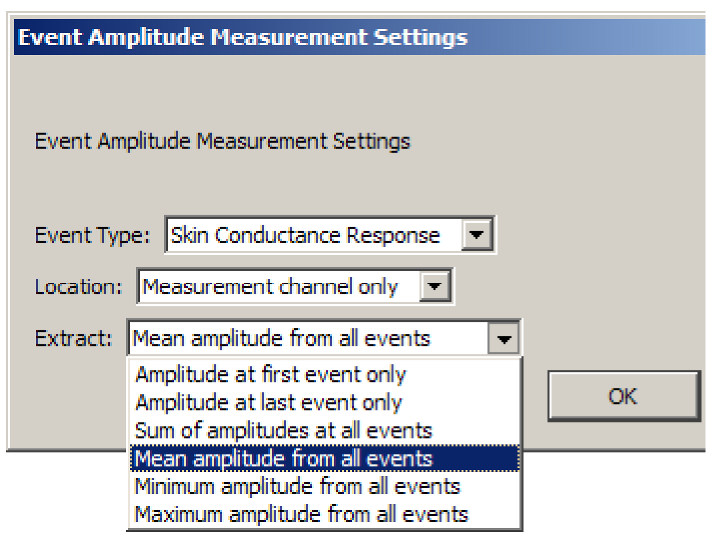
To perform Event-related EDA analysis, choose Analysis > Electrodermal Activity > Event-related EDA Analysis.

To take measurements from the skin conductance response analysis, set measurements for event count, event location and/or event frequency. Set the source channel as the Tonic EDA channel and select the location (measurement channel only, global events only, anywhere) and measurement parameters as desired. This method is useful for spontaneously occurring skin conductance response analyses. Take measurements over a manually selected area or use Find Cycle analysis to take automatically measurements over a user-defined time interval.

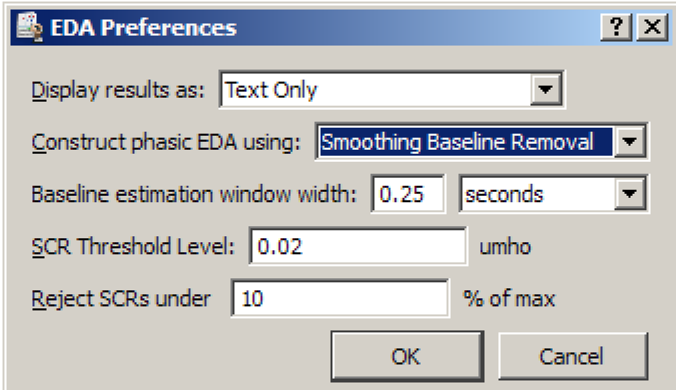






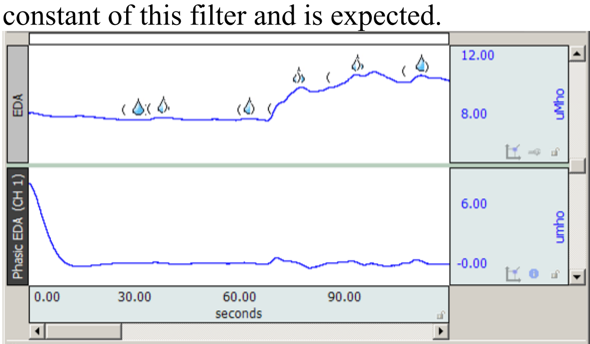


EDA Preferences…

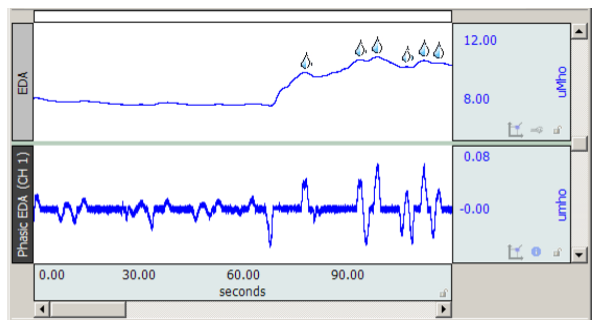


The following EDA Preferences can be configured and will be applied to all options in the analysis package:

- **Display results** as text, graph channels, or Excel
- **Construct Phasic EDA using** High pass Filtering or Smoothing Baseline Removal
  - High pass Filtering—High pass filtering constructs phasic EDA by applying a digital IIR high pass filter (f = 0.05 Hz, Q = 0.707) to the tonic EDA signal. This high pass filter essentially AC couples the tonic EDA signal similar to using the high pass hardware filter available on the GSR100C module. When using high pass filtering, the first few seconds of the phasic EDA may not be centered on zero and will appear to contain invalid data and a valid response may be excluded; this artifact is related to the long time constant of this filter and is expected.

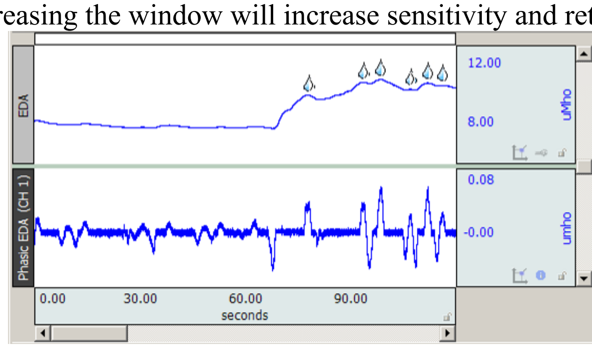


0.05 Hz High Pass Filter

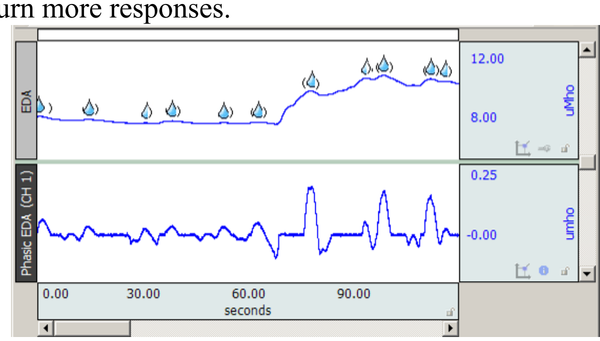


Smoothing Baseline Removal

  - Smoothing Baseline Removal—Smoothing baseline removal constructs phasic EDA by subtracting an estimate of the baseline conductance from the tonic EDA. Set the baseline estimation
- **Baseline estimation**: The estimate of the baseline is generated using median value smoothing. This is more computationally intensive than high pass filtering but does not illustrate artifact at the start of the signal. Increasing the window will increase sensitivity and return more responses.



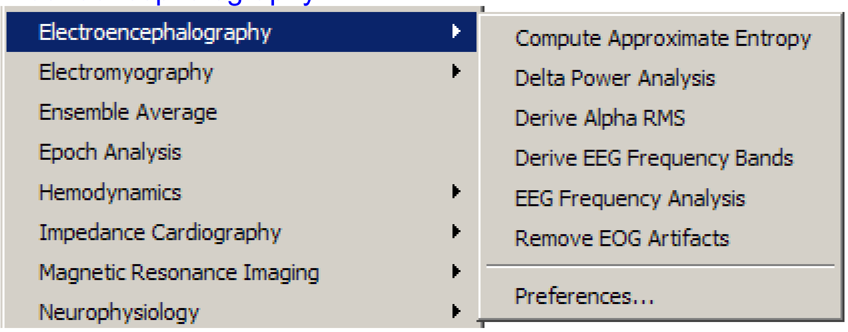
Baseline window set to 4 seconds



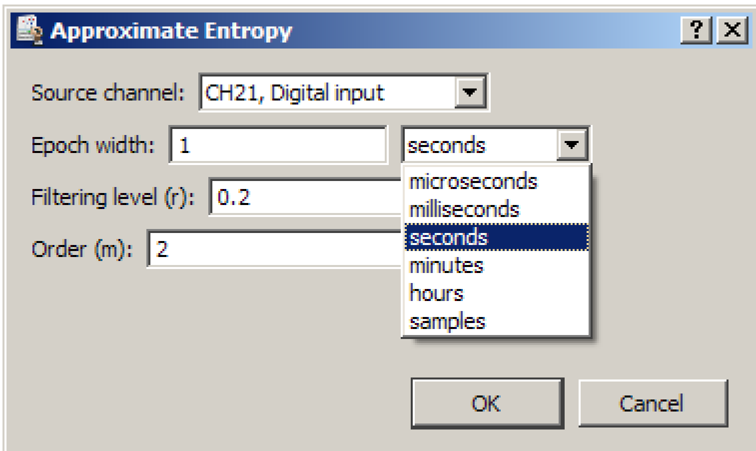
Baseline window set to 8 seconds

- **SCR detection parameters**: threshold detection level H and percentage P, see page 349.
  - The default values are H = 0.02 μmho, P = 10, where H is detection threshold and P is percentage
  - Setting H to 0 and P to 10% will approximate the SCR detection algorithm referenced in K. H. Kim, S. W. Bang and S. R. Kim, "Emotion recognition system using short-term monitoring of physiological signals," Medical & Biological Engineering & Computing, vol. 42, pp. 419-427, 2004.
  - Setting P to 0% will retain all potential SCRs (none will be rejected in the second phase).

Electroencephalography



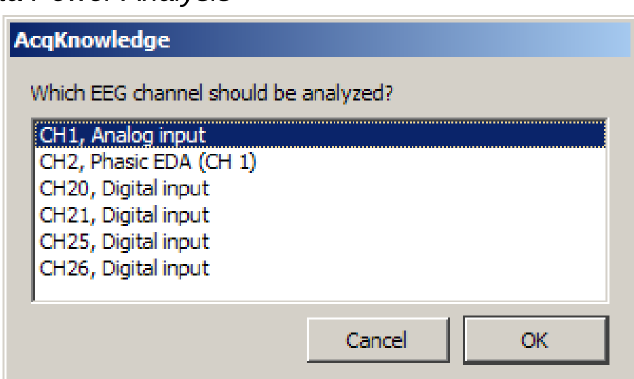
Compute Approximate Entropy

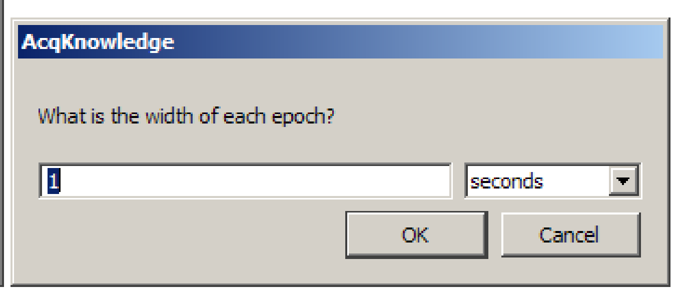


Approximate entropy is a statistical measure that attempts to quantify the predictability of a data sequence. A perfectly predictable data series (such as a pure sine wave) has approximate entropy of zero. Several studies are beginning to examine approximate entropy of EEG data and its relationship to external factors such as drugs and sleep states.

The Compute Approximate Entropy script divides an EEG signal into fixed-width epochs and computes the approximate entropy for each epoch. Derivation of the approximate entropy is a computationally intensive process and may take several minutes or hours to complete. To obtain only the sub-ranges of the EEG data, copy and paste the ranges into new graph windows to restrict the approximate entropy computations to that data range; the analysis is performed for all of the data in the graph window regardless of the selected area.

Delta Power Analysis



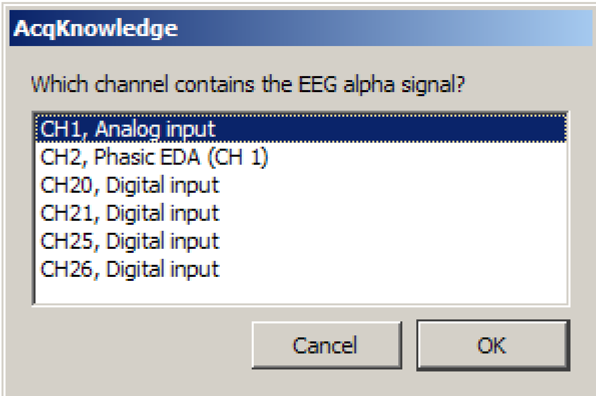


Delta power is the total power of the EEG signal that occurs within the delta frequency band as configured in the Preferences. Delta power has been examined in a number of various EEG studies as an indicator of sleep/wakefulness and other conditions. By examining changes in the delta power, it may be possible to correlate delta power with effects of external factors.

The Delta Power Analysis script divides an EEG channel into fixed-width epochs. For each epoch, the power spectral density is computed and the total power within the delta frequency band is derived from the PSD. This delta power value is then placed into the graph or into the journal as specified by the output preferences.

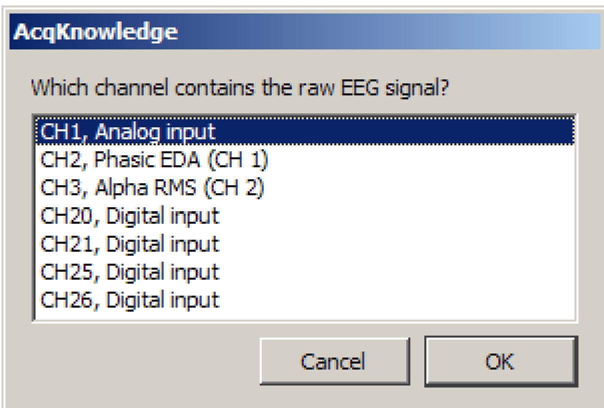
Delta power can be measured from either a filtered or unfiltered EEG channel. To compute delta power for individual frequency bands, they must be derived prior to running the Delta Power Analysis script.

Derive Alpha RMS



The Derive Alpha RMS script constructs a standard alpha RMS waveform from an alpha EEG signal. Alpha RMS is the windowed root mean square value of the signal using a window width of 0.25 seconds.

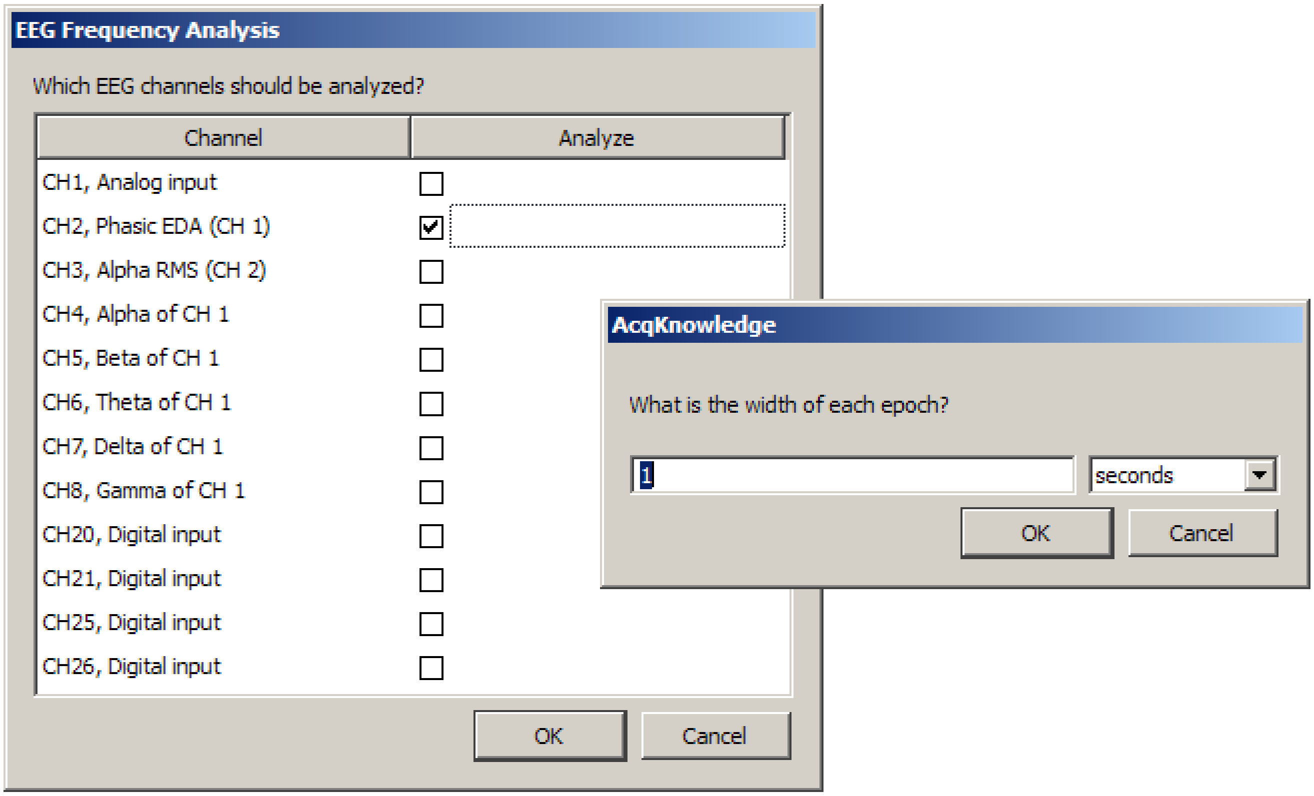
Derive EEG Frequency Bands



The Derive EEG Frequency Bands script applies filtering to an unfiltered EEG lead signal to generate the following five standard EEG bands: Alpha, Beta, Theta, Delta, and Gamma.

The frequencies used for each band are taken from the analysis package preferences. Filtering is performed using IIR lowpass+high pass combination filters.

EEG Frequency Analysis

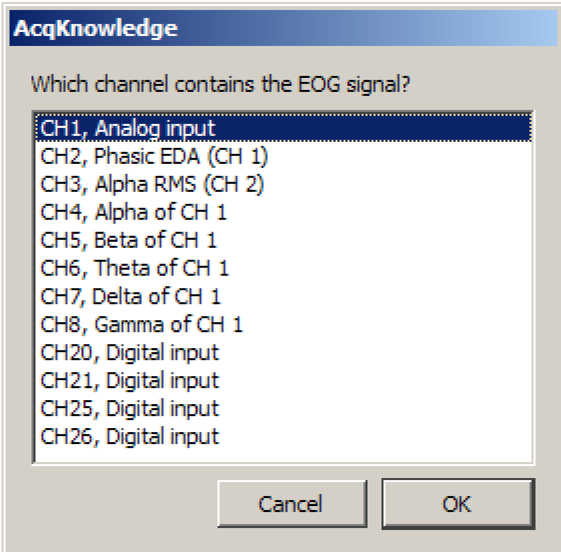


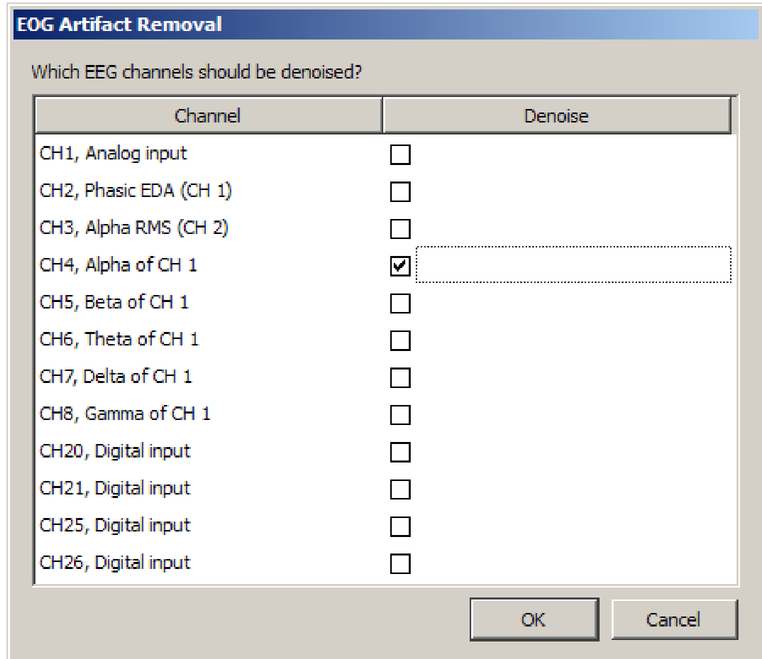
EEG may be characterized in terms of frequency and the power within specific frequency bands. The EEG Frequency Analysis script performs various feature extractions from EEG signals using FFT and other techniques to examine the power within the EEG signals. This analysis may be performed for multiple EEG leads simultaneously, allowing for either analysis of multiple leads or analysis of multiple EEG alpha, beta, theta, or delta bands from a single raw lead.

The EEG Frequency Analysis script divides the EEG signals into fixed-width time epochs. For each individual time epoch, Acq*Knowledge*'s Power Spectral Density function is used to estimate the power spectrum of that epoch using a Welch periodogram estimation method. From this PSD the following measures are extracted for each epoch:

Name	*Abbrev.*	*Description*	*Units*
Mean Power	MeanP	The average power of the power spectrum within the epoch. (Units Note: V will be replaced with the voltage units in which the EEG was recorded)	$\frac{V^2}{Hz}$
Median Frequency	MedianF	Frequency at which 50% of the total power within the epoch is reached.	Hz
Mean Frequency	MeanF	Frequency at which the average power within the epoch is reached.	Hz
Spectral Edge	Spectral Edge	Frequency below which a user-specified percentage of the total power within the epoch is reached. This percentage can be set using "Preferences" and defaults to 90%.	Hz
Peak Frequency	PeakF	Frequency at which the maximum power occurs during the epoch.	Hz

Remove EOG Artifacts





Some EEG recordings involve subjects performing various visual tasks such as reading or watching video. Under these conditions, EEG may be susceptible to interference from the much stronger EOG signal arising from eye motion, particularly if EEG is recorded from near the front of the skull. Remove EOG Artifacts helps remove EOG interference from the EEG signals, recovering the EEG data for use in further analysis.

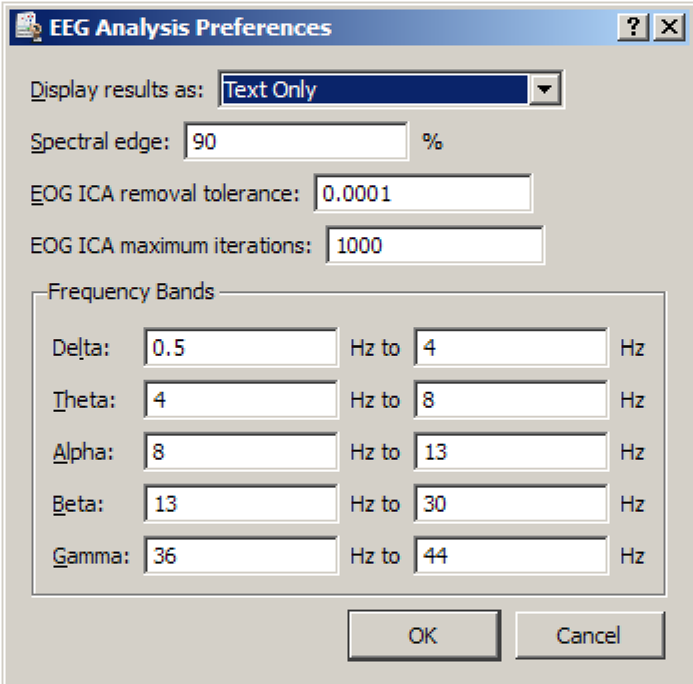
EOG removal is performed using a blind signal separation technique known as Independent Component Analysis. ICA is used to split up statistically independent signals that have been mixed together during recording. Since EOG is independent of EEG, ICA can be used to remove it.

In order to use Remove EOG Artifacts, a distinct EOG signal must be acquired in addition to the EEG signals. The EOG signal is required to identify the components correlated to eye motion.

EOG artifact removal functions better when it is performed on multiple EEG leads simultaneously. Better results may be obtained by including EEG leads that do not exhibit EOG interference since the increased number of leads allows for more fine-grained signal separation. Good results can be seen with as few as two EEG leads and one EOG lead. While this technique can be performed with a single EEG lead, the results will not be as dramatic.

Note ICA is a non-deterministic technique, so it may not be possible to automatically separate the signals for every EOG/EEG data set. For ICA to be successful, it may be necessary to fine-tune the parameters of the ICA search procedure to match the data, use a different electrode configuration, or use fewer or more leads.

Preferences…



Adjust the EOG ICA Tolerance level and the EOG ICA maximum number of iterations by accessing Transform > Specialized Analysis > Electroencephalography > Preferences. EOG ICA Tolerance is used as the termination condition of ICA signal separation. The EOG ICA maximum number of iterations is another termination condition of ICA signal separation and represents the maximum point at which the search is aborted. For more information on these settings, see the documentation for the Independent Component Analysis transformation.

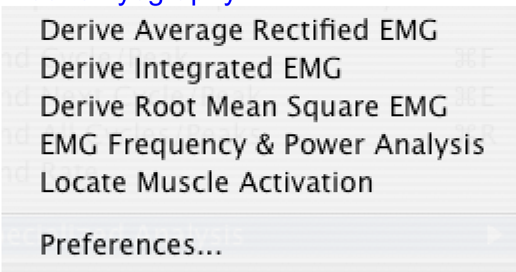
Because ICA is a statistical technique, any filtered data produced with Remove EOG Artifacts should be carefully verified against other information to ensure that the approximations produced via ICA represent information that is truly correlated to the expected ECG.

The spectral edge percentage indicates the cutoff percentage of the total power at which spectral edges will be placed. The default value is 90%.

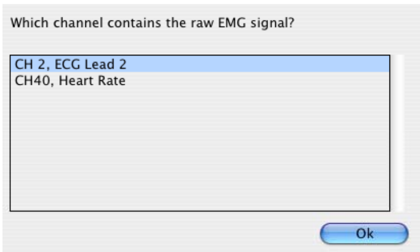
The frequency bands of alpha, beta, delta, and theta may be modified to match different analysis protocols. The default frequency ranges are:

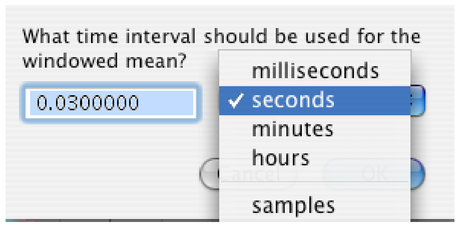
- Alpha—8 Hz-13 Hz
- Beta—13 Hz-30 Hz
- Delta—0.5 Hz-4 Hz
- Theta—4 Hz-8 Hz
- Gamma—36 Hz-44 Hz

Electromyography



Derive Average Rectified EMG



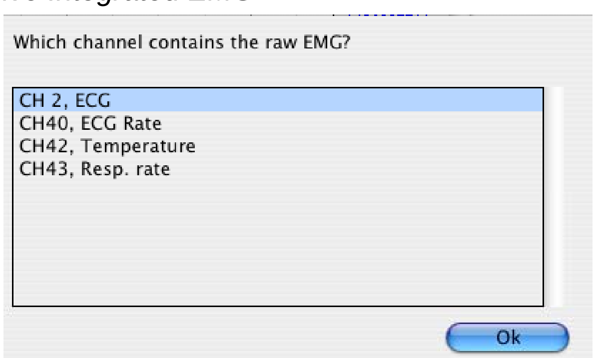


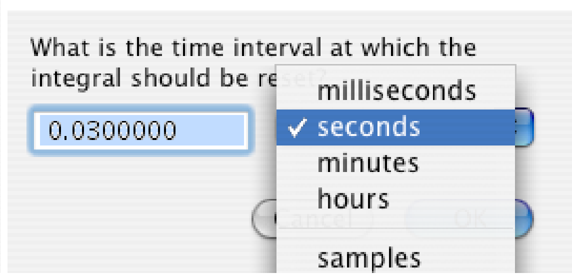
Average rectified value (ARV) is defined as a time windowed mean of the absolute value of the signal. ARV is one of the various processing methods used to construct derived signals from raw EMG data that can be useful for further analysis.

To perform ARV, a time window must be specified for the sliding mean. The default time window setting is 30 milliseconds, but this value can be adjusted depending on the desired amount of smoothing effects. It is advisable to closely examine results for time windows larger than 30 milliseconds as it is possible for delay to be introduced into the result.

The ARV is computed using the Integrate transformation with a Rectified Average over Samples configuration.

Derive Integrated EMG

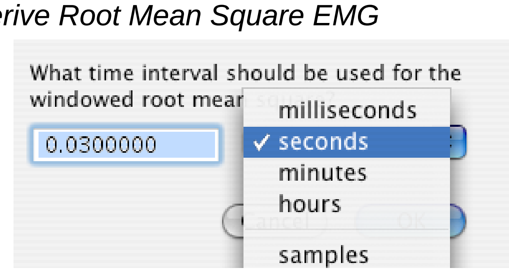




Integrated EMG (iEMG) is defined as the area under the curve of the rectified EMG signal, that is, the mathematical integral of the absolute value of the raw EMG signal. When the absolute value of the signal is taken, noise will make the mathematical integral have a constant increase. Integrated EMG splits up the signal into fixed-width timeslices and resets the integral at the start of each timeslice. To derive iEMG, the width of this timeslice must be specified. Similar to ARV, timeslices longer than 30 milliseconds may introduce delay into the result.

The integrated rectified EMG signal will appear like a "sawtooth" style wave. In addition to the true iEMG, this script will output a second waveform whose value is the maximum value of the iEMG signal in each timeslice. This Maximum iEMG is easier to interpret visually and approximates the envelope of the iEMG signal.

Derive Root Mean Square EMG



Root Mean Square EMG (RMS EMG) is defined as the time windowed RMS value of the raw EMG. RMS is one of a number of methods used to produce waveforms that are more easily analyzable than the noisy raw EMG.

To construct the windowed RMS signal, a time window must be specified for the sliding mean. The default time window setting is 30 milliseconds, but this value can be adjusted depending on the desired amount of smoothing effects in the RMS EMG. It is advisable to closely examine results for time windows larger than 30 milliseconds as it is possible for delay to be introduced into the result.

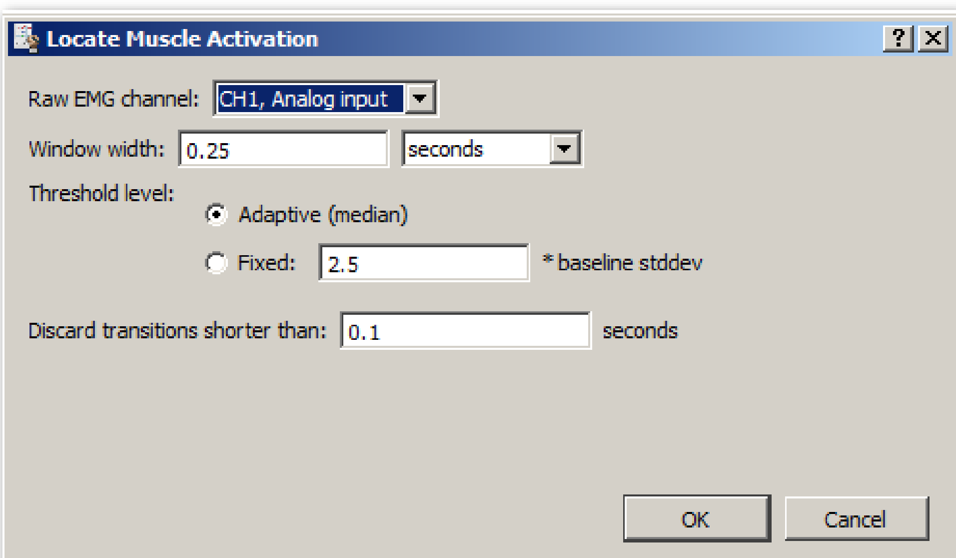
RMS EMG is computed using the Integrate transformation in a Root Mean Square Average over Samples configuration.

EMG Frequency & Power Analysis

Several frequency domain techniques may be used for data reduction of EMG signals. The EMG Frequency & Power Analysis script extracts several measures derived from the power spectrum of an EMG signal. The EMG signal is split up into a fixed number of time periods; within each window, the power spectrum is computed using the Power Spectral Density transformation. For each time period, the following measures are extracted:

Name	*Abbrev.*	*Description*	*Units*
Median Frequency	MedianF	Frequency at which 50% of the total power within the epoch is reached.	Hz
Mean Frequency	MeanF	Frequency at which the average power within the epoch is reached.	Hz
Peak Frequency	PeakF	Frequency at which the maximum power occurs during the epoch.	Hz
Mean Power	MeanP	The average power of the power spectrum within the epoch. (Units Note: V will be replaced with the voltage units in which the EMG was recorded)	$\frac{V^2}{Hz}$
Total Power	TotalP	The sum of the power at all frequencies of the power spectrum within the epoch. (Units Note: V will be replaced with the voltage units in which the EMG was recorded)	$\frac{V^2}{Hz}$

Locate Muscle Activation



When performing gait analysis, exercise physiology, or other research, identification of periods where the muscle is active can allow for correlation of external factors to muscle activity. Locate Muscle Activation attempts to identify various periods of muscle activity using statistical methods. The transformation requires a raw, unfiltered surface EMG channel. It takes a window width of *w* seconds, by default 0.25 seconds. It is important that the first *w* seconds of the EMG signal be "background noise", that is, that the muscle being examined is relaxed for the first quarter second. This quarter-second period is used to estimate baseline parameters that affect the entire process.

Note The LMA analysis expects EMG to be an AC-coupled signal centered around zero without baseline offset. If the signal is centered below zero, then no muscle activations are located. The Remove Mean function from the Analysis menu can be used to center the signal around zero for most waveforms.

This transformation implements a variation of the Hodges and Bui detection algorithm as described in:

P. W. Hodges and B. H. Bui, "A comparison of computer-based methods for determination of onset of muscle contraction using electromyography," *Electroenceph. Clin. Neurophysiol.*, vol. 101, pp. 511-519, 1996.

The variation implemented is a threshold-based algorithm roughly consisting of the following steps:

1. Determine mean value μ_0 and resting standard deviation σ_0 of the first *w* seconds of the signal.
2. Construct a filtered ARV EMG signal, *z*. The window width *w* is used when constructing the ARV signal.
3. Extract the variance of the signal with respect to the noise with the formula

$$g = \frac{z - \mu_0}{\sigma_0}$$

4. Using a threshold *h*, determine when the signal *g* lies below and above the threshold. Portions of time above the threshold are periods of muscle activity.
5. Discard any transitions across the threshold if they are shorter in duration than a user-specified time, *t*.

There are two methods of specifying the threshold *h*. An adaptive method examines the signal *g* and chooses the threshold to be the median of *g* over the entire waveform. Alternatively, the threshold can be specified manually. Using a manual threshold can be useful in adjusting the detection to better match specific EMG data. A suggested threshold is 2.5. By lowering the threshold, a larger quantity of data will be considered as muscle activity. By raising the threshold, a larger quantity of data will be considered to be noise.

The transition discard time *t* is specified in seconds. The default value of *t* is 0.1 seconds. If muscle activity is being inaccurately identified as inactivity for short periods within active times, try increasing the value of *t*. Do not set *t* to be greater than the smaller of either the shortest duration of a single muscle contraction or the shortest rest interval between consecutive muscle contractions.

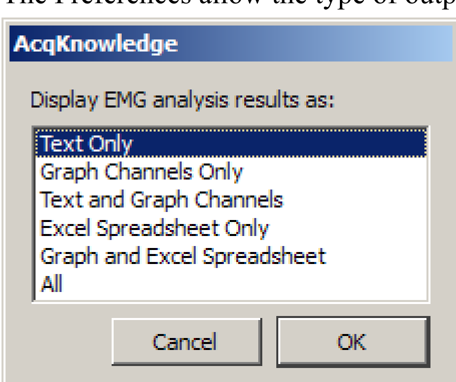
There are two outputs from the Locate Muscle Activation script.

- A new waveform, Muscle Active, will be added to the graph. The value of this wave will be zero when the muscle is at rest and one when the muscle is active. This wave can be used to quickly visually examine the record for periods of activity.
- Events are also generated on the raw EMG waveform. A Waveform Onset event is placed at each transition from inactive to active, and a corresponding Waveform End event is placed at each active-to-inactive transition. You can use these events in conjunction with the Cycle Detector to perform further data reduction based on muscle activity.

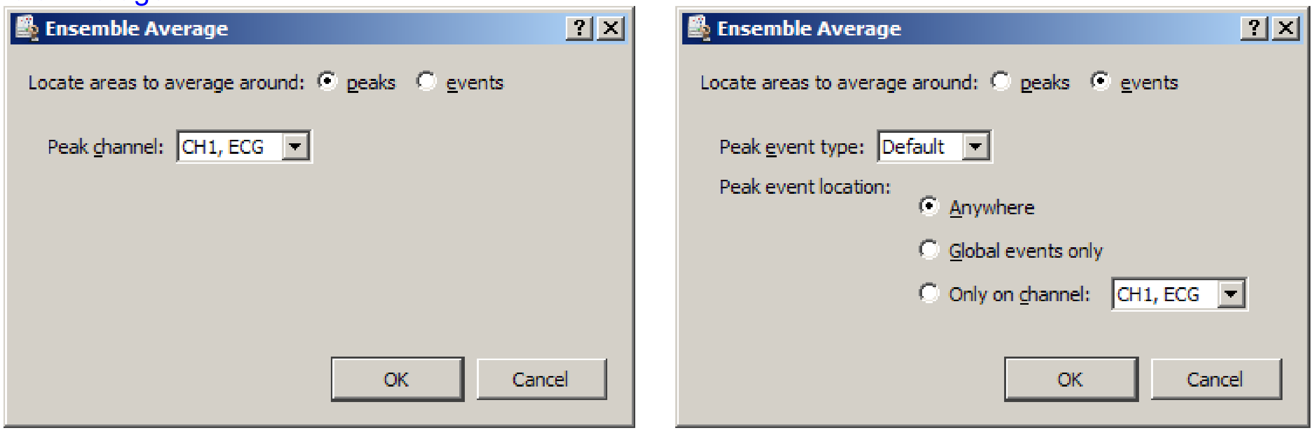
The detection of muscle activation onset and end from surface electrode EMG is an imprecise process. The output of this location should be visually examined for misidentification of activation periods that are too short, too long, overlapping, or missed.

Preferences…

The Preferences allow the type of output to be chosen for displaying results: text, graph channels, or Excel.



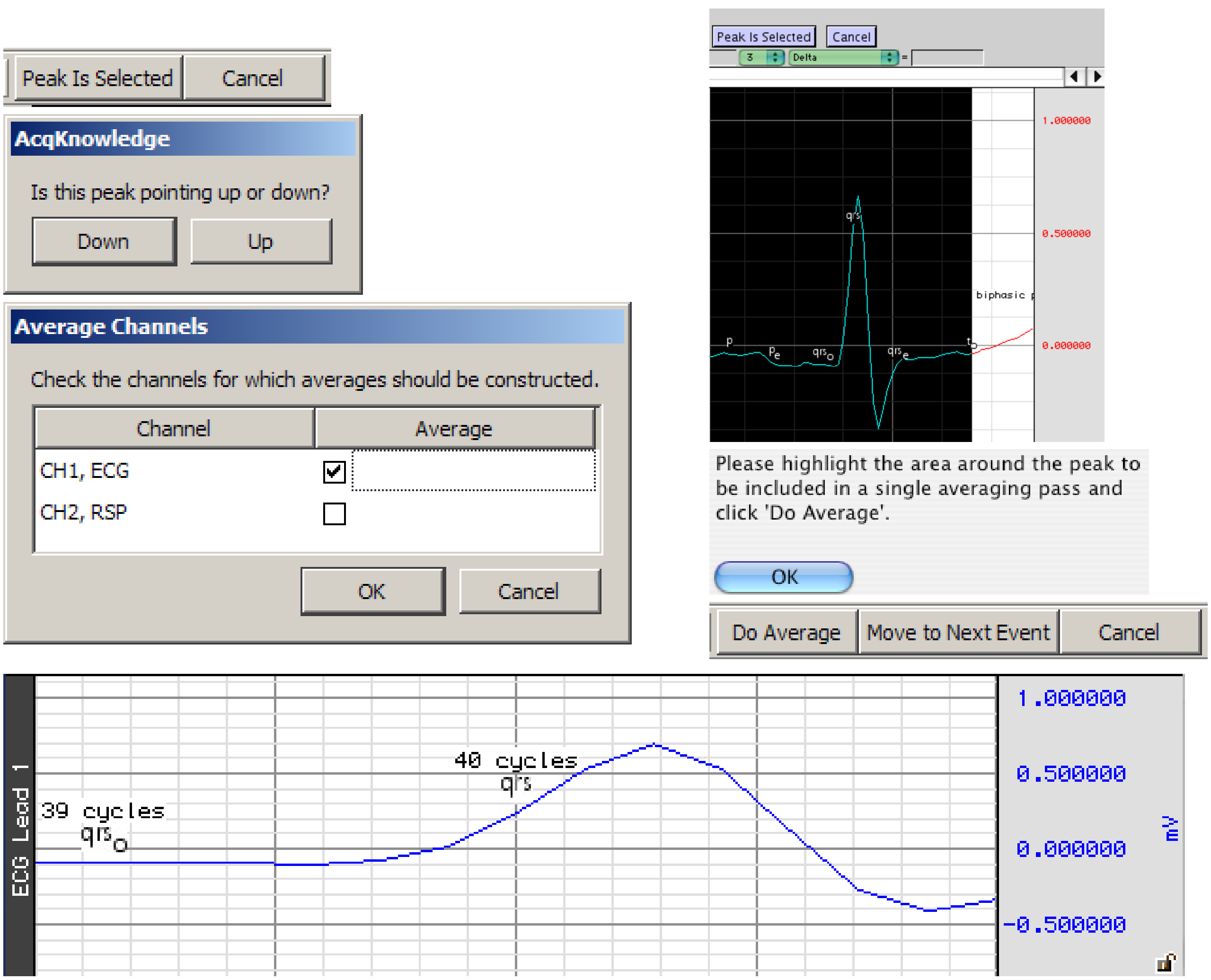
Ensemble Average



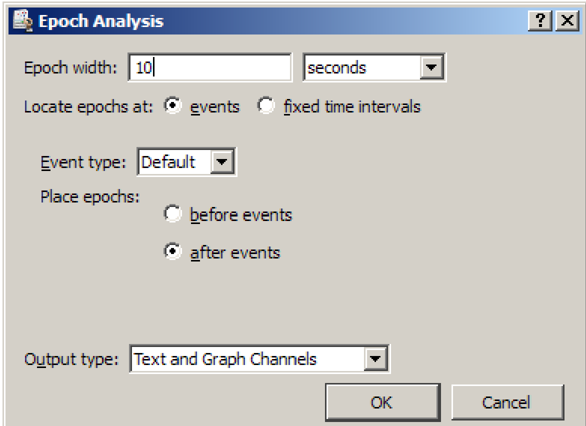
Ensemble Average assists in performing offline averaging. Offline averaging produces an average waveform from a number of cycles, also known as an *ensemble average*. Averages of multiple channels can be extracted simultaneously and be consolidated into a single graph window showing the results.

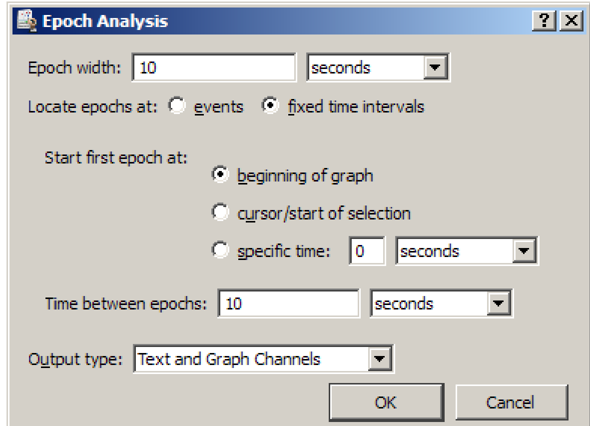
This option provides two methods for locating individual members of the ensemble.

- **Peaks**: Data-driven peak detection with positive or negative peaks in the data. This method automatically derives appropriate threshold levels from a user-selected peak and is useful for constructing averages keyed to periodic signals with strong spikes, such as ECG.
- **Events:** Place members of the ensemble surrounding events in the waveform. Events must be previously defined by the user, either manually or through another automated process. This method is useful for constructing averages keyed to any types of events in a graph.

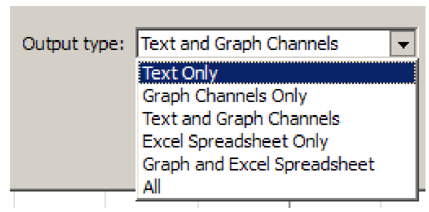


Epoch Analysis



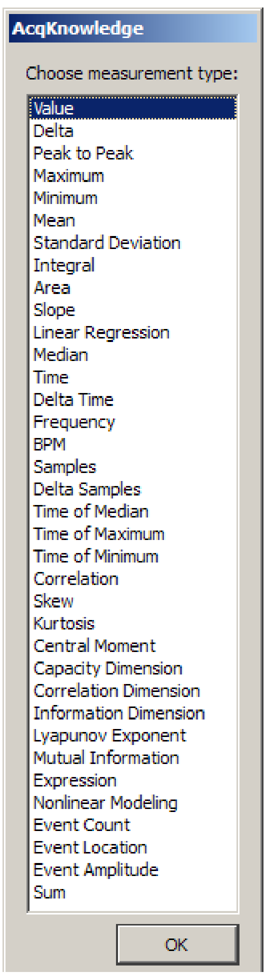


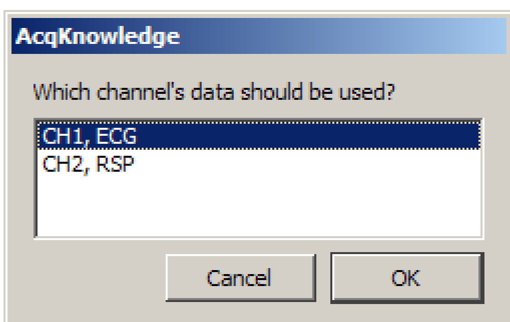
Extracts basic measures from fixed-width time segments of data. A fixed-width time segment of data is known as an *epoch*. The location of these fixed-width intervals can either be keyed off of locations of events in the graph or tied to regular time intervals (e.g. occurring at a constant frequency). All of the standard Acq*Knowledge* measurements can be extracted on an epoch-by-epoch basis with the exception of calculation measurements.

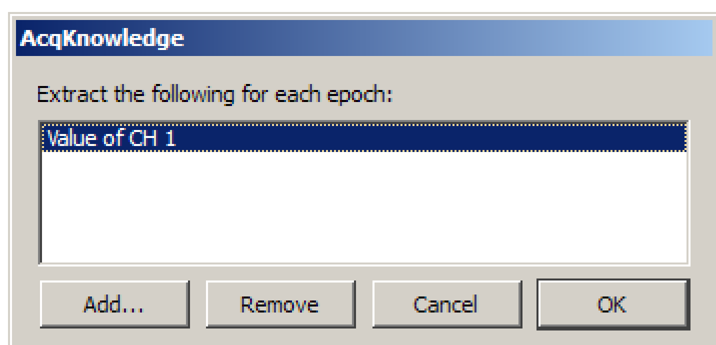


Epoch-by-epoch measurement results can be viewed either as channels of data in the graph, a textual summary, or on an Excel spreadsheet; textual summaries include a final row with an overall average of each extracted measurement.

Times output by Epoch Analysis are always expressed in seconds; all other units correspond to the current preferred measurement unit settings accessible under Display > Preferences.







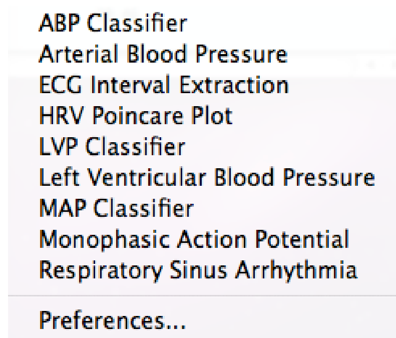
Hemodynamic Analysis

Hemodynamics is the study of blood and circulation related data. This analysis package concerns itself with interpretation of ECG, blood pressure, and monophasic action potential data; ECG signals must be sampled at 5 kHz or below to be analyzed with this package.

IMPORTANT: These routines are designed specifically for human subjects and may not function well, or at all, on animal subjects, particularly small animals.

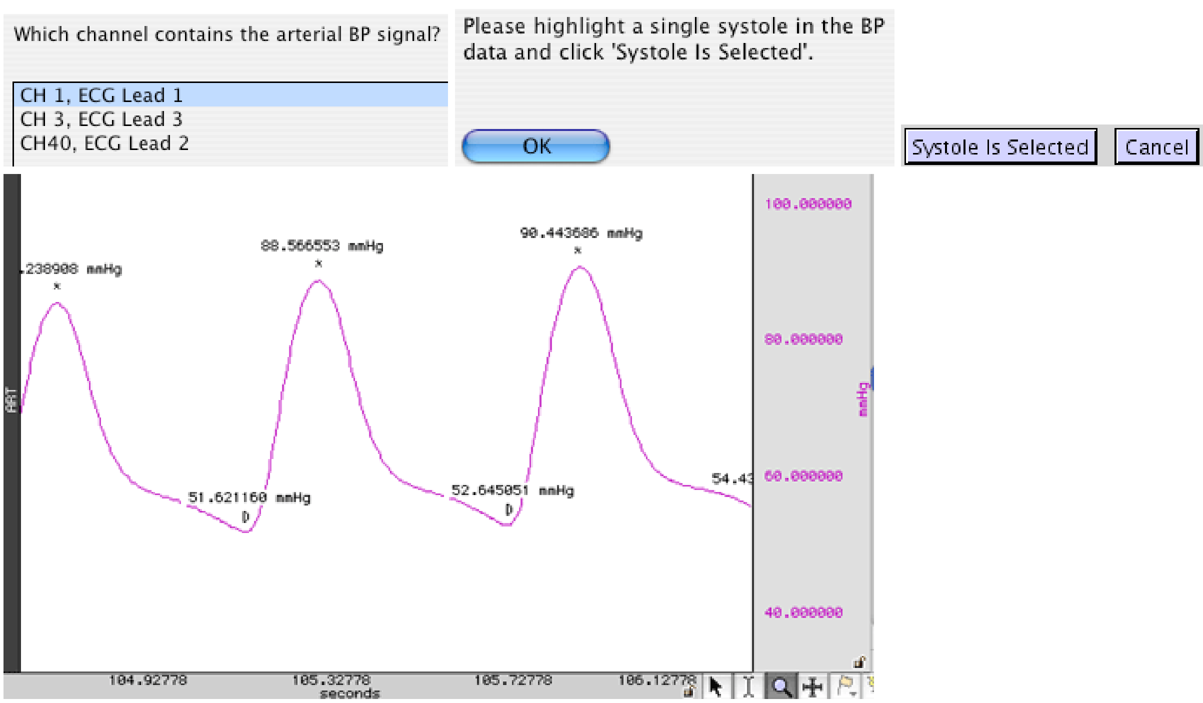
The Hemodynamic analysis package consists of:

a) ABP Classifier
b) Arterial Blood Pressure
c) ECG Interval Extraction
d) HRV Poincare Plot
e) Left Ventricular Blood Pressure
f) LVP Classifier
g) MAP Classifier
h) Monophasic Action Potential
i) Respiratory Sinus Arrhythmia
j) Preferences

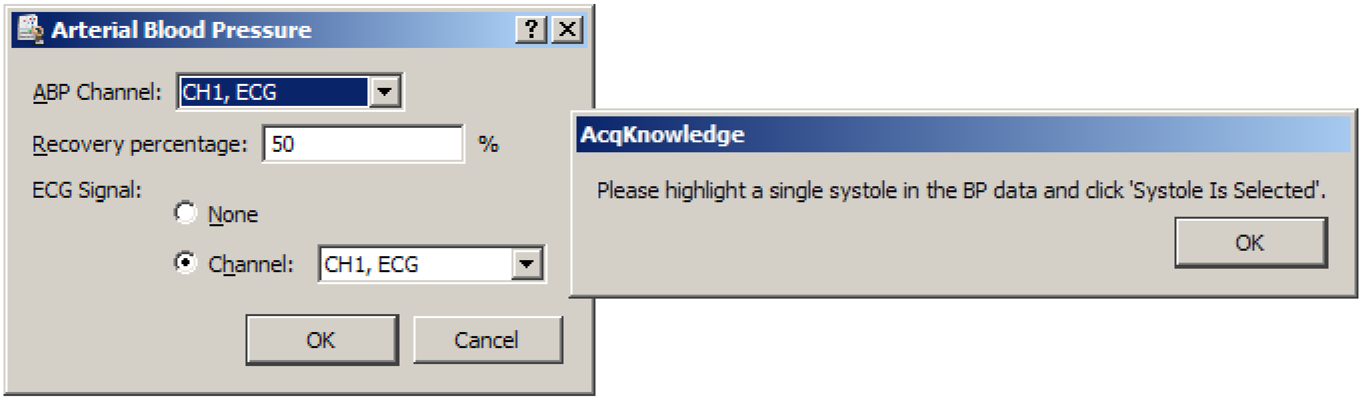


The time units reported by all of these transformations are in seconds unless otherwise noted.

ABP Classifier



Places systolic and diastolic events at appropriate locations on a continuous arterial blood pressure signal recording using either invasive means or a continuous noninvasive pressure monitoring system. The ABP classifier functions directly on the pressure data and may fail for signals that exhibit strong noise characteristics or large baseline drifts. Pre-filtering the signal may improve classification accuracy.



Extracts various cycle-by-cycle measures from arterial blood pressure (ABP) and ECG signals. It can function on an individual ABP signal or, when used in conjunction with an ECG Lead II signal, extract additional Q relative measurements.

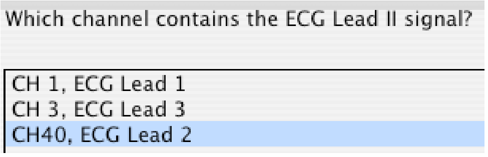
- If the ECG and ABP signals have not been classified when this analysis is performed, events for diastolic, systolic, and ECG boundaries will be inserted as necessary.
- If systolic, diastolic, and Q events are already present on the signals, however, they will be used.

On a cycle-by-cycle basis, the arterial blood pressure analysis transformation extracts the following measures:

Name	Abbrev.	Description
Diastolic	-	Minimum pressure occurring during the cycle
Ejection time	ET	Time interval between the diastolic pressure and the minimum of dP/dt
Heart rate	HR	Heart rate in BPM as extracted from the diastolic-to-diastolic time interval for a given cycle
Maximum dP/dt	dP/dt max	Maximum amount of the change in the pressure during the cycle
Mean blood pressure	MBP	Mean blood pressure: $P_{diastolic} + \frac{P_{systolic} - P_{diastolic}}{3}$
Minimum dP/dt	dP/dt min	Minimum amount of change in the pressure during the cycle
QA Interval	QA	Time interval between ECG Q wave and the diastolic pressure
Recovery interval	%REC	Time required for the pressure signal to decrease by a user specified percentage of the pulse height
Systolic	-	Maximum pressure occurring during the cycle
Time to peak pressure	TTPK	Time interval between the diastolic and the systolic pressures

When textual output is used, the average of all of these measures will be output as the last row of the table.

ECG Interval Extraction



Extracts cycle-by-cycle time and voltage measurements for various points and intervals between waveforms in the cycle on ECG Lead II signals. This interval extraction is based off of the waveform boundary locations with additional logic for defining explicit Q and S wave events. QRS peak events as output for boundary location are used as the R peak location.

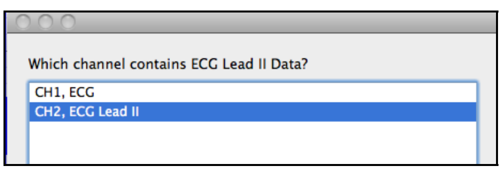
- If the ECG signal was not classified before running the interval extraction analysis, it will be classified automatically.

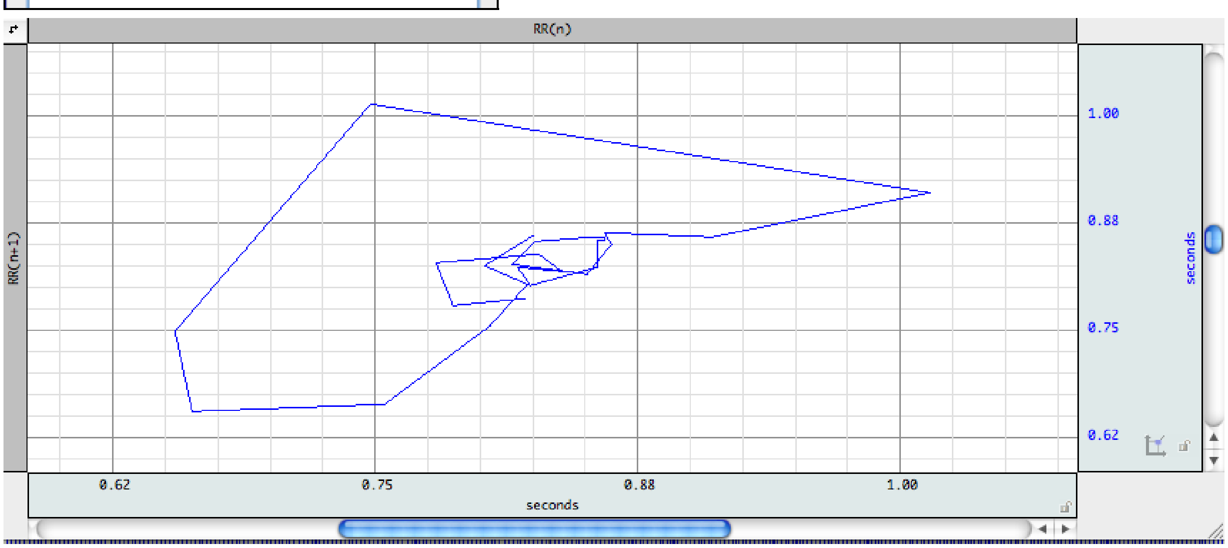
This analysis extracts the following cycle-by-cycle measures:

Name	*Abbrev.*	*Description*
Corrected QT interval	QTC	QT time interval divided by the square root of the RR interval
Heart rate	HR	RR time interval expressed in BPM
P height	P-H	Amplitude at the peak of the P wave in a cycle
PRQ interval	PRQ	Time between the onset of the P wave to the Q wave
QRS width	QRS	Time between onset of the QRS complex and the end of the QRS complex. Equivalent to the time between onset of Q and end of S
QT interval	QT	Time between the beginning of the Q wave and the end of the T wave
R height	R-H	Amplitude of the R wave in a cycle
RR interval	RR-I	Time between consecutive R peaks in the waveform
ST interval	ST	Time between the S wave to the end of the T wave

At the end of the text table output, the average of all of the cycles will be displayed. Additionally, both text and Excel output will indicate the number of cycles that did not have all three of the QRS, P, and T waves defined. These are cycles where the classifier missed a boundary and are listed as “Bad cycles,” which may happen due to noise or other artifacts in the signal.

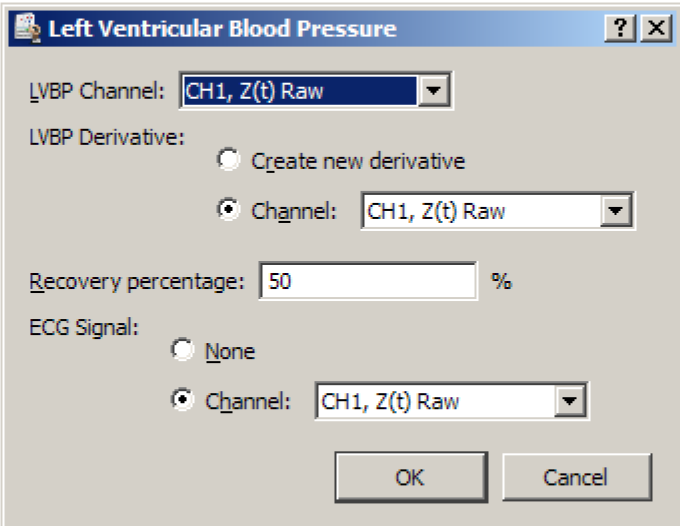
HRV Poincare Plot





Poincare plots are constructed from ECG Lead II data. A Poincare plot is an XY plot with RR intervals in seconds on one axis and on the other axis the sequence delayed by one beat (RR vs. RR+1). This plot may be used to visually inspect for patterns in the sequence similar to an attractor plot. The RR intervals are measured in seconds. This generates a new graph window in XY mode, no textual output is generated. (Acq*Knowledge* 4.2 and higher)

Left Ventricular Blood Pressure



Extracts various cycle-by-cycle cardiac measures of left ventricular blood pressure data, optionally in conjunction with an ECG Lead II signal. Examines the LVP signal, ECG, and derivative of the LVP signal.

- If the LVP and ECG signals have not been classified before this analysis is executed, they will be classified automatically.
- Derivatives of the LVP signal can be pre-existing or can be constructed automatically.
- If an ECG signal is not included, only pressure related measures will be extracted.

The analysis outputs the following information on a cycle-by-cycle basis and the textual output cites the average of all of these cycle-by-cycle measurements:

Name	*Abbrev.*	*Description*
Contractility index	CI	maximum value of dP/dt during the cycle divided by the pressure at that time location
Developed pressure	DP	Amplitude interval between end diastolic pressure and systolic pressure
dP/dt Max	-	Maximum change in pressure over the cycle
dP/dt Min	-	Minimum change in pressure over the cycle
End diastolic pressure	LVEDP	End diastolic pressure for the cycle. This is not necessarily the minimum pressure during the entire cycle. LVEDP is located on the LVP signal using the method set in the preferences.
Minimum pressure	MIN	Absolute minimum pressure occurring during the entire cycle. This is not necessarily equivalent to the end diastolic pressure
QA Interval	QA	Time interval between the Q wave of the ECG and the end diastolic pressure
Rate	-	heart rate in BPM as extracted from the time interval between consecutive end diastolic pressure locations
Recovery time	%REC	Time it takes for dP/dt to increase from the minimum dP/dt location to a user specified percentage of that minimum value
Systolic pressure	SYS	Maximum pressure occurring during the entire cycle
Tau	-	Monoexponential time relaxation constant tau computed on a cycle by cycle basis. See “Computation of Tau” on page 366 for specifics.
Tension time index	TTI	Integral of the pressure between end diastolic and the time of minimum dP/dt

Computation of Tau

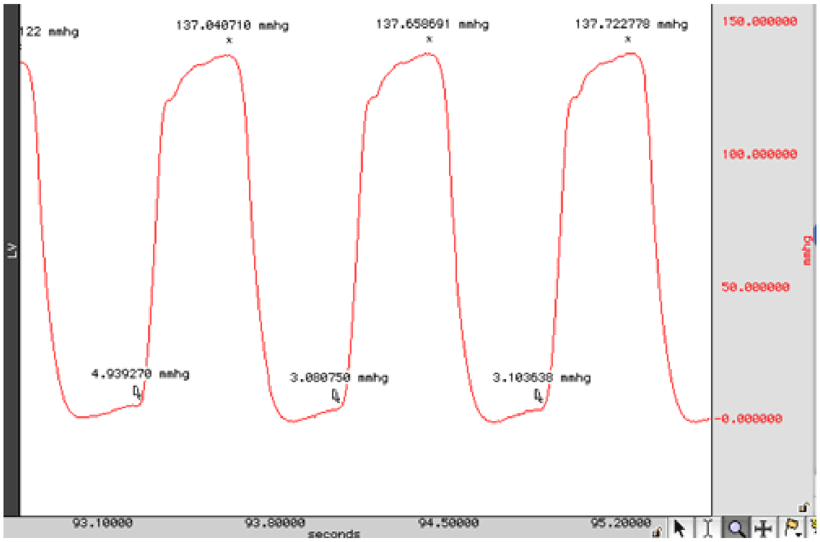
There are many different methodologies used to extract the time constant from LVP data. The time constant is extracted from a best fit parameter of a model to the trailing edge of LVP data on a cycle by cycle basis. This analysis uses a monoexponential model of zero asymptote for computing tau. The relaxation period is defined as the range of data between the time of minimum dP/dt in the cycle to the point where the LVP pressure signal drops below the previous LVEDP level. Within this range, the following model is fitted to the data using the simplex search method:

$$P_0 e^{\frac{t}{\tau}}$$

where P_0 is the value of the LVP signal at the time of dP/dt minimum and *t* is the time coordinate shifted such that *t* is 0 at the time of dP/dt minimum. The best fit value from this model is used as the value of the relaxation time constant.

LVP Classifier

Operates on left ventricular blood pressure (LVP) data to define events at the systolic pressure and the left ventricular end diastolic pressure for each cycle.

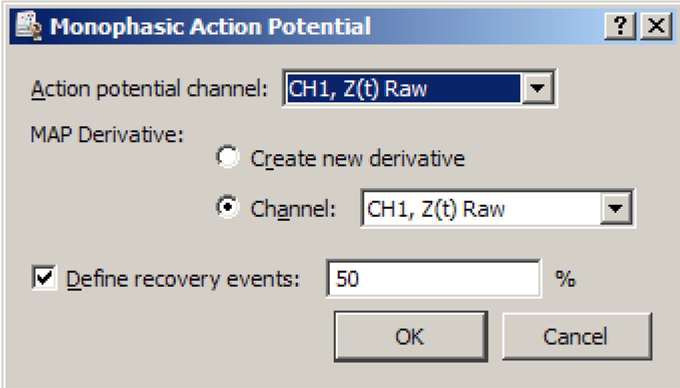


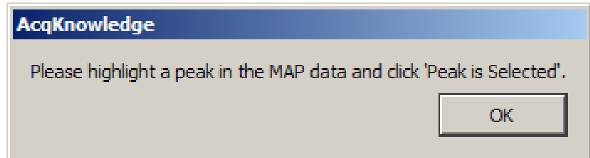
The location of these points is performed using filtered derivatives of the original LVP signal. Pre-filtering the signal (lowpass of 50 Hz or less) or smoothing the signal before running the classifier may improve accuracy.

The LVP classifier locates LVEDP (left-ventricular end diastolic pressure) by examining the derivative of the pressure signal based upon the location method specified in Preferences:

- Adaptive threshold of 0 plus a percentage of the peak to peak change in pressure. The percentage is user-specified; the default is 1%. If the LVP signals do not have "flat" valleys, this percentage may need to be increased to fine-tune positioning of LVEDP.
- First zero crossings before contraction.

Monophasic Action Potential





Performs classification of MAP data acquired from a human or animal subject and extracts various cycle by cycle intervals. Locates upstroke, maximum, 100% recovery, and user-specified recovery points on the action potential.

- Classification is performed using the action potential with its smoothed derivative; pre-filtering noise with low pass filters may improve classification.
- If upstroke, maximum, and plateau events are already defined on the MAP signal, the classifier is not invoked and only recovery events are defined.

Plateau position

To better handle animal subjects and different potential morphologies, there are two methods for locating the plateau position in monophasic action potential data; use Preferences to set the method. Each method defines recovery percentage time locations depending on the signal between its maximum and the beginning of the plateau. The plateau is located by examining the derivative of the MAP immediately following its maximum value after an upstroke.

- The first method uses an adaptive threshold of zero plus a percentage of the peak to peak change in the derivative between the maximum and the first zero crossing after the maximum. If the signal remains above the upstroke voltage in this interval, a quick algorithm is used to locate 100% recovery and user-specified percentage levels. The default percentage is 0.1%, which will place the plateau position very close to the second zero crossing. This slight window around zero helps place plateau start events better for MAP data that has plateaus that continue increasing after their starting position.
- Searches for the second zero crossing after the maximum. If the signal drops below the voltage level of the upstroke in this interval, a different (slower) algorithm is used to ensure the recovery percentage is relative to the upstroke voltage and not the minimum occurring between the maximum and plateau.

The analysis outputs the following information on a cycle-by-cycle basis and the textual output cites the average of all of the cycle-by-cycle values:

Name	*Abbrev*	*Description*
100% recovery period	100% REC	Time interval from the upstroke for the signal to recover back to the upstroke voltage level
dV/dt maximum	dV Max	Maximum change in voltage over the cycle
dV/dt minimum	dV Min	Minimum change in voltage over the cycle
End diastolic voltage	EDV	The value of the signal at the beginning of the upstroke
Max voltage	MAX	The maximum value of the signal over a single cycle
Minimum voltage	MIN	The minimum value of the signal over a single cycle. This may be less than the upstroke voltage depending on the morphology of the action potential
Plateau voltage	PLAT	The value of the signal at the start of the plateau after the completion of the upstroke
Rate	-	This is the heart rate in BPM as extracted from the time interval between consecutive upstrokes
Stroke amplitude	AMP	Voltage interval between the plateau and the upstroke voltage
User recovery period	%REC	Time interval from the upstroke for the signal to recover a specific percentage of the interval between the upstroke and the maximum voltage between the upstroke and the plateau

MAP Classifier

The classifier portion of Monophasic Action Potential only – defines upstroke, plateau, and percentage recovery events on MAP signals without performing the additional MAP data extraction.

The start of the plateau is located using either the second zero crossing of the derivative or a percentage of the cyclic peak-to-peak distance of the derivative. The plateau location method can be configured in Preferences.

Respiratory Sinus Arrhythmia

IMPORTANT—Respiration analysis assumes a bidirectional airflow signal that records both inhale and exhale. Unidirectional respiration signals cannot be analyzed at this time.

Respiratory Sinus Arrhythmia is used to explore the connection between respiration and changes to heart rate. Variations in the heart rate can be directly correlated with vagal tone. The RSA index can be used to investigate changes in this connection during recording.

This RSA index is computed using the peak-valley method as outlined in:

Grossman, P., van Beek, J., & Wientjes, C. (1990). A comparison of three quantification methods for estimation of respiratory sinus arrhythmia. *Psychophysiology*, 27, 702-714.

This method uses both a recorded ECG Lead II signal and a respiration signal. By using respiration information, this analysis method can provide breath-to-breath analysis that does not require parameter tweaking for individual subjects.

While designed for use with the RSP100C/TSD201 respiration module and transducer combination, it should be possible to use other estimates of respiration. The respiration signal is used to locate periods of inhalation and exhalation. Inhalation begins at valleys in the signal while expiration at peaks. Any respiration estimate that exhibits this morphology should be sufficient.

The RSA index outputted by this analysis is linearly scaled as per the recommendations in Grossman et. al. For comparison to other methods or studies using logarithmic scaling, Transform > Math Functions > Ln transformation can be used after analysis to convert results to logarithmic scaling.

RSA results are triggered from the respiration cycle. The RSA analysis outputs the following measures:

Cycle Index of the respiration cycle in the analysis.

Time Location of the start of the respiration cycle on the time axis.

Min Rate Minimum heart rate occurring during the inspiration window of the respiration cycle, expressed in milliseconds (IBI).

- If a respiration cycle is invalid, this measure will be set to 0.

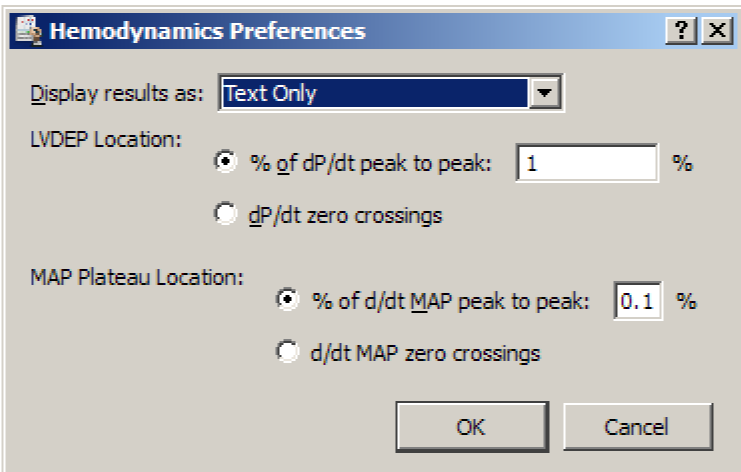
Max rate Maximum heart rate occurring during the expiration window of the respiration cycle, expressed in milliseconds (IBI).

- If a respiration cycle is invalid, this measure will be set to 0.

RSA RSA index for the respiratory cycle, expressed in milliseconds. This is the max rate minus the min rate. This is output in linear scaling. Conversion to logarithmic scaling must be performed manually, if desired.

- If a respiration cycle is invalid, this measure will be set to 0.

Preferences



Display results as

Several of these transformations produce large amounts of cycle-by-cycle derived measures. Results can be displayed as a tab delimited table in the journal, as waveforms in the graph, as an Excel spreadsheet or various combinations. Results are displayed as text-only by default.

LVEDP location method – see page 367

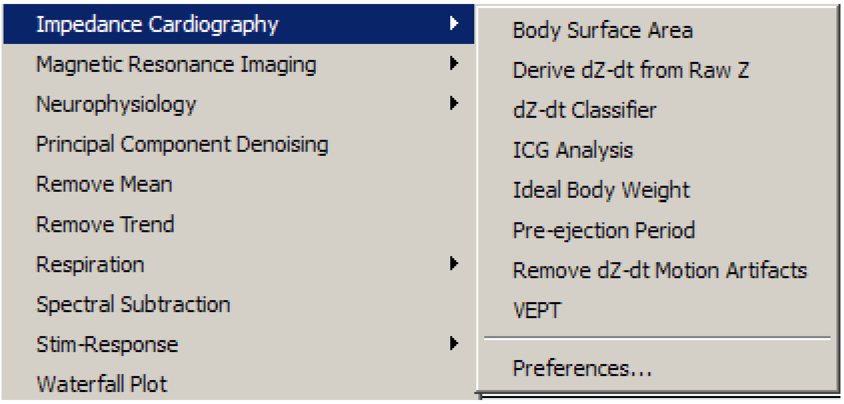
- adaptive threshold of 0 plus a % of pk-pk change in pressure
- first zero crossings before contraction on the dP/dt signal

MAP Plateau location method – see page 368

- adaptive threshold of 0 plus a % of pk-pk change in the derivative between the max and the first 0 crossing after the max
- second zero crossing after the maximum

Impedance Cardiography Analysis

The Impedance Cardiography analysis package assists in the analysis of cardiac output and other hemodynamic parameters using noninvasive bioimpedance monitoring techniques; signals must be sampled at 5 kHz or below to be analyzed with this package. It offers a variety of approaches for estimation of cardiac measures.



Body Surface Area

Determines the body surface area estimation in square meters for a subject of a given height and weight, using the formula set in Preferences. It can be used to calculate body surface area independent of any of the other analysis routines, which may be useful for validation purposes or other derived calculations.

Body Surface Area equation

Use the Preferences option to select an algorithm for estimating body surface area of a subject and deriving stroke volumes from impedance data.

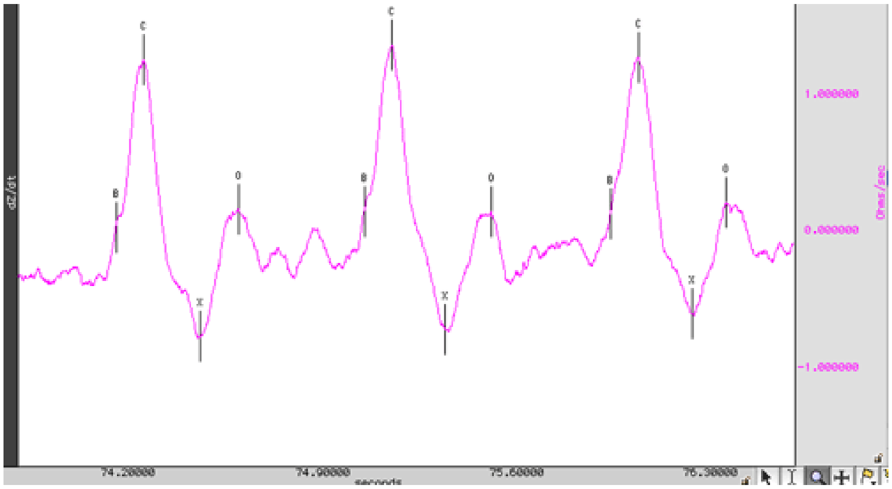
Method	*Formula*
Boyd	$BSA = 0.0003207 \times Height(cm)^{0.3} \times Weight(g)^{0.7285-0.0188\log(Weight(g))}$
DuBois and DuBois	$BSA = 0.20247 \times Height(m)^{0.725} \times Weight(kg)^{0.425}$
Gehan and George	$BSA = 0.0235 \times Height(cm)^{0.42246} \times Weight(kg)^{0.51456}$
Haycock	$BSA = 0.024265 \times Height(cm)^{0.3964} \times Weight(kg)^{0.5378}$
Mosteller	$BSA = \sqrt{\dfrac{Height(cm) \times Weight(kg)}{3600}}$

dZ/dt Derive from Raw Z

This is a convenience utility for working with impedances recorded using the BIOPAC EBI100C amplifier or the raw impedance output of the BIOPAC NICO100C module. When computing derivatives from raw impedance signals from an EBI100C, this will apply appropriate filtering for a thoracic impedance signal and properly invert the derivative to match traditional dZ/dt presentation.

dZ/dt Classifier

Places events at common inflection points on a dZ/dt waveform to derive other measures.



The classifier will attempt to locate the following points on the ICG signal:

- B point – opening of aortic valve (set location in Preferences)
- C point – Maximum left ventricle flow (set location in Preferences)
- X point – Closing of aortic valve (set location in Preferences)
- Y point – Closing of pulmonal valve
- O point – Widest opening of mitrial valve

The algorithm for locating these points on the ICG signal examines local minima and maxima in the dZ/dt signal as well as values of its second derivative. Filtering is applied to the second derivative signal to improve accuracy.

- Pre-filtering the dZ/dt signal may improve accuracy slightly.

In a particular cardiac cycle, if there is not enough definitive change in the ICG signal to locate a particular point, the point will be omitted. This may most commonly occur with the Y point since its inflection between X and O is subtle and may be lost.

The location routine, as with impedance cardiography measurements in general, is sensitive to motion artifacts. It is intended to function on signals acquired from subjects at or near perfect rest. Swings in the dZ/dt signal may cause the classifier to fail. It is recommended that motion artifacts be removed before running the dZ/dt classifier or any other ICG analysis tools that may invoke the classifier on an ICG signal. If artifacts are present within the signal, the template matching cycle location method will exhibit better behavior than the fixed threshold method. The choice between these two methods can be made with the Preferences option of the analysis package.

B-point Location—Use Preferences to set the dZ/dt B-point location method.

There is no standard method generally accepted for programmatically locating B-points on an ICG waveform. The appropriate choice of B-point location method may depend on the data or on subjective preference. On average, all three methods will produce similar results for clean data. ICG Preferences has three options for B-point location:

- Second derivative classification – Given a C peak, it searches within a 150ms to 100ms time window before the C peak for the maximum of the second derivative of impedance ($\ddot{Z}$). The B point is placed at this maximum.
- Third derivative classification – Given a C peak, it searches for the maximum value of the third derivative of impedance ($\dddot{Z}$) within 300ms before the C peak. The B point is placed at this maximum.
- Cycle-by-cycle 'Isoelectric' crossings – Given a cycle defined by two C peaks, the mean of the dZ/dt signal is computed over the cycle. The B point is then placed at the closest time to the right C peak that is still underneath this baseline zero level.

C-point Location—Use Preferences to set the dZ/dt C-point location method.

In several of the ICG analysis scripts, the B, C, X, Y, and O points will need to be located on the dZ/dt waveform. The starting point of this process is locating individual cycles on the dZ/dt waveform to define the C points. Use Preferences to set the cycle location method:

- Template Matching – the user is expected to select a representative cycle of the dZ/dt waveform. The entire cycle should be selected (e.g. visually to approximate a C-C interval, a X-X interval, etc.). The entire dZ/dt signal is then correlated with that representative cycle, and individual cycles are picked out from locations of maximum correlation.

- Fixed Thresholding – the user is prompted to select one of the C peaks of the dZ/dt waveform. The voltage level of this peak is then used to compute an Ohms/sec thresholding level. Peak detection is then run on the dZ/dt waveform using that voltage level as the threshold.

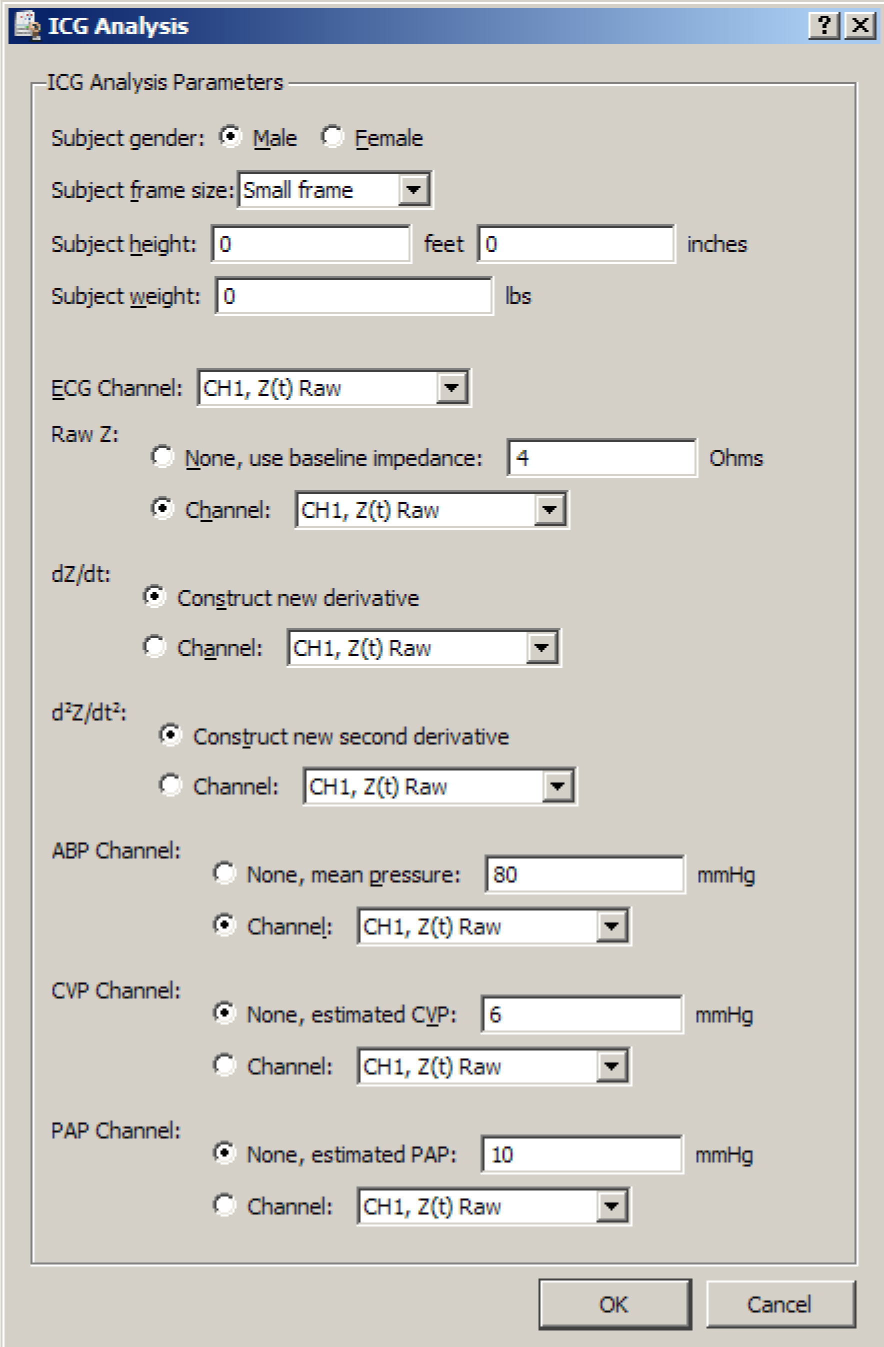
  Since ICG is subject to many artifacts such as respiration components and motion artifacts, the default method used is template matching. For extremely clean ICG signals, however, fixed thresholding can be used effectively as well and will provide a quicker analysis.
- Adaptive template matching – the user is prompted to select a representative cycle of the dZ/dt waveform. This is used as a basis for an adaptive match to locate cycles. Adaptive template matching will adapt to changes in the dZ/dt waveform as conditions change within the experiment. Two parameters may be set. The window size is the number of ICG cycles to use for estimating the next template. Smaller values will track changes more quickly; larger values will reduce interference from artifact. The correlation threshold is the value above which a match is found. It refers to the normalized cross correlation of dZ/dt with the template and should be between 0 and 1. Values closer to 1 will require precise matches and skip artifacts. Values closer to 0 will use looser match constraints and may be required if the ICG is changing rapidly.

X-point Location

There are two methods that may be used to locate the X point of the ICG waveform at the closing of the aortic valve. The choice of appropriate X point location method is dependent on the electrode configuration that is used to acquire the ICG signals. In certain electrode configurations, the dZ/dt minimum may actually occur closer to the A-wave complex than to X, making the first (and default) option of searching for the first turning point a more reliable solution. You may want to acquire a phonocardiogram in conjunction with ICG to help determine which method will be more accurate at locating X.

- Search for the first turning point in the dZ/dt signal that occurs after the C point location and place X at the first positive zero crossing in the second derivative of impedance (d^2Z/dt^2).This is the default X point location method.
- Locate the X point at the minimum value of dZ/dt over each cardiac cycle.

ICG Analysis



The ICG Analysis routines include 20 derived impedance and hemodynamic measures that correspond to various values that are generated by other industry-standard impedance cardiography analysis tools. Many users tend to be interested only in a subset of the various measures produced by the analysis (e.g. only heart rate and cardiac output); the extra measures can "clutter" the output and frustrate users who have to delete them manually.

The ICG Analysis output options feature adds a new step to the ICG Analysis where the user may toggle the output of individual measures on and off. This allows users to suppress generation of all output for a measure including the graph channels, column in the Excel spreadsheet, and column in the text output.

ICG Analysis performs a full impedance cardiography analysis on data, extracting intervals and derived cardiac measures. The minimal set of signals required to run this analysis is an ECG Lead II signal and either a raw impedance signal or a dZ/dt signal.

- If a raw impedance signal is present from an EBI100C or NICO100C and no derivative has been constructed, the analysis will automatically construct the appropriate derivative and perform classification.

- If both a raw impedance and a dZ/dt signal are present, the baseline impedance will be derived on a cycle-by-cycle basis to improve the accuracy of the analysis.
- If no raw impedance signal was acquired, a default fixed baseline impedance can be used.
- If a NICO100C amplifier is used, it is recommended that both the raw impedance and dZ/dt signals be acquired to improve analysis accuracy.
- To automatically apply motion filtering to the dZ/dt signal, use Preferences to enable Motion Filtering (see page 379).

In addition to the minimal set of signals, it is also possible to use arterial blood pressure, central venous pressure, and pulmonary arterial pressure signals to improve the quality of the algorithm results. If any of these signals are not present, default fixed estimated values can be substituted for the mean pressures instead of deriving pressures on a cycle-by-cycle basis.

ICG Analysis may potentially perform classification of both the dZ/dt and the ECG Lead II signals. The various notes for understanding the limitations of these classifiers apply and should be understood to properly interpret failures in the analysis.

ICG Analysis will produce the following information on a cycle-by-cycle basis:

At the end of the textual table an average of all of the cycle-by-cycle values will be appended.

Name	*Abbv.*	*Description*	*Units*	*Formula*
Acceleration index	ACI	Maximum blood acceleration	1 / sec^2	$\frac{\frac{d^2Z}{dt^2}_{max}}{TFI}$
Cardiac index	CI	Normalized cardiac output	m^2 / min	$\frac{CO}{BSA}$
Cardiac output	CO	Volume of blood pumped each minute	l / min	$SV \times HR$
Heart rate	HR	Heart rate in BPM as computed from the RR interval.	BPM	$\frac{60}{RR_i}$
Left cardiac work	LCW	Work exerted by the left ventricle each minute	kg m	$(MAP - PAP) \times CO \times 0.0144$
Left cardiac work index	LCWI	Normalized left cardiac work	kg m / m^2	$(MAP - PAP) \times CI \times 0.0144$
Left ventricular ejection time	LVET	Time interval between B and X. Time interval between aortic valve open and close.	sec	*Not applicable*
Mean blood pressure	MBP	Mean blood pressure as measured on the arterial blood pressure signal, or fixed estimate if no ABP signal is present.	mmHg	$P_{diastolic} + \frac{P_{systolic} - P_{diastolic}}{3}$
Mean central venous pressure	CVP	Mean central venous pressure over cycle, or default value if no CVP signal is present.	mmHg	*Not applicable*
Mean pulmonary arterial pressure	PAP	Mean value of the pulmonary arterial pressure of a cycle, or default value if no PAP signal is present.	mmHg	*Not applicable*

Name	*Abbv.*	*Description*	*Units*	*Formula*
Pre-ejection period	PEP	Time interval between the Q wave of the ECG and the B point of the ICG. Time interval between systole and aortic valve open.	sec	*Not applicable*
RR interval	RR-i	Time interval between R peaks in the waveform.	sec	*Not applicable*
Stroke index	SI	Normalized stroke volume	(ml / beat)/ m^2	$\frac{SV}{BSA}$
Stroke volume	SV	Volume of blood pumped by left ventricle in a single beat	ml / beat	Set equation in Preferences: Kubicek—Estimates SV from the derivative of the impedance signal and blood resistivity: $SV = \rho \times \frac{L^2}{{Z_0}^2} \times \frac{dZ}{dt}_{\max} \times LVET$ Note $\frac{dZ}{dt}_{\max}$ may be either the absolute maximum or the BC delta in amplitude, as set in Preferences. ▪ Sramek—Estimates SV from the derivative of the impedance signal and the estimated volume of electrically participating fluid (VEPT): $SV = \frac{VEPT}{Z_0} \times \frac{dZ}{dt}_{\max} \times LVET$ o In the ICG analysis routines, VEPT is estimated using a truncated cone model. $VEPT = \frac{(0.17H)^3}{4.25}$ ▪ Sramek-Bernstein—Estimates SV from the volume of electrically participating tissue scaled according to body habitus. The SV equation is: $SV = \frac{\delta(VEPT)}{Z_0} \times \frac{dZ}{dt}_{\max} \times LVET$ *where* $\delta(VEPT) = \frac{weight_{actual}}{weight_{ideal}} \times \frac{(0.17H)^3}{4.25}$ Ideal body weight is computed using the method set in the Preferences. To best match the original Sramek-Bernstein equation, use the Met Life Tables ideal body weight method.
Systemic vascular resistance	SVR	Afterload; arterial flow resistance	dynes sec / cm^5	$80 \times \frac{MAP - CVP}{CO}$

Name	*Abbv.*	*Description*	*Units*	*Formula*
Systemic vascular resistance index	SVRI	Normalized afterload	dynes sec m^2 / cm^5	$80 \times \frac{MAP - CVP}{CI}$
Systolic time ratio	STR	Ratio between electrical and mechanical systole	none	$\frac{PEP}{LVET}$
Thoracic fluid content	TFC	Electrical conductivity of the chest cavity	1 / Ohms	$\frac{1}{TFI}$
Thoracic fluid index	TFI	Mean value of the raw impedance over the cycle, or fixed baseline value if no raw impedance signal is present.	Ohms	*Not applicable*
Velocity index	VI	Maximum velocity of blood flow in the aorta.	1 / sec	$\frac{\frac{dZ}{dt}_{max}}{TFI}$ Note $\frac{dZ}{dt}_{max}$ may be either the absolute maximum or the BC delta in amplitude, as set in Preferences.

Ideal Body Weight

Body Weight is derived from a person's height, gender, and (for the Met Life method) frame size. It describes the ideal weight based upon various estimates. Ideal body weight is subject to much interpretation, so a number of methods are provided. Ideal Body Weight results are always expressed in kilograms.

Use Preferences to set the Ideal Body Weight computation method; the selected method is also used for ICG Analysis.

Method	*Formula*
Devine	*Men* 50 kg + 2.3 kg per inch over 5 feet *Women* 45.5 kg + 2.3 kg per inch over 5 feet
Metropolitan Life Tables	The weight is taken from the standard Metropolitan Life tables, which are based on gender, height, and frame size. The Metropolitan Life tables specify weight ranges; the ideal body weight is computed as the average of the endpoints of each weight range. Ideal weights are based on height with shoes on and are only defined for heights between *Men* 5' 2"and 6' 4" *Women* 4' 10"and 6' 0"
Miller	*Men* 56.2 kg + 1.41 kg per inch over 5 feet *Women* 53.1 kg + 1.36 kg per inch over 5 feet
Robinson	*Men* 52 kg + 1.9 kg per inch over 5 feet *Women* 49 kg + 1.7 kg per inch over 5 feet

PEP Pre-ejection Period

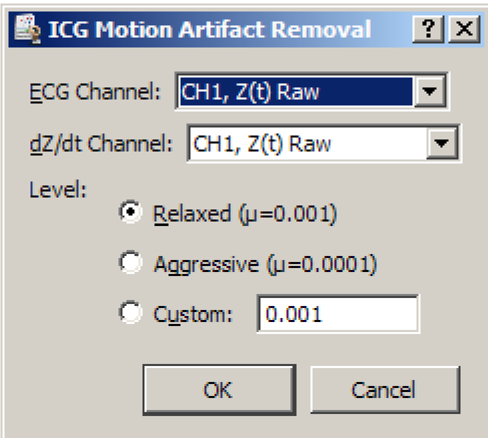
The pre-ejection period is the time interval between the electromechanical systole and the onset of ejection of blood from the left ventricle of the heart. This can be derived from standard ECG data and ICG data as the interval between the Q point on the ECG and the B point on the ICG. The Pre-ejection Period analysis tool helps extract PEP measurements from ECG Lead II and ICG data. PEP can also be computed using the full ICG Analysis tool on page 374.

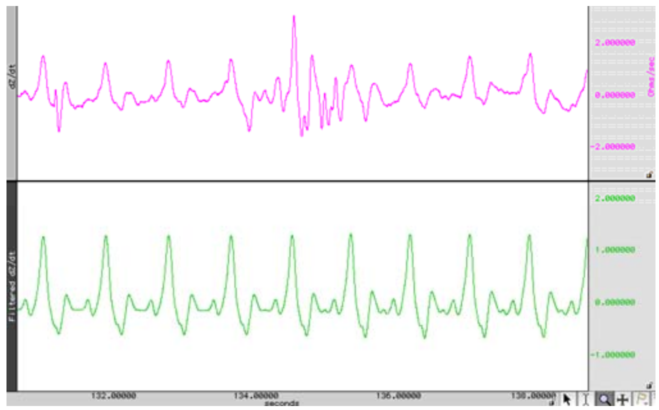
To use Pre-ejection Period analysis, both an ECG Lead II and an ICG (dZ/dt) signal must be present. If either of these signals requires classification, the analysis will run the appropriate classifier to define the relevant events on the signals. To automatically apply motion filtering to dZ/dt, use Preferences to enable Motion Filtering (see page 379).

PEP analysis will output the following information on a cycle-by-cycle basis and the final line of the textual output will be the average of all of the cycle measurements. All time unit output is in seconds unless otherwise noted.

Name	*Abbrev.*	*Description*
Heart rate	BPM	The heart rate for the cycle as indicated in BPM. Derived from the RR interval.
Pre-ejection period	PEP	Time interval between the Q wave of the ECG and the B point on the ICG for the cardiac cycle. If the PEP cannot be computed for a particular cycle, it will have the value "----" in the textual output or 0 in the graphical output.
RR interval	RR-i	Time interval between R peaks of a single cycle of cardiac data.

dZ/dt Remove Motion Artifacts





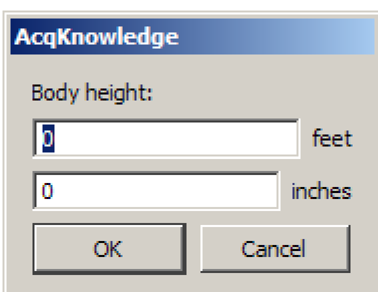
Applies SFLC motion artifact removal to a dZ/dt signal. Uses cycle information from an ECG signal to construct a sinusoidal model of the ICG signal containing only components that are correlated to the heart rate.

IMPORTANT

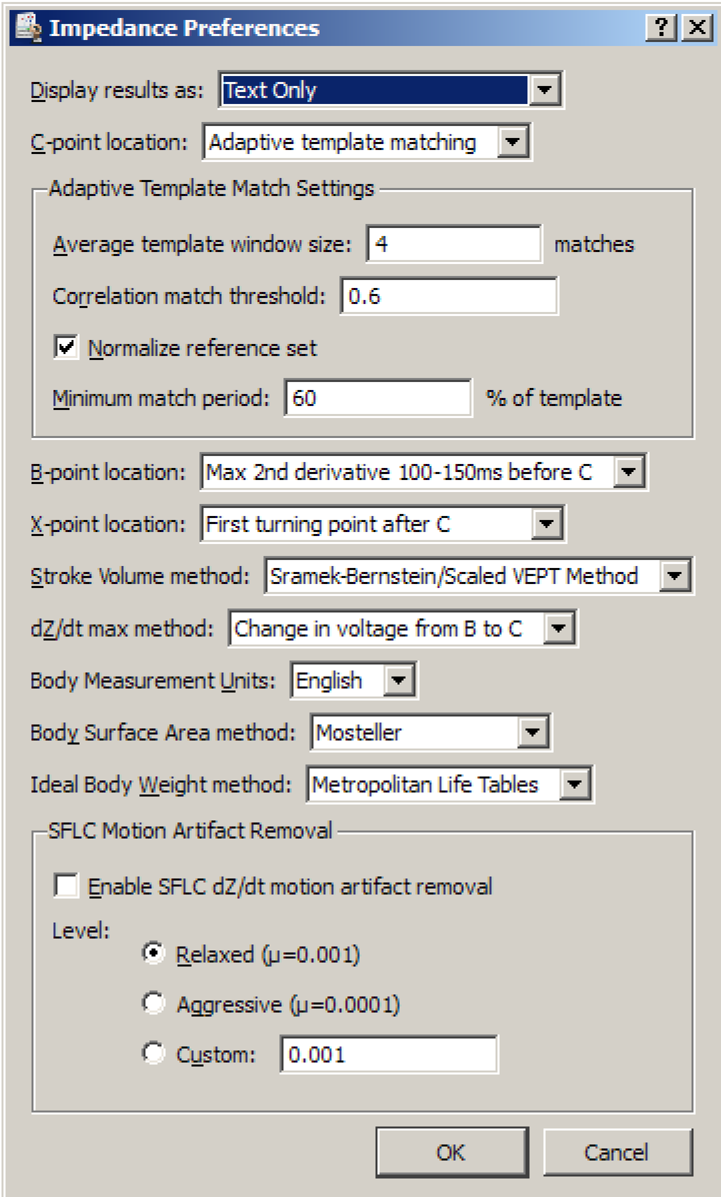
Motion artifact removal will affect the amplitudes of the dZ/dt signal, so results derived from a motion filtered dZ/dt signal should be additionally verified for accuracy.

This tool performs the same type of filtering as the ICG Analysis and Pre-ejection Period tools when the Motion Filtering preference is enabled.

VEPT



Uses the truncated cone method to compute the volume of electrically participating tissue (VEPT) in cubic centimeters of a subject. You will be prompted to enter the height of the subject in the units set under Preferences. It can be used to calculate VEPT independent of any of the other analysis routines, which may be useful for validation purposes or other derived calculations.



Display results as

- Textual tables in the journal
- Channels of data inserted into the graph.

C-point location –see page 372

B-point location – see page 372

X-point location – see page 373

Stroke volume equation – see page 376

- Kubicek, or Sramek, or Sramek-Bernstein

dZ/dt Max method – Baseline drift in ICG signals can introduce drift artifacts into stroke volume, cardiac output, and other measures that are sensitive to changes in dZ/dt max. The Preferences offer two settings. "Max dZ/dt in cardiac cycle" will extract the maximum amplitude of dZ/dt as the max value. This is the traditional way of measuring dZ/dt max. A second estimate option, "change in voltage from B to C" will take the amplitude delta between B and C as the estimate of dZ/dt max. This will produce different stroke volume results, but is useful for removing motion artifact and improving consistency.

Body Measurement Units system for inputting

- English system: body height in feet and inches, distance between measuring electrodes in inches, and body weight in pounds
- Metric system: body height in meters and centimeters, distance between measuring electrodes in centimeters, and body weight in kilograms.

Body Surface Area equation – see page 371

- Boyd; DuBois and DuBois; Gehan and George; Haycock; or Mosteller

Ideal Body Weight method– see page 377

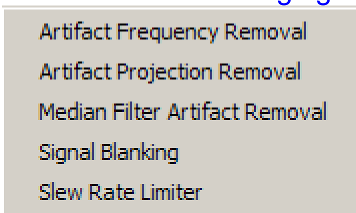
Motion Artifact Removal

The Pre-ejection Period and ICG Analysis transformations have the ability to optionally apply motion filtering automatically to the dZ/dt signal. Motion filtering is performed using an SFLC keyed to the R waves of an ECG signal. The SFLC filtering approach is similar to performing cycle-by-cycle averaging of the dZ/dt signal. This motion filtering approach may cause errors to be introduced in derived calculations, so any results with motion filtering turned on should be validated additionally.

Filter Magnitude Level – relaxed, aggressive, and custom.

- "Relaxed" uses a SFLC step size of .001. This allows the filter to adapt moderately quickly to changes in the dZ/dt signal.
- "Aggressive" uses a SFLC setting of .0001. The filter will adapt less quickly to changes in the ICG signal, allowing better filtering out of motion artifacts at the expense of a lessened response to changes in underlying ICG morphology.
- "Custom" allows for an arbitrary SFLC step size. The step size must be greater then zero and much less than 1 for the filter to converge.

Magnetic Resonance Imaging



Magnetic resonance imaging, or MRI, is often used to study the brain and other organs in the body. As access increases to MRI machines, researchers are beginning to combine MRI with traditional physiological signal recording. The strong magnetic fields used by MRI equipment can cause profound artifacts in physiological recordings, which can make the analysis of physiological recordings acquired in an MRI difficult. Some artifacts are external interference while other artifacts can be caused by currents being induced in electrode leads or even in the body itself.

Artifact Location and Trigger Signals

Most of the MRI analysis options require information to identify the positions of various artifacts. Event positions can be used or a "trigger signal" waveform in the graph can be used to identify periods when the MRI is active. Some MRI machines have a TTL output that is synchronized with periods where the MRI is on.

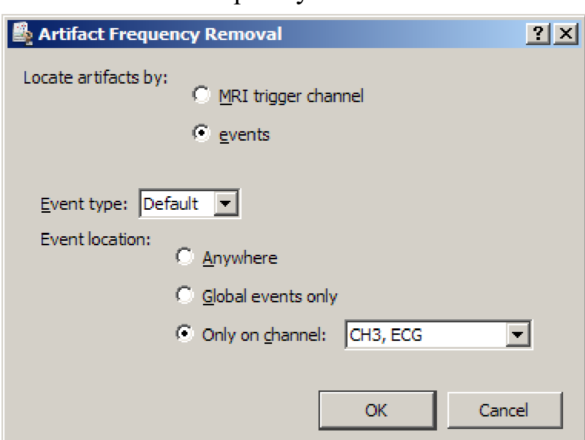
- Whenever possible, this trigger signal should be acquired with the MP unit along with the physiological data.

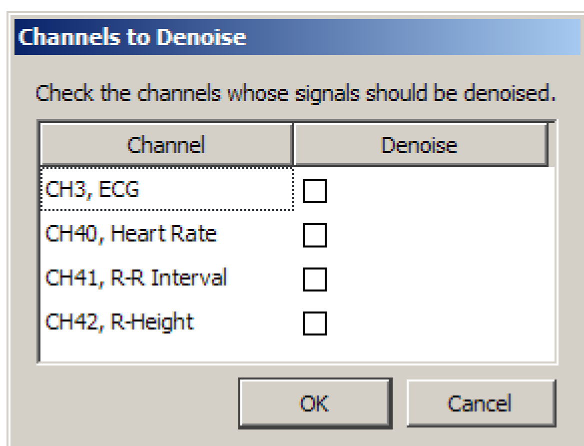
Trigger detection off of an MRI trigger signal waveform is performed using fixed level thresholding on the waveform data. The threshold level is set to be the minimum value of the entire trigger signal plus 1/10th of the peak-to-peak distance of the trigger signal. The threshold is kept data dependent to allow for artificial trigger signals to be derived from data if the MRI unit does not provide its own. The trigger signal may be acquired on either an analog or digital channel.

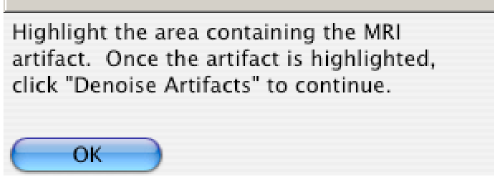
Event driven artifact location can be useful when trigger signals are not available from the MRI or are not recorded. A cycle detector analysis can be used to place events at the onset of each artifact, or these events may be placed manually. Event based detection is also useful for applying the procedures for artifacts that are not directly related to the MRI trigger signal, such as for removing the cardiac interference from EEG data caused by the magnetic field of the MRI machine.

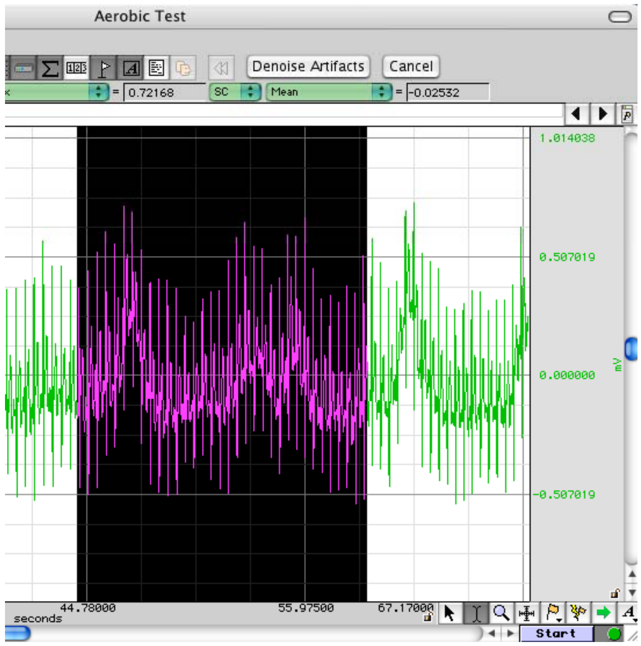
Artifact Frequency Removal

MRI > Artifact Frequency Removal









Two large sources of interference in MRI recordings are the current induced by the MRI magnetic field and the RF pulses used for triggering molecule alignment. While the overlap of this interference may be difficult to separate in the time domain, the MRI interference may have a distinctive signature in the frequency domain.

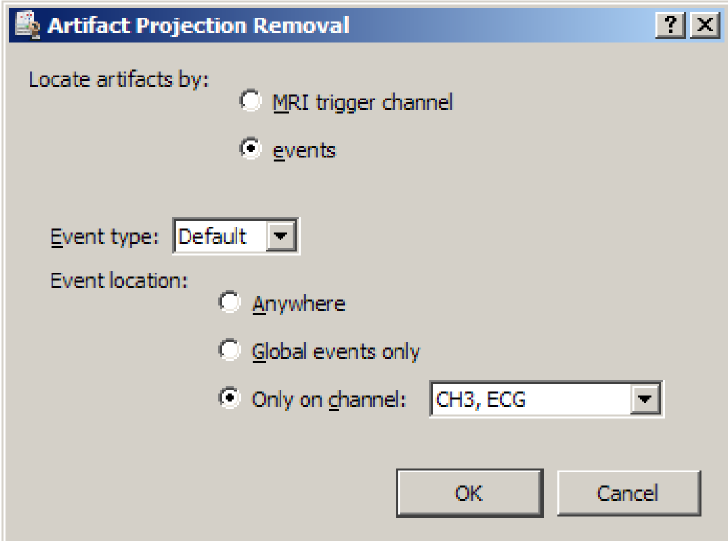
Artifact Frequency Removal is a frequency domain adaptation of the ensemble projection removal of the Artifact Projection Removal transformation. It attempts to cancel out MRI artifact by removing the frequencies most strongly associated with the MRI signal.

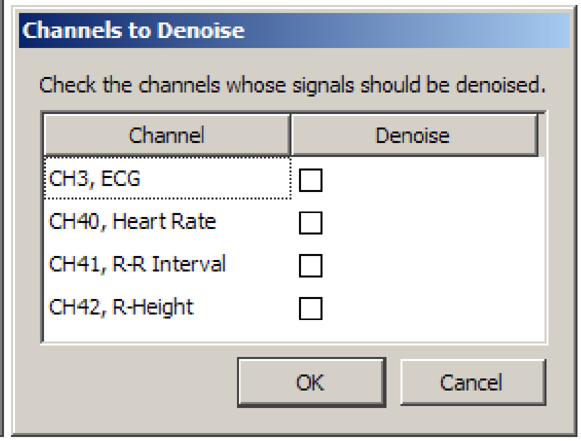
For each channel of data to be denoised, either the MRI trigger signal or event positions are used to locate periods of MRI activity for constructing an ensemble average. The FFT of this ensemble average is computed, and the magnitude of the average FFT is set as the reference. Cyclic mean removal is applied to each period of artifact to compensate for baseline drift or signals with expected DC offset. A second pass is then made through the data. For each individual artifact, the FFT of that artifact is computed and the projection of that FFT onto the average FFT is removed. After projection removal, negative Fourier components are discarded and a time-domain signal is reconstructed using the inverse Fourier transform. This reconstructed, filtered signal is used to replace the MRI artifact in the original data.

Application of projection removal in the frequency domain has similar limitations to applying it in the time domain, that is, it assumes that the MRI interference is stationary (which is not necessarily the case). Variations in the MRI interference may cause this method to fail.

IMPORTANT Artifact Frequency Removal requires an MRI triggering signal or artifact onset events to locate artifact positions.

Artifact Projection Removal





Artifact Projection Removal attempts to remove the noise components from the artifacts within a signal. An ensemble average is made for each period of MRI artifact in a channel. Cyclic mean removal is applied to each period of artifact to compensate for baseline drift or signals with expected DC offset. As the artifacts are averaged together, the actual interference with the physiological signal caused by the MRI should become the dominant feature if a sufficient number of artifacts are present. A second pass is made through the artifacts to remove this average MRI artifact from each individual period.

The average artifact is removed using the Remove Projection transformation. This performs a vector projection of the signal onto the averaged artifact estimation and subtracts this projection. This is an improvement over straight subtraction of the average artifact as vector projection can compensate for changes to amplitude that may occur over time.

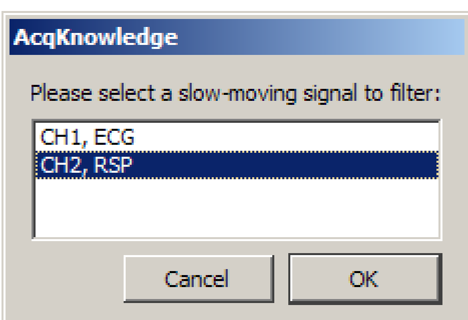
Artifact projection removal cannot compensate for MRI interference that varies in frequency due to changes in orientation of electrode leads within the MRI or other factors that may alter the MRI artifact.

Artifact projection removal is an adaptation of a denoising technique described in:

M. Samonas, M. Petrou and A. Ioannides, “Identification and Elimination of Cardiac Contribution in Single-Trial Magnetoencephalographic Signals,” *IEEE Trans. Biomed. Eng.*, vol. 44, no. 5, pp. 386-393, 1997.

IMPORTANT Artifact Projection Removal requires an MRI triggering signal or artifact onset events to locate artifact positions.

Median Filter Artifact Removal

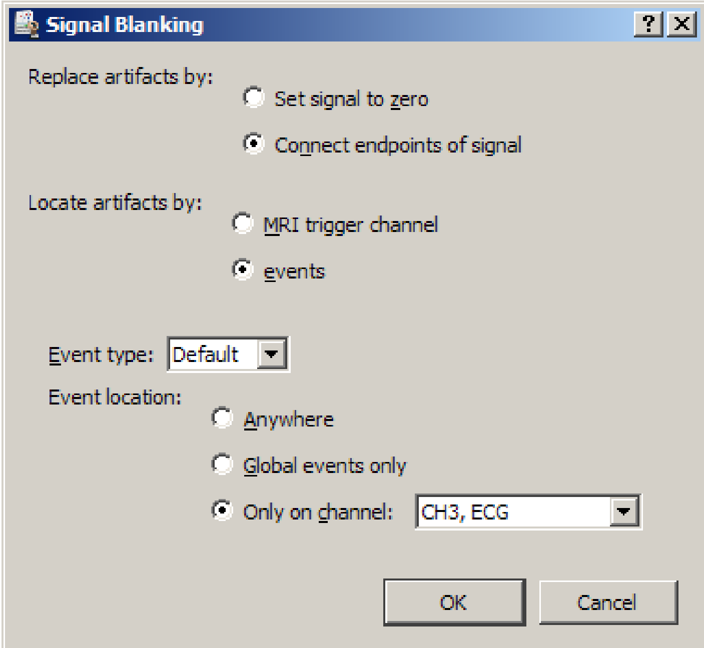


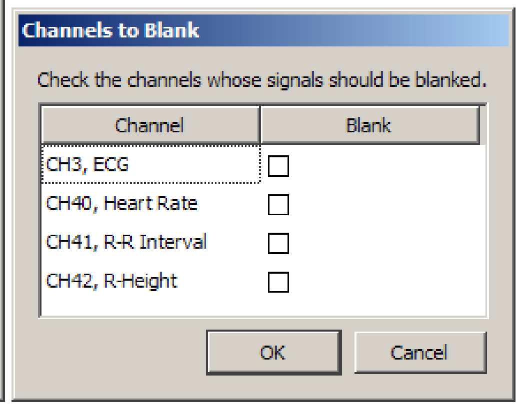
Median Filter Artifact Removal provides a basic artifact removal suitable for slow moving signals such as respiration, GSR, or temperature. It performs a windowed median transformation on the source channel with a window width of 1/10th of the acquisition sampling rate.

This median filtering approach is explained in the BIOPAC MRI application note AH223.

Median Filter Artifact Removal does not require an MRI triggering signal.

Signal Blanking





MRI artifact can grossly distort low level physiological signals, and this distortion can be several orders of magnitude larger than the signal of interest. A common practice for analyzing the physiological data is to discard the MRI artifacts and only examine the portions of the signal in between the MRI artifacts. One approach for this is outlined in BIOPAC MRI application note AH223.

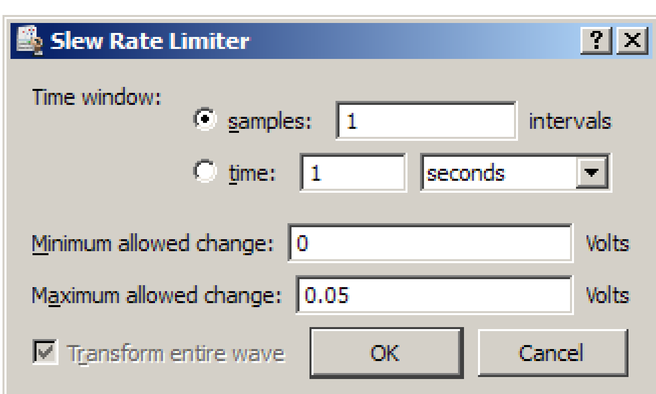
Signal Blanking provides an alternate approach for discarding MRI artifacts from the signal. Using the MRI triggering signal or artifact event locations, this analysis option will locate the periods of MRI activity and "blank" the physiological signal during this period.

Two types of "blanking" can be performed:

- Set value to zero – The waveform is set to zero during each artifact.
  - For integrated measures, zeroing the signal may be preferable as it will have no effect on the running sum.
- Connect endpoints – For each artifact, a selection is made and the values within the interval are replaced with a line connecting the signal value before the MRI artifact to the signal value at the end of the interval.
  - For statistical measures or DC coupled signals, connect endpoint (linear interpolation within the interval) may be preferable to avoid causing the output to trend towards zero.

IMPORTANT Signal Blanking requires an MRI triggering signal or artifact onset events to locate artifact positions.

Slew Rate Limiter



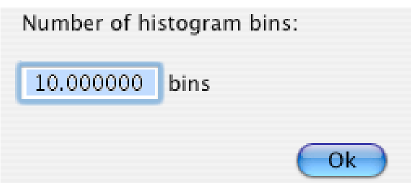
The Slew Rate Limiter restricts the maximum allowed change in amplitude across sample intervals, which is useful for certain types of denoising. The ability to restrict the maximum rate of change is useful for certain types of signal separation where a signal with a high expected rate of change is mixed with a low rate of change signal. The slew rate limiter removes noise of a specific type, without impacting source data, whereas a linear filter is not suitable for removing MRI artifact because it simply integrates the noise.

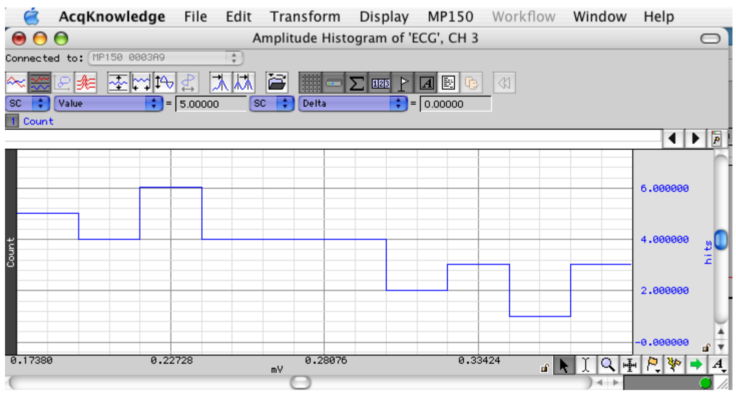
Neurophysiology

The Neurophysiology analysis package assists in the analysis of spikes within extracellular microelectrode recordings, such as those recorded using an MCE100C module. All of these analysis options require a continuous recorded single channel of microelectrode data.

- A *spike* is a deviation from the baseline caused by a neuron action potential. Frequently extracellular spikes will resemble exponentials. The point of maximum value of the spike will be used to locate neuron firing.
- A spike *episode* consists of a fixed time window around a spike that aims to capture the underlying neuron firing time. The episode consists both of the rise time (the time taken to reach maximum) and the relaxation period around the spike.

Amplitude Histograms



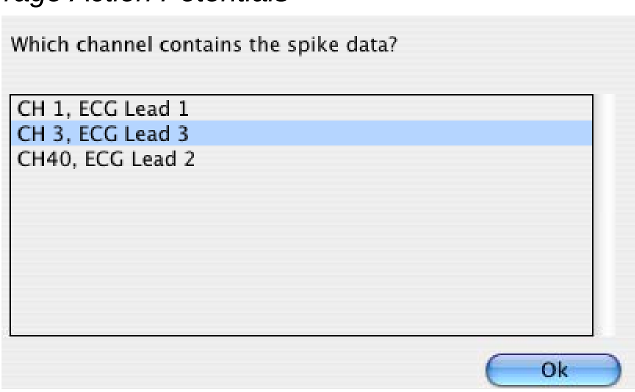


IMPORTANT To run this analysis option, the signal must first be transformed by the Locate Spike Episodes option or the Classify Spikes option.

Amplitude histograms show the population density of the maximum amplitude of neuron firing events. They may be used to interpret changes in neuron firing due to drug response or as rough indicators of the approximate number of classes of action potentials in a signal. Amplitude histograms can be generated on classified or unclassified signals.

- On classified signals, an overall amplitude histogram will be created for all of the spikes in addition to a single amplitude histogram per class (reflecting only the episodes of that class.
- On unclassified signals, a single amplitude histogram will be created from the maximum voltage within all of the spike episodes.

Average Action Potentials

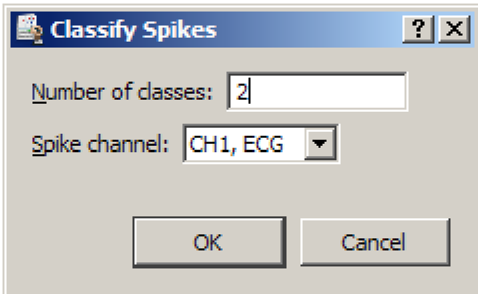


IMPORTANT To run this analysis option, the signal must first be transformed by the Locate Spike Episodes option or the Classify Spikes option.

After a classification has been completed for a spike signal, to assign spike episodes to different groups, users may wish to view the average shape of the waveforms of each class. Examining the shape of the different classes provides visual feedback as to the efficiency of the clustering, can allow for identification of certain classes as noise or artifacts, and helps to determine if the identified classes are indeed unique. Average Action Potentials can be generated on classified or unclassified signals.

- On classified signals, the resulting ensemble averages will have multiple channels.
  - o The first channel will be the overall average of all of the spike episodes.
  - o The remaining channels show the average of the members of each individual spike class.
- On unclassified signals, a graph will be produced with a single channel showing the average of all of the spike episodes.

Classify Spikes



IMPORTANT If cluster events from a previous spike classification are already defined on the recorded waveform, this option will erase them and replace them with the new classification of the potentials.

This analysis option will automatically classify action potentials in microelectrode data and divide them into different spike classes.

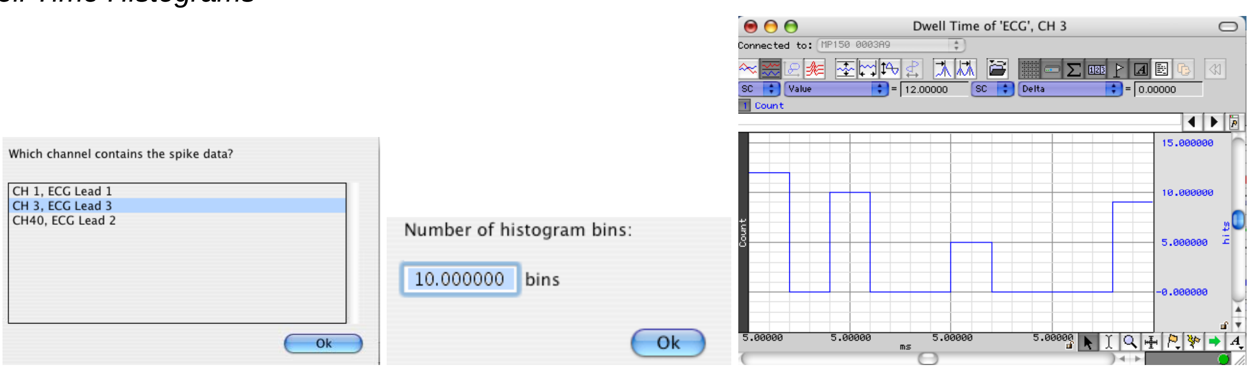
A single-feature k-means clustering classifier is used, and the entire data set is used for the clustering portion of the algorithm. The determining feature is the Sum criteria— that is, the sum of all of the data points within the waveform segment; this was one of the first features used in early action potential classifiers.

If the Locate Spike Episodes option has not been used to find spikes before this option was selected, the Locate Spike Episodes option will be automatically performed prior to the clustering.

The analysis routine will ask for a number of spike classes and then use k-means clustering to group each spike episode into a class. The clustering may not produce meaningful classes, so results should be examined for accuracy.

This style of classifier is for rudimentary spike analysis. For more advanced classification techniques, use the clustering algorithm in the peak detector.

Dwell Time Histograms



IMPORTANT To run this analysis option, the signal must first be transformed by the Locate Spike Episodes option or the Classify Spikes option.

A dwell time histogram shows the population density of the duration of a neuron firing event. Dwell times can be approximated for an action potential by measuring the absolute value of the time interval between their maximum and minimum voltage levels reached during the firing of the neuron. After the minimum value in the firing recording has occurred, the neuron will be returning to its resting state, so the time difference is a good approximation for the firing duration. The dwell time histogram plots this time difference versus number of action potentials that have similar time differences. Examining varieties in dwell times can help to illustrate drug responses or to perform rudimentary classification of action potentials.

Dwell times will be defined as the time difference between the positions of the maximum signal value and minimum signal value within a spike episode. Since dwell time histograms can be used for classification purposes, they can be run on classified or unclassified microelectrode signals.

- On classified signals, an overall dwell time histogram will be constructed for all of the spikes in addition to a single histogram per class, showing times of only the spikes in that class.

- On unclassified signals, a single dwell time histogram will be created for all of the spikes. When run on a classified signal.

Find Overlapping Spike Episodes

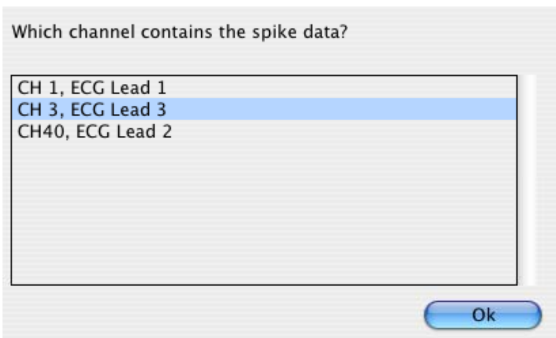
IMPORTANT To run this analysis option, the signal must first be transformed by the Locate Spike Episodes option or the Classify Spikes option.

In many extracellular recordings, it is frequent for there to be more than one neuron firing in response to the same stimulus. This can result in overlapping spike episodes when both neurons fire in close succession. Some types of analysis and spike classification are not able to produce meaningful results if too many overlapping episodes occur. "Find Overlapping Spike Episodes" can be used to locate overlapping episodes. After the spikes have been located in a signal, this option can be used to iterate only to those that are overlapping.

"Next Overlap" and "Cancel" buttons are available in the toolbar of the graph window to allow for iteration through the episodes.

Note This option is "view only." Overlapping episodes are not affected by the analysis and will need to be manually removed manually to delete them from the file.

Generate Spike Trains



IMPORTANT To run this analysis option, the signal must first be transformed by the Locate Spike Episodes option or the Classify Spikes option.

Spike trains are good visual indicators of when action potentials are firing and are good synchronization waves for further analysis and data reduction. A spike train is a channel in a graph whose value is 0 when there is no spike and 1 when there is a spike.

Spike train generation will operate only on signals whose action potentials have already been classified.

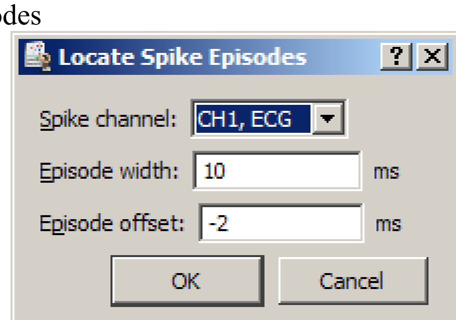
A single spike train will be generated as a channel in the graph for each class of action potential in the signal.

If text output is enabled, the spike trains will be pasted as tables in the journal with one table per spike class.

If spreadsheet output is enabled, the tables will be placed side by side so index 1 of the tables lines up for each action potential.

Locate Spike Episodes

Neurophysiology > Locate Spike Episodes



This option provides the basic spike detection for a microelectrode signal. Spike detection is performed using the following steps:

1. Obtain mean value of the entire signal.
2. Obtain standard deviation of the entire signal.

3. Detect spikes where the signal rises above a fixed threshold determined by adding a multiple of the standard deviation to the mean.
4. Position the episode around the threshold crossings according to the width and offset entered previously.

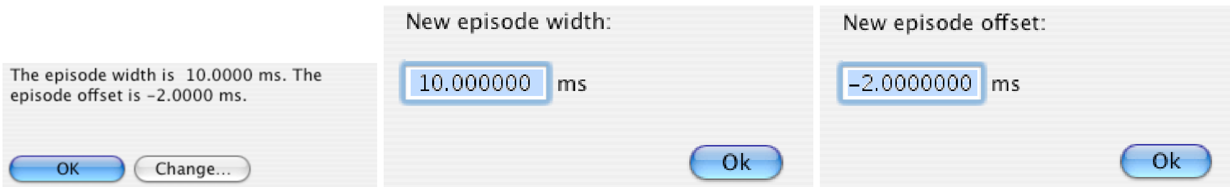
A “Spike Episode Begin” event will be placed at the start of each spike episode and will be located offset milliseconds away from the threshold crossing. A “Spike Episode End” event will be placed at the end of each episode.

If text output is enabled, a table of the start time of each episode will be placed in the graph’s journal.

If spreadsheet output is enabled, a new spreadsheet will be created with the start time of each episode.

Spike episodes may also be located manually by using the Cycle Detector to define “spike episode begin” and “spike episode end” events in the graph.

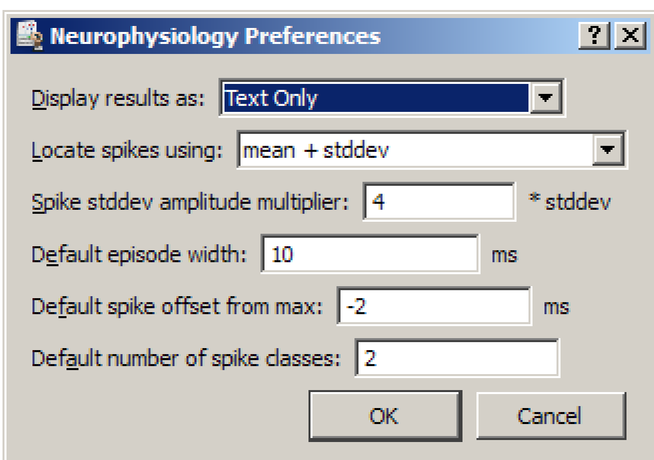
Set Episode Width and Offset



The first time spike detection is performed on a graph, the episode width and offset need to be entered. This width and offset is remembered and is used for all future spike detections in the graph performed by “Locate Spike Episodes” and other transformations. The width and offset that are entered are retained even if the file is saved and reopened.

Use this option to view or change the current width and offset.

Preferences



Preference	*Description*	*Default Setting*
Output type	Determines whether analysis results will be displayed as graph channels, textual tables in the journal, or Excel spreadsheets. Not all of the output types are applicable for each Neurophysiology analysis option.	Text output to journal only.

Preference	*Description*	*Default Setting*
Spike Location Method	Choose how spikes are searched for in the signal. **Mean + Stddev**—uses fixed level peak detection with a level that is computed from the mean value plus a configurable number of standard deviations of the data. **Amplitude/Half-width Discriminator**—allows for basic isolation of spike shapes that have peak voltages within a configurable range and spike half-widths within a configurable range; uses the amplitude of the spike as well as the width of the spike to determine what constitutes a valid spike event. *Half-width* For a given spike, the discriminator searches from the maximum value of the spike to both the left and right of the maximum for the sample positions where the value has dropped below 50% of the maximum. The time interval between these sample positions is defined as the estimate of the half width. The acquisition sampling rate can be increased to improve accuracy of the spike half width estimates as neuron firing events involve high frequency components.	Mean + Stddev

Each time the discriminator is run, the user must input the amplitude low and high values as well as the minimum and maximum spike width. The discriminator searches for spikes in a signal *x* as follows:

1. Performs regular peak detection on *x* using a fixed threshold a_{low}. This locates the local maxima occurring after each threshold crossing of the low amplitude area. This results in a sequence *p* of potential spike locations.

2. For each potential spike location *p*, computes the half-width time interval.

$$t_{half}(p) = t_{50r}(p) - t_{50l}(p)$$

where t_{50r} is the first time $> p$ such that $x(t_{50r}) \leq 0.5\,x(p)$
t_{50l} is the first time $< p$ such that $x(t_{50l}) \leq 0.5\,x(p)$

3. Accepts the spike for each potential spike location *p* as a valid spike *s* if, where *a* is amplitude and *t* is time window:

$$a_{low} \leq x(p) \leq a_{high} \wedge t_{low} \leq t_{half}(p) \leq t_{high}$$

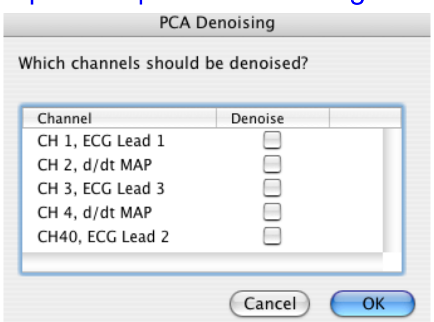
4. For each valid spike location *s*, positions the spike episode

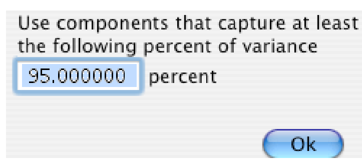
   start output at *s+offset*
   end output at *s+offset+width*

The spike discriminator generates output only for spikes that fall within the bounds of the amplitude and offset windows. If a spike candidate falls outside the windows, no output is generated.

Preference	*Description*	*Default Setting*
Spike Detection Level	Spikes are located in the signal by looking for locations where the signal deviates from its baseline by a certain number of standard deviations. This multiplier is set in this preference.	4 standard deviations
Default Episode Width	The first time that any of the spike detection is run on a graph, the time width of each fixed width episode must be specified. This preference provides the default value that is seeded in the dialog. The episode width for an individual graph does not need to match this default.	10 milliseconds
Default Episode Offset	Each fixed width episode is located around one of the spikes in the signal. The offset allows for the episode to begin before (or after) the spike threshold crossing so the leading edge of the spike can be captured. Negative numbers indicate episodes are to start before the spike threshold crossing, positive numbers indicate episodes that start after.	-2 milliseconds
Default Number of Spike Classes	The Classify Spikes script requires the user to input the number of classes into which the spikes will be partitioned. This preference allows the default number to be modified. The number of classes that wind up being used does not need to match this default.	2

Principal Component Denoising





Removes noise from certain types of signals. For principal component denoising to be effective, more than two signals should be used as sources and all source channels must have identical waveform sampling rates. PCA denoising is most effective on signals that are known to contain a high degree of similarity, such as multiple ECG leads or multiple EEG leads. PCA denoising should not be used on signals of different types or units as all of the principal components may be needed to fully capture the differences in the signals.

➲ To determine if PCA denoising will be effective on a particular set of data or to compute a appropriate variance percentage for denoising, examine the principal components directly with “Transform > Principal Component Analysis” before selecting this option.

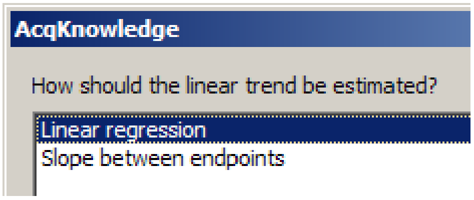
Given a set of signals, a principal component analysis is performed. The strengths of the components are then analyzed, and the original signals are reconstructed from a subset of the principal components that capture a certain percentage of the total variance of the signals. This essentially eliminates one or more of the higher-order principal components. For certain types of signals, these principal components are the ones that model the noise inherent in the signals.

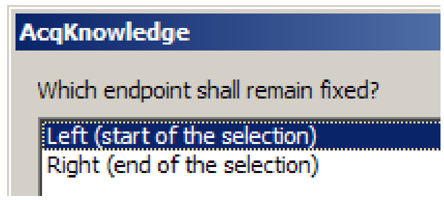
1. Check the “Denoise” column for the channels to be denoised.
2. Enter the overall percentage of the variance.
3. After the percentage is entered, the denoising process will begin.

Remove Mean

Available in Acq*Knowledge* 4.1 and above—Remove Mean allows for mean subtraction to be performed for the selected area (or entire wave if no data is selected). It will result in the mean value being the new zero value for the waveform.

Remove Trend





Available in Acq*Knowledge* 4.1 (and 4.0 Windows or 3.9 Mac)—Remove Trend helps to remove baseline drift or other linear trends from data. This tool makes it easier to apply trend removal to only specific segments of a waveform. Given a selected segment of data, or an entire waveform, it computes the trend between the two endpoints (similar to the Slope measurement) and then removes this trend from the selected area such that the endpoints of the selection lie at the same voltage.

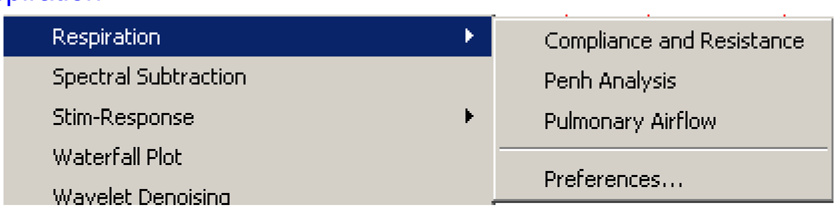
Linear Regression

Use linear regression to estimate the trend to be removed from the waveform.

Slope between endpoints

- **Left** keeps the starting point of the selection fixed at the same voltage. The software adjusts the data from left to right such that the right endpoint is aligned with the initial starting voltage.
- **Right** keeps the ending point of the selection fixed at the same voltage. The software adjusts the data from right to left such that the left endpoint is aligned with the initial ending voltage.

Respiration



IMPORTANT—**Respiration analysis assumes a bidirectional airflow signal that records both inhale and exhale. Unidirectional respiration signals cannot be analyzed at this time.**

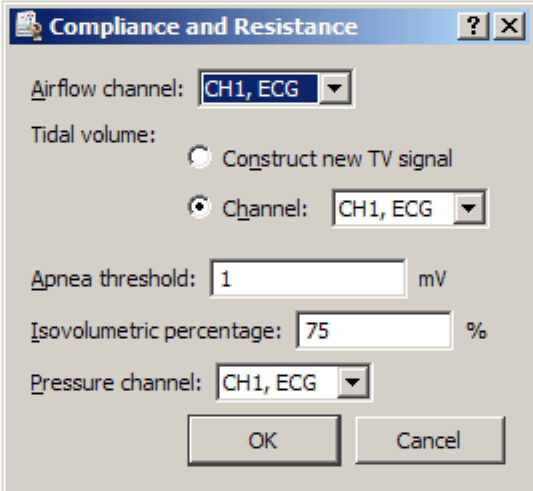
The respiration analysis package helps to analyze respiration- and airflow-related data. Other tools exist for respiration related analysis including Acq*Knowledge* transformations and the Respiratory Sinus Arrhythmia analysis in the Hemodynamics analysis package.

Compliance and Resistance

Compliance and Resistance analysis can be used to extract pulmonary resistance and pulmonary compliance in addition to basic airflow measures. This analysis requires an airflow signal and a pressure signal. The analysis will extract all of the measures of the Pulmonary Airflow analysis for the airflow signal. It also will locate apnea periods after exhalation using the same user-configurable threshold method as the Pulmonary Airflow analysis.

IMPORTANT— **The flow signal must be recorded correctly for Compliance and Resistance analysis to work.** Compliance and Resistance analysis assumes positive flow indicates inhalation and negative flow indicates exhalation (the flow conventions of the recommended connections for a BIOPAC TSD107 pneumotach or a TSD117 airflow transducer).

- If the flow signal was recorded with exhalation positive instead of inhalation positive, multiply the flow signal by -1 to invert the signal.



Pulmonary resistance is computed using the isovolumetric method. On both sides of the tidal volume peak for a breath, the position where the volume reaches a user-specified percentage of the tidal volume is located. The pulmonary resistance is defined as the difference in pressure divided by the difference in flow at these two isovolumetric positions. Due to the discrete nature of sampled data, these points may not be exactly equal in volume. To improve the accuracy of the isovolumetric method, increase the sampling rate used to acquire data.

Dynamic pulmonary compliance is extracted on a breath-by-breath basis by dividing the tidal volume by the change in pressure between the exhale start and inhale start locations of the breath.

Individual breaths are defined as the period between consecutive Inhale Start events. Airflow units are assumed to be the standard liters/sec and pressure units mmHg. For each breath period, the analysis will define the following events:

- Inhale Start event on flow signal at start of inhale
- Exhale Start event on flow signal at start of exhale
- Apnea Start event on flow signal at beginning of apnea period (if present)
- Recovery events on volume signal at isovolumetric positions to left and right of tidal volume peak

If Inhale Start and Exhale Start events are already present on the flow signal at the start of analysis, those events will be used to define the breath periods. Apnea Start and Recovery events will always be regenerated by the analysis.

The analysis will extract the following measures from the data:

Name	*Abbrev.*	*Description*	*Units*
Cycle		Index of the breath in the data, beginning at 1.	
Time		Starting time of the inhale of the breath.	seconds
Peak Inspiratory Flow	PIF	Maximum absolute flow occurring during the inhale portion of the breath.	liters/sec
Peak Expiratory Flow	PEF	Maximum absolute flow occurring during the exhale portion of the breath.	liters/sec
Tidal volume	TV	Total volume of air inhaled during the breath.	liters
Minute volume	MV	Volume of air that would be inspired during a minute given the tidal volume and breathing rate of this breath. TV * BPM	liters/ minute
Breaths per minute	BPM	Breathing rate. $\frac{60}{TT}$	BPM

Name	Abbrev.	Description	Units
Inspiration time	IT	Time interval between the start of inhale and the start of exhale.	seconds
Exhalation time	ET	Time interval between the start of exhale and either: • start of apnea (if apnea present) • start of subsequent breath (if no apnea present)	seconds
Total breath time	TT	Time interval between the start of inhale and the start of inhale of the following breath. This is the sum of the inhalation time, exhalation time, and apnea time.	seconds
Apnea time	AT	Time after end of exhalation where the airflow signal remained within the apnea threshold defined at the start of the analysis.	seconds
Pulmonary resistance	RES	Change in pressure divided by change in flow at the isometric volume locations: $\frac{\Delta p}{\Delta f}$	mmHg/ (liters/ sec)
Pulmonary compliance	Cdyn	Tidal volume divided by the change in pressure between exhale and inhale locations in the breath: $\frac{TV}{\Delta p}$	liters/ mmHg

If text output is being generated, an additional row will be added containing the average values of the measures. Time and count are not output as waveforms in the graph since they can be found in the horizontal axis.

Penh Analysis

Penh Analysis script assumes standard recording methodology for a full body plethysmograph. Positive flow is treated as exhalation and negative flow is treated as inhalation.

Penh Analysis extracts measures from data recorded in a full body plethysmograph. It operates on a single channel of data recorded from an airflow transducer connected to the plethysmograph. The analysis takes a single parameter: the Rt percentage. This percentage is used to locate the plateau, or “pause,” in the airflow signal. The pause begins at the time when the Rt percentage of the exhalation volume has been reached. The Rt percentage may be adjusted by the user and is set to a default of 65%. This analysis will place Inhale Start and Exhale Start events on the airflow signal. If these events are already present when the analysis starts, the user-defined inhale and exhale events will be used. This allows for the analysis to be repeated after manual inspection and correction of inhale and exhale locations and allows for different methods to be used to define the breathing boundaries.

Penh analysis will place Recovery events on the airflow channel at the time positions where the corresponding percentage of the volume has been exhaled. The percentage used for the analysis is displayed in the label of the Recovery events.

For each exhalation period, the Penh Analysis will extract the following:

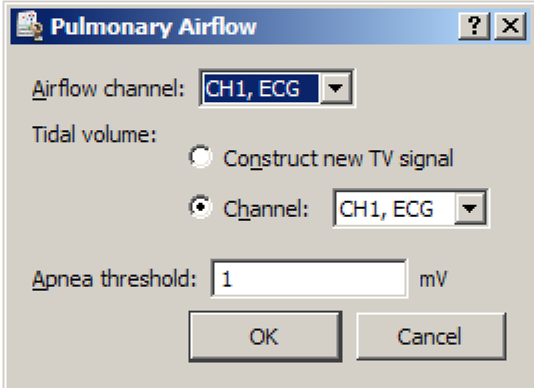
Name	***Abbrev.***	***Description***	***Units***
Cycle		Index of the exhalation cycle in the data, beginning at 1.	
Time		Starting time of the exhale for the cycle. This is the location of the Exhale Start event.	Seconds
Peak inspiratory flow	PIF	Maximum absolute airflow occurring in the inspiration cycle immediately preceding the exhalation cycle. This measure is recorded as an interval, so its value is always positive.	Airflow channel units
Peak expiratory flow	PEF	Maximum airflow during the exhalation cycle being examined.	Airflow channel units
Exhalation time	Te	Total time elapsed between the start of the exhalation cycle and the end. This is the time interval between the Exhale Start and following Inhale Start events.	Seconds
Relaxation time interval	Rt	Time required for the subject to exhale the specified percentage of the total exhaled air. This is the time interval between the Exhale Start and the subsequent Recovery event.	Seconds
Pause		Numerical factor describing the characteristics of the plateau at the end of the expiration cycle. Computed using the formula: $\frac{Te}{Rt} - 1$	
Enhanced pause	Penh	Pause scaled to be relative to the strength of the inhale and exhale. This helps take breathing variability into account. Computed using the following formula: $\frac{PEF}{PIF} * Pause$	

The Penh analysis excludes the following exhale cycles from the analysis:

- Exhale cycles that do not have a preceding inhale (may occur for partial cycles at the start of the data recording).
- Exhale cycles that do not have a corresponding recovery time (often occurs during apnea).

In addition, during periods of apnea, the analysis may produce invalid results, such as zero width recovery times. These results may be excluded from the analysis by either using waveform editing to remove apnea periods, discarding all events during apnea periods and rerunning the analysis, or deleting the corresponding rows from the Excel output.

Pulmonary Airflow



The Pulmonary Airflow analysis follows the flow conventions of the recommended BIOPAC connections for a TSD107 pneumotach or a TSD117 airflow transducer. Positive flow is assumed to indicate inhalation; negative flow is assumed to indicate exhalation.

The Pulmonary Airflow analysis extracts basic parameters from a calibrated airflow signal, such as would be recorded using a pneumotach or airflow transducer. In addition to inspiration and expiration, Pulmonary Airflow also can be used to examine apnea. Apnea is defined in this analysis as pauses in breathing that occur after an exhalation.

When performing the analysis, an airflow signal f is chosen. An apnea threshold a_f is also entered. Inhalation is defined to begin at the point where $f > a_f$. Exhalation is defined to begin at the point where $f < -a_f$. Apnea is defined to be the period between exhalation and inhalation where the flow lies within the apnea threshold: $f \in \left(-a_f, a_f\right)$. At least two consecutive samples must occur within the apnea threshold for a period of apnea to be defined. This allows for valid transitions from exhalation to inhalation to occur even if one of the samples in the transition happens to fall within the apnea threshold due to sampling.

The Pulmonary Airflow analysis will generate a tidal volume waveform if it is not present in the graph. It also will add Inspire Start and Expire Start events on the airflow signal if they are not present. New Apnea Start events will be defined each time the analysis is performed.

Individual breaths are defined as the period between consecutive Inhale Start events. Airflow units are assumed to be the standard liters/sec.

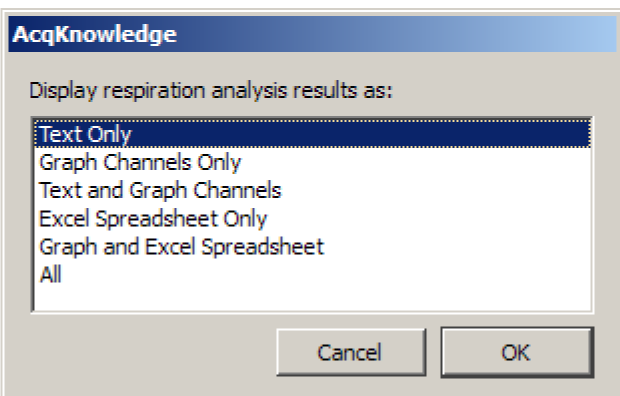
For each breath period, the analysis will extract the following:

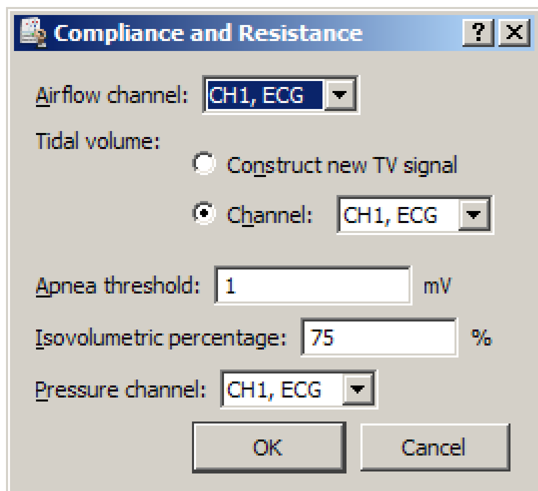
Name	***Abbrev.***	***Description***	***Units***
Cycle		Index of the breath in the data, beginning at 1.	
Time		Starting time of the inhale of the breath.	seconds
Peak Inspiratory Flow	PIF	Maximum absolute flow occurring during the inhale portion of the breath.	liters / sec
Peak Expiratory Flow	PEF	Maximum absolute flow occurring during the exhale portion of the breath.	liters / sec
Tidal volume	TV	Total volume of air inhaled during the breath.	liters
Minute volume	MV	Volume of air that would be inspired during a minute given the tidal volume and breathing rate of this breath. $TV \square BPM$	liters / minute
Breaths per minute	BPM	Breathing rate for the breath. $\frac{60}{TT}$	BPM

Name	Abbrev.	Description	Units
Inspiration time	IT	Time interval between the start of inhale and the start of exhale in the breath.	seconds
Exhalation time	ET	Time interval between the start of exhale and either: • start of apnea (if apnea present) • start of subsequent breath (if no apnea present)	seconds
Total breath time	TT	Time interval between the start of inhale and the start of inhale of the following breath. This is the sum of the inhalation time, exhalation time, and apnea time.	seconds
Apnea time	AT	Time after end of exhalation where the airflow signal remained within the apnea threshold defined at the start of the analysis.	seconds

If text output is being generated, an additional row will be added containing the average values of the measures. Time and count are not output as waveforms in the graph as they can be found from the horizontal axis.

Preferences





Spectral Subtraction

Spectral subtraction is a denoising technique that operates on data projected into the frequency domain. It is frequently used in speech analysis denoising applications. Spectral subtraction examines a reference noise signal and performs a Fourier transform to get the noise frequency distribution. To denoise a signal, the Fourier transform of the signal is performed. The noise estimate frequency distribution is then subtracted from the source signal. The resulting processed spectrum with the noise frequencies removed is then reconstructed into a time domain signal using the inverse Fourier transform.

Spectral subtraction performs noise removal on the entire channel in a single Fourier transformation, which allows for denoising where the noise is stationary; there is no provision for sliding window spectral subtraction at this time.

The spectral subtraction is performed using a formula with two adjustable parameters. Given a frequency spectrum F_{noise} and a mixed signal F_{mix}, the denoised frequency spectrum is computed using the following formula:

$$F_{denoise} = \left[F_{mix}^{\gamma} - \alpha F_{noise}^{\gamma} \right]^{\frac{1}{\gamma}}$$

where

Alpha is the “scaling factor” and can be used to adjust the strength of the noise estimate.

Gamma (γ) is the “power factor” and can be used to vary how the noise is removed.

$\gamma = 1$ allows for pure subtraction

$\gamma = 2$ allows for Euclidean distance formulas

and so on

$F_{denoise}$ that is less than zero is discarded and replaced by zero to maintain a valid set of Fourier coefficients for the reconstruction.

When spectral subtraction is being used in practice, the noise signal may not always match the length of the signals to be denoised. To define the subtraction formula, the spectrum of the noise must have the same number of points as the spectrum to be denoised. If there is a length mismatch, the noise spectrum is resampled automatically to match the length of the spectrum to be denoised. Cubic spline interpolation is used during the resampling to provide a better estimate of the overall noise spectrum.

Stim-Response

The Stim-Response analysis package can aid in analysis of stimulus-response studies. It allows for measurements to be extracted in tabular format for multiple stimulus classes. Stim-response configuration enhancements in Acq*Knowledge* 4.1 add the following functionality:

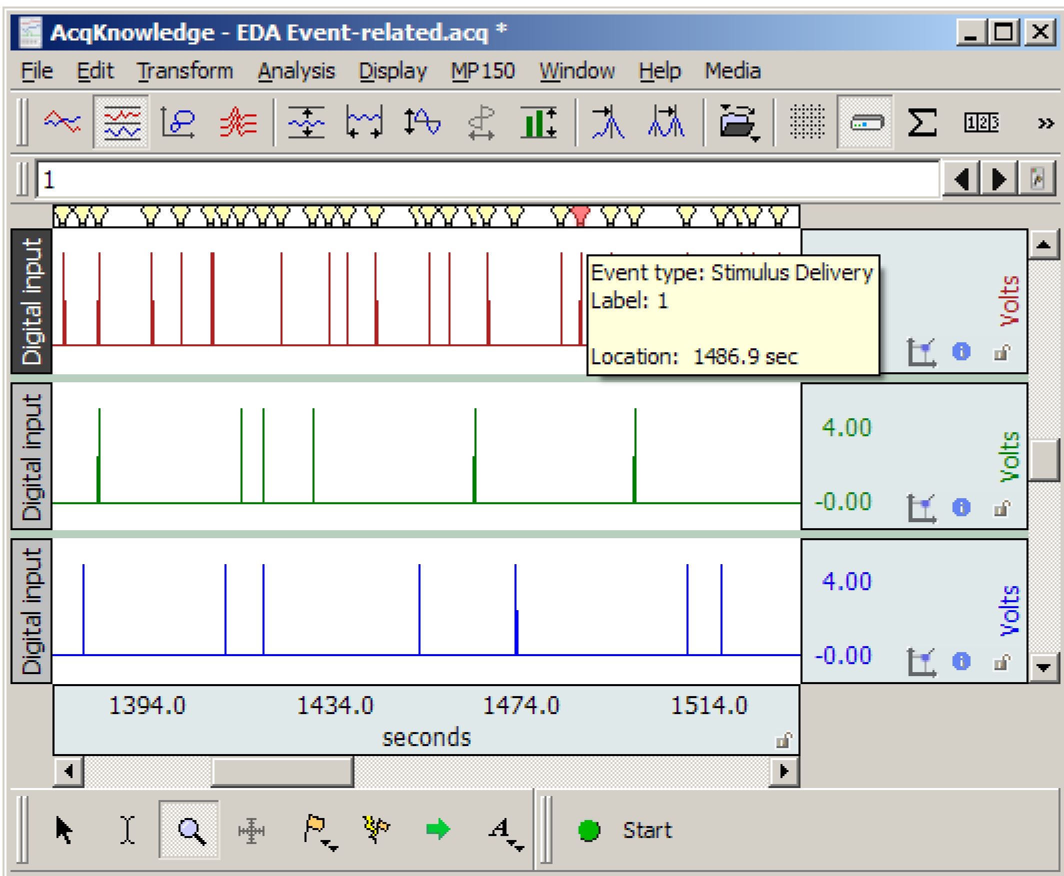
- Measurement configuration is preserved across launches of the application
- Measurement presets may be accessed directly from the specialized analysis routine
- Additional checking for invalid channels and measurement expressions that cannot be applied to the source data

The Event-related EDA Analysis routine uses the stimulus events to categorize specific and non specific responses. Responses are matched to the appropriate stimulus events using a user defined time window. See the Electrodermal Activity EDA Event-related analysis section for further information.

> *Note*: Excel spreadsheet generation is supported in Acq*Knowledge* 4.0 Windows or Acq*Knowledge* 3.9.1 Mac and higher.

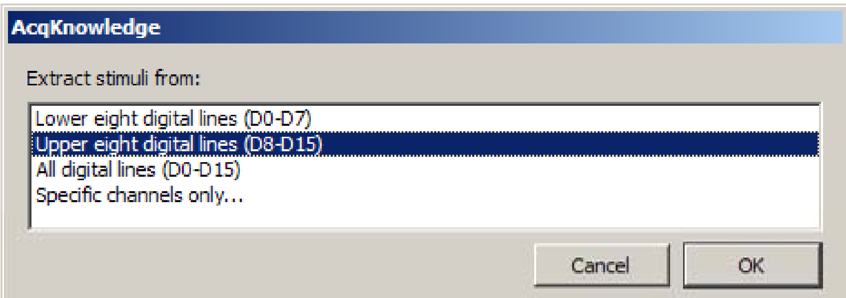
Digital Input to Stim Events

Digital Input to stim events identifies and labels stimulus events corresponding to any combination of digital inputs. A lightbulb icon is placed in the global event marker bar, the event is labeled with the stimulus event type, and the mouse-over tag includes the event time. All event information is accessible and exportable from the Event Palette.

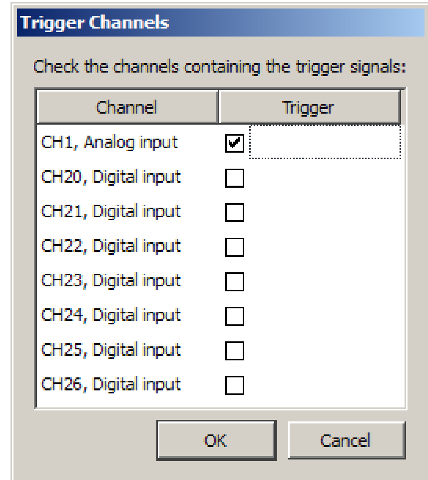


The Digital input to stim events function works with TTL trigger information coming from applications such as E-Prime®, SuperLab®, DirectRT®, MediaLab®, Inquisit®, and Presentation. It converts TTL data acquired on the digital channels of an MP device into stimulus events. The system also works with analog and calculation channel signals coming from switch transducers. Unlike TTL signals, a voltage threshold level is used to determine the transition from low to high.

This analysis option converts TTL or switch data acquired on an MP device into stimulus events. Stimulus delivery events are defined in the graph for each low to high transition of the digital data, the indications of stimulus delivery. The digital channels are interpreted as a binary number. Each stimulus event placed into the graph has the corresponding number included with its label. This allows further analysis to distinguish between different types of stimulus events by using the Cycle Detector's label matching capability.

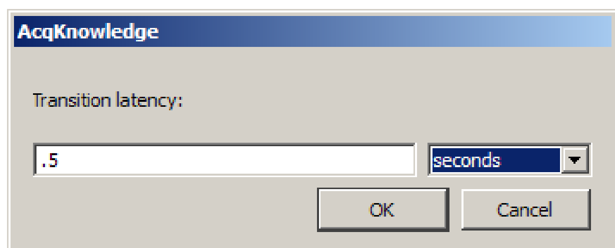


"Specific channels only" dialog

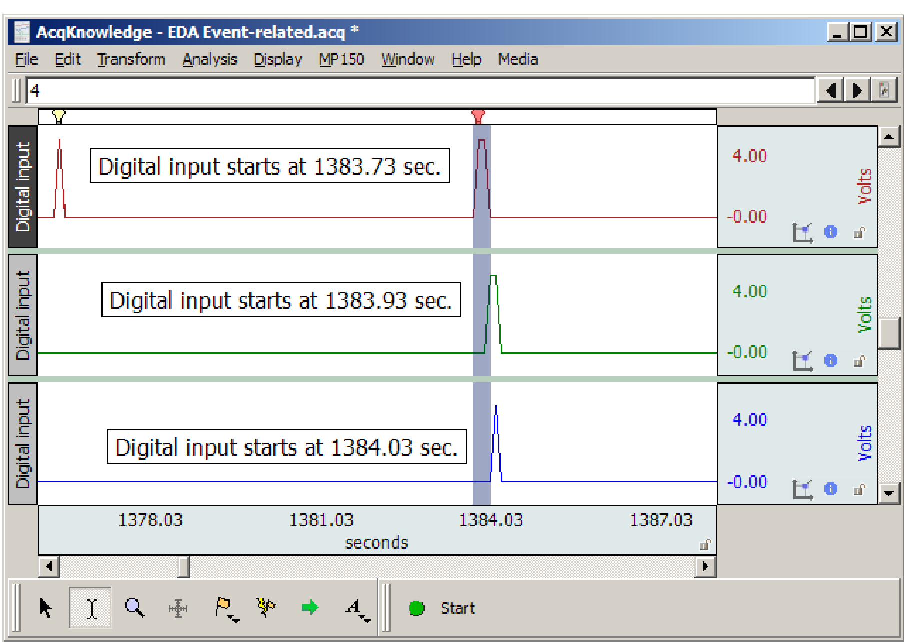


Digital line decoding can be two byte (using all 16 digital lines) or single byte (on either the low eight or high eight digital lines). Big endian bit and byte ordering are used, with digital line 0 representing the least significant bit.

When the stimulus labels are constructed, all numbers are zero-prefixed. All stimulus events will have the same number of base-10 digits with leading zeros, regardless of magnitude. This provides each stimulus event type with a unique label that can be used with the Cycle Detector (which uses substring matching).



Some systems that trigger digital lines such as parallel ports may not be able to do so instantaneously; they may require a time window before the transition from one state to another is fully complete. A "**transition latency**" time window can be given to the analysis, specified in microseconds, milliseconds, seconds, minutes, hours, or samples. If non zero, any transitions that are separated by less than this latency are treated as a single transition and only one stimulus event is inserted. The decoded value used for the transition is the maximum value observed during the transition latency window. In the following example graph, the three digital TTL inputs correspond to one event., as marked by the red icon in the global marker bar. A transition latency of .5 seconds will consider all three as part of the same event since the transitions occur within .5 seconds of each other.



Stim-Response Analysis

Stim-Response Analysis allows for extraction of measurements within fixed width intervals occurring at Stimulus Delivery events. Stimulus events must be present to perform this analysis. The Stimulus Delivery events may be defined either manually, with the Cycle Detector, or using the Digital Input to Stim Events analysis option. The information that can be extracted includes the majority of the measurements available from the graph window measurement toolbar, matching the Epoch Analysis options.

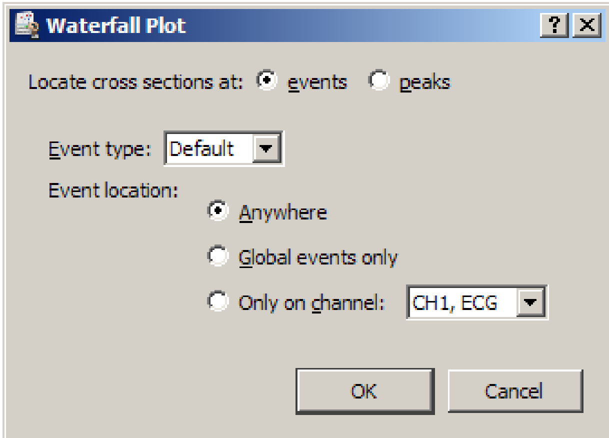
Unlike Epoch Analysis, the Stim-Response Analysis splits the analysis based upon the event labels. Stimulus Delivery events with different labels are interpreted as different stimulus types. Analysis results for each individual stimulus type are summarized in separate tables. Each independent text table has its own average of the measurements over that stimulus type.

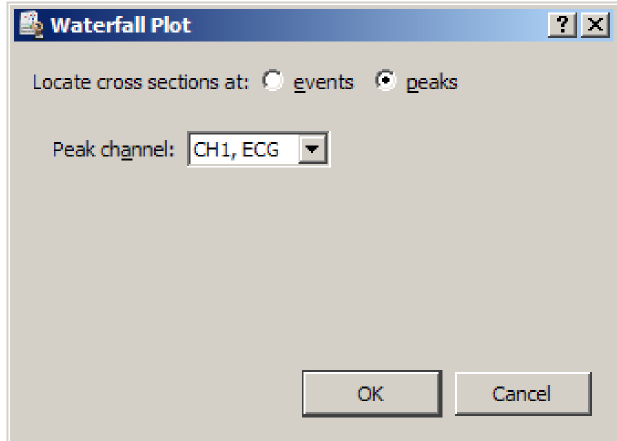
Additional options are available for positioning the fixed width interval where measurements should be made:

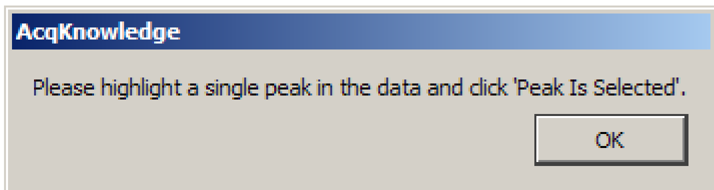
- At each stimulus event – The measurement interval is aligned so the start of the measurement matches the time of the Stimulus Delivery event.
- At fixed interval offset before or after stimulus – The measurement interval begins a fixed amount of time either before (for pre-stim studies) or after the time of the Stimulus Delivery event. This allows measurements to be made at a time relative to each stimulus onset and may be useful for measurements focusing on a specific time range (e.g. P300).
- At matching response event – This option assumes that a second set of Response events have been defined for each stimulus either manually or using the Cycle Detector. Each Stimulus Delivery event is paired with the closest Response event occurring after it. The fixed width measurement interval is aligned so the start of the measurement window is the time of this matching Response event.
  - To use the "at matching response event" window positioning option, Response events must be defined in the graph. Response events are in the "Stimulus/Response" event submenu. These events are *not* defined automatically.
    - Response events can be inserted manually into the graph using the Event tool.
    - Response events can be inserted using the event output of a data-driven Cycle Detector analysis.

Note If EDA/SCR signals are being analyzed in response to stimulus delivery, also examine the "Event-related EDA Analysis" transformation located under Analysis > Electrodermal Activity.

Waterfall Plot

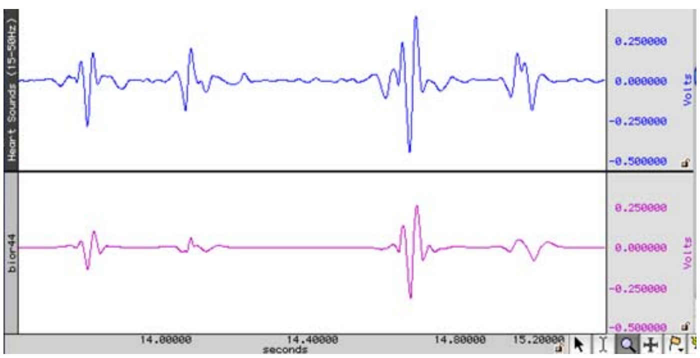






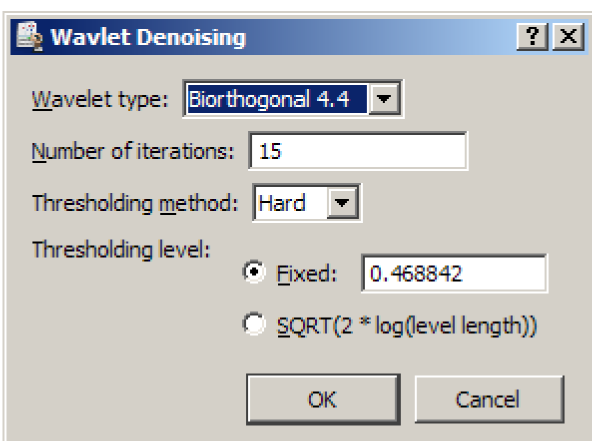
Assists in configuring the Peak Detector for 3D surface generation. These surfaces showing cycle-by-cycle data of the graph are commonly known as *waterfall plots*. Cycles are located in the graph using the same sequence of steps as the Ensemble Average transformation script. Instead of generating the averaged graph, however, a number of 3D surfaces are generated. One surface is generated for each channel that is selected by the user.

Wavelet Denoising



Sample output

Wavelet Denoising applied to heart sounds data may help clarify S_1 and S_2, as shown:



Wavelet Denoising uses the forward and reverse wavelet transformations to project source data into the wavelet domain, modify the wavelet coefficients (called "shrinking" the coefficients), and then reconstruct the data from the modified coefficients. Wavelet Denoising allows for noise to be removed from a signal while minimizing effects on portions of the signal that strongly adhere to a wavelet's shape.

To perform wavelet denoising:

1. Choose the wavelet type to use for the denoising (Biorthogonal 4.4, Symlet 4, Coiflet 6, or Daubechies 8).

Certain signals may work best with different wavelet types.

2. Enter the number of iterations to use in the wavelet decomposition.

   Different numbers of iterations will have different effects on the results.

3. Choose which type of thresholding should be used to shrink the wavelet coefficients.
   - Hard thresholding replaces coefficients below the threshold with zero while leaving all other coefficients unmodified.
   - Soft thresholding zeroes out coefficients below the threshold and subtracts the threshold for coefficients that are above it.

   Soft thresholding may be useful for reducing edge effects, but hard thresholding will affect amplitudes less.

4. Choose the threshold level to use for shrinkage.
   - Fixed threshold for all levels. If you choose a fixed threshold, an additional window will appear into which you can type your threshold.
   - Adaptive threshold level based on the number of coefficients in the DWT iteration (a VIS shrink procedure).

ECG Analysis Algorithm References

Acq*Knowledge* 3.9 software implements the open source ecgpuwave ECG boundary location software and the open source OSEA QRS detector and beat classification library for ECG analysis.

Automated ECG Waveform Boundary Location

➲ ecgpuwave ECG boundary location software

Acq*Knowledge* 3.9 software incorporates the ecgpuwave ECG boundary location software. Ecgpuwave is an implementation of a waveform boundary detection algorithm primarily developed by Pablo Laguna at the University of Zaragoza in Spain. This algorithm incorporates a variant of the Tompkins QRS detector, but contains additional rules that allow it to automatically extract the following characteristics of an ECG signal on a cycle by cycle basis: onset of P, P peak, end of P, onset of QRS, peak of QRS, end of QRS, onset of T, peak of T, and end of T.

The algorithm is tuned to human ECGs through comparison with manual classification. Particularly, it seems to be within the standard deviation of human examiners for the onset and end of T waves, a particularly difficult feature to extract from an ECG complex. It also has the ability to take multiple ECG leads into account to reduce errors and misclassifications and appears to function for one to twelve lead ECGs. The algorithm is well documented in a number of papers. This algorithm development was sponsored by several government agencies including CICYT in Spain and the NIH.

The ecgpuwave tool is distributed from the PhysioNet NIH servers (http://www.physionet.org). This is a tool written in Fortran that will read WFDB formatted files. It will then output a series of annotations in WFDB format indicating the locations of the various ECG complexes within each cycle. It also depends on another tool, sortann (available from PhysioNet), to perform post-processing. This software reads and writes PhysioBank formatted files. This tool is only available on OS X.

Acq*Knowledge* can automate the process of running ecgpuwave on source data and import its output back into Acq*Knowledge*. To run ecgpuwave on an ECG signal from within Acq*Knowledge*, first make the ECG channel the active channel and then choose Transform > Specialized Analysis > Locate ECG Complex Boundaries. Acq*Knowledge* will execute ecgpuwave on that signal and read in its waveform boundary location output, placing events on the channel. You will only be able to see this output if you have events shown.

Alternatively, you can save your file to PhysioBank format, run ecgpuwave manually from a Terminal, save the annotations to "atruth" and then reopen that PhysioBank file to see the ecgpuwave results; this is the same process that Acq*Knowledge* performs.

Source code for ecgpuwave detector is released under a GPL license and can be found on the Acq*Knowledge* CD.

OSEA QRS Detector

- OSEA QRS detector and beat classification library

AcqKnowledge 3.9 software incorporates the open source OSEA QRS detector and beat classification library.

The OSEA library is a set of routines provided by EP Limited (http://www.eplimited.com). This C++ based software library provides robust QRS complex detection and rudimentary beat classification. This library is well documented and tested. The QRS detector uses a standard Tompkins-based filtering and derivative detection algorithm and has been in development for about 15 years; the beat classifier has been developed for about a year or two. This algorithm development is sponsored by the NIH.

This algorithm is fairly robust against arrhythmias, baseline drifts, discontinuities, and other artifacts in the ECG signal. It achieves a 90% success rate on identifying QRS complexes on sample arrhythmia databases. The algorithm is tuned to human ECGs.

The QRS detector is optimized for 200 Hz sampled data. If the sampling rate is lower or higher, data will be internally resampled to 200 Hz before processing. The sampling rate difference may result in slightly different placement of beat events for different sampling rates.

QRS detection can be performed by selecting the desired channel of ECG data and choosing Transform > Specialized Analysis > Detect and classify beats. Acq*Knowledge* will execute the OSEA beat detector on the source data and output a sequence of events on that channel of ECG data. You will only be able to see this output if you have events shown.

Source code for the QRS detector is released under an LGPL license and can be found on the Acq*Knowledge* CD.

Open Source Licensing

The ecgpuwave and OSEA algorithms are available as open source, which means that their source code is publicly available. The source code can only be used, however, under conditions of their licenses.

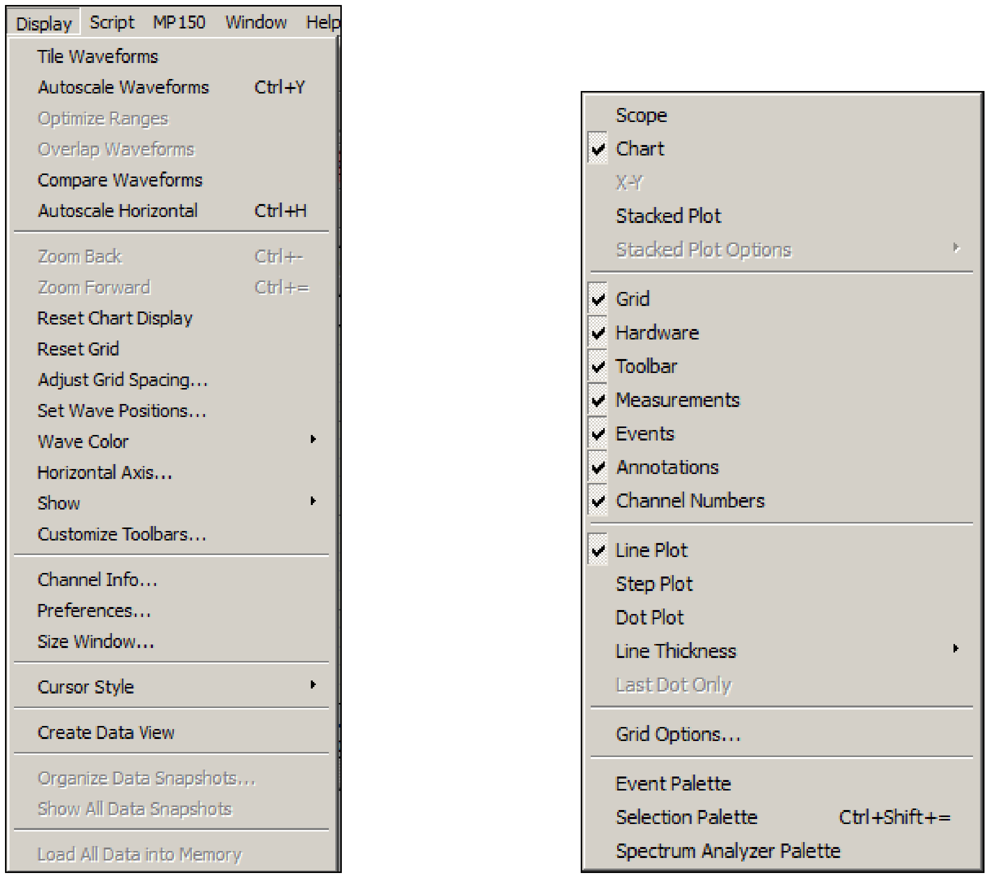
- ecgpuwave is under the GPL license
- OSEA is under the LGPL license

For the full text of both licenses, visit the Free Software Foundation (http://www.fsf.org).

Chapter 18 Display menu commands

Overview

The Display menu includes a number of features that control how the waveforms appear on the screen and how much data is displayed at a time.



Display menu and Show sub-menu

Although these options change the appearance of the data, they do not change the data itself. In other words, changing the color of a waveform or showing only a portion of the data on the screen will not alter the data stored in the file.

See the following shortcut options for Display menu commands:

- Toolbar shortcuts, page 55
- Context-sensitive shortcuts—page 68

Tile Waveforms

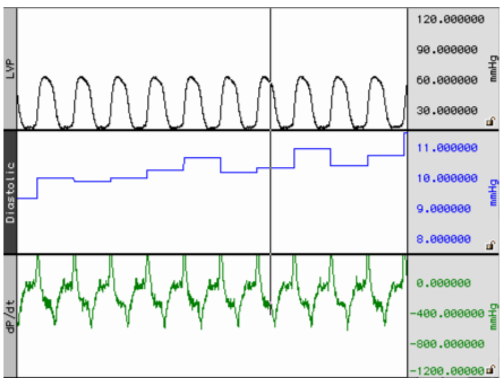
Tiling is an operation performed on all waveforms to visually separate them on the screen. Tile Waveforms adjusts the vertical offset to center waveforms in the display; if there are multiple waveforms displayed in chart mode, the waveforms will be centered in their “tracks.” Tiling does not adjust the scale of the waveforms; it only affects the midpoints of the visible portion of the waveform. Tiling does not affect the vertical scale factor previously set for each channel (whereas Autoscale may affect the vertical scale factor as well as the offset).

In Scope mode, tiling staggers the midpoint of the channels to visually separate them on the screen while maintaining their scales. In Scope mode, waveforms are spaced evenly along the vertical axis of the screen, and each waveform is centered vertically in its division.

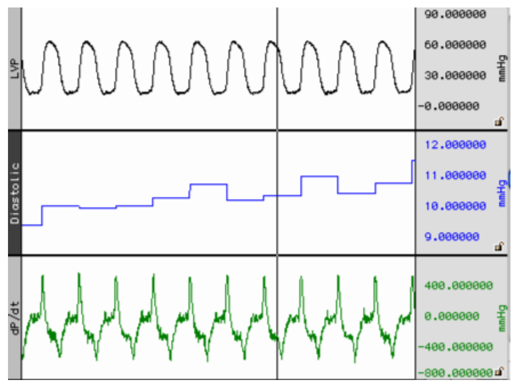
Choosing Tile Waveforms will center the waveform in the display by adjusting the vertical offset of the selected waveform. If there are multiple waveforms displayed in chart mode, the waveforms will be centered in their “tracks.” To apply tiling only to the selected waveform, hold down the CTRL key on Windows or the Option key on Mac OS X before selecting Tile Waveforms. In scope mode, waveforms are spaced evenly along the vertical axis of the screen, and each waveform is centered vertically in its division. Tiling does not affect the vertical scale factor previously set for each channel (whereas Autoscale may affect the vertical scale factor).

When grids are locked, tiling will retain the appropriate heights and percentages.

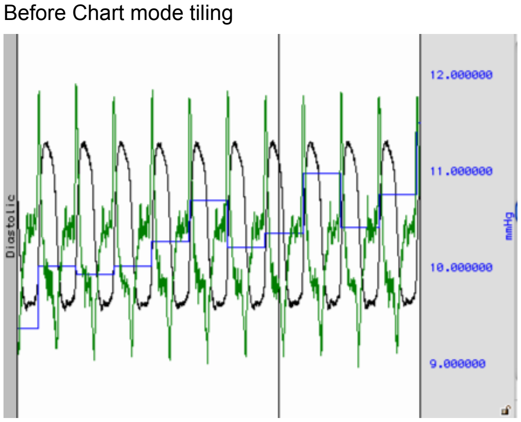
When grids are unlocked, the scale may be slightly larger in order to optimize the tick marks displayed on the vertical axis.



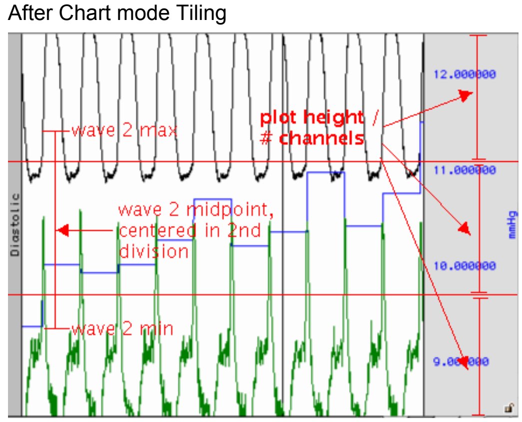
Before Chart mode tiling



After Chart mode Tiling



Before Scope mode tiling



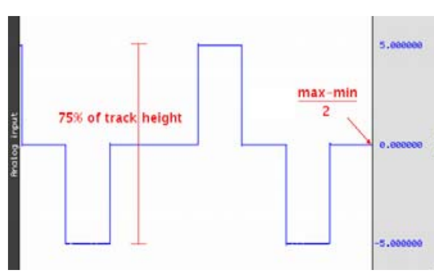
After scope mode Tiling (red lines for illustration only)

Note that the waveforms are centered relative to the horizontal divisions of the plotting area; the range and midpoint of the second waveform (blue square wave) are indicated in the figure above.

Autoscale Waveforms

The primary use of Autoscale is to make all of the data of the channel within the current time range visible on the screen.

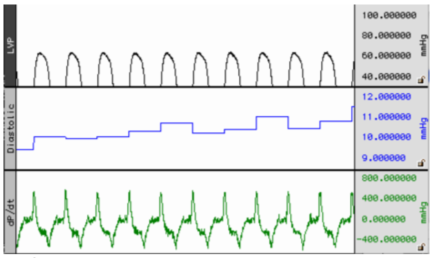
When Autoscale Waveforms is selected, Acq*Knowledge* determines what the “best fit” is for each displayed waveform. The percentages and midpoints are identical whether grids are locked or unlocked.



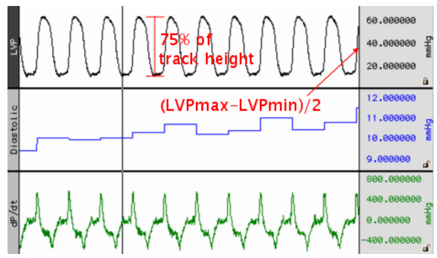
The software adjusts the vertical offset so that each channel is centered in the window (or within the channel track in chart mode) and adjusts the units per division on the vertical axis so that the waveform fills approximately two-thirds of the available area. In chart mode, the waveforms are autoscaled to fit their sections. In scope mode, the screen is evenly divided into horizontal “bands” and each waveform is scaled to fit the division without overlapping.

➲ The autoscaling algorithm for Chart mode and X/Y mode is:

1. Find maximum value of the channel in the time area, *max*.
2. Find minimum value of the channel in the time area, *min*.
3. If grids are locked, adjust scale such that *max-min* occupies 75% of the channel's track in Chart mode, or 75% of the entire plotting area X/Y mode.
4. Adjust the midpoint so (*max-min*)/2 is at the vertical center of the channel's track in Chart mode, or vertical center of the entire plotting area in Scope and X/Y modes.



Before autoscaling LVP channel



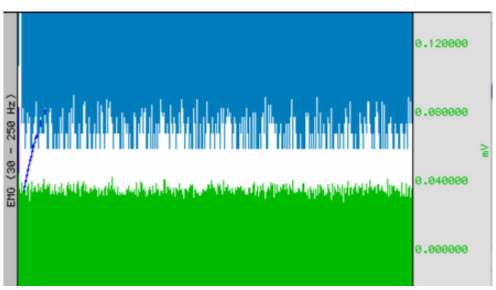
After autoscaling LVP (red lines for illustration only)

➲ The autoscaling algorithm for Scope mode is:

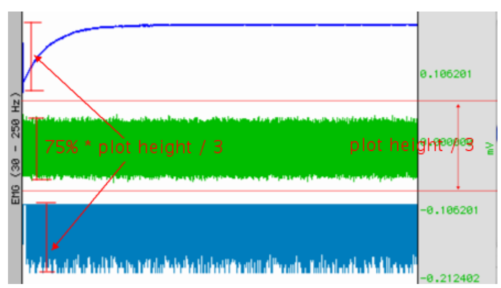
1. Divide the plot height into *m* equal sections of height *h* each.
2. Assign each visible channel to one of these plot sections.
3. If grids are locked, Scale the waveform such that the range between the max and min values will occupy 75% of *h*.
4. Place the midpoint between the max and min at the center of the waveform's section.

   In scope mode, the screen is evenly divided into horizontal “bands” and each waveform is scaled to fit the division without overlapping.

   Note: Autoscaling a single channel in Scope mode results in that channel occupying 1 / (num_visible_channels) of the overall waveform plotting area. It will be autoscaled into the topmost division of the screen.



Before autoscaling in Scope mode

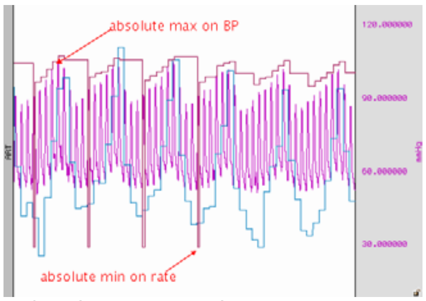


After autoscaling in Scope (red lines for illustration only)

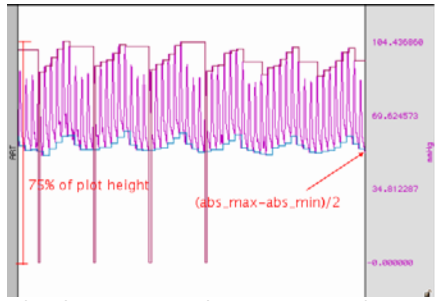
Overlap Waveforms

Overlapping waveforms places all of the waveforms at the same scale and midpoint so that the plotting location of a specific voltage on screen is at the same spot for every channel. Overlapping is useful for examining closely associated waveforms, such as the calculated diastolic, systolic and mean calculation channels “overlapped” with the raw blood pressure waveform from a continuous blood pressure signal.

In scope mode, when Overlap Waveforms is selected, the waveforms are “overlapped” into one screen. All of the currently displayed waveforms are arranged in the graph window with the same vertical scale and offset so all the displayed waveforms will fit on the graph; their magnitude reflects their size relative to the other waveforms. The overall chosen scale for all the displayed waveforms will be a function of the pk-pk value of the combined waves



Before Overlapping in Scope mode

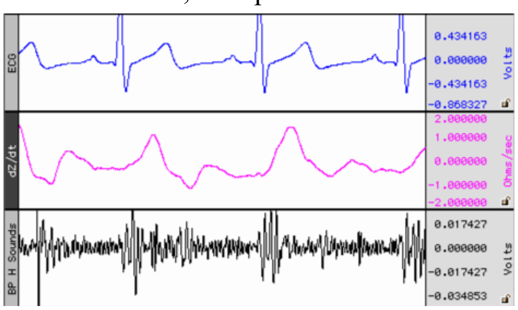
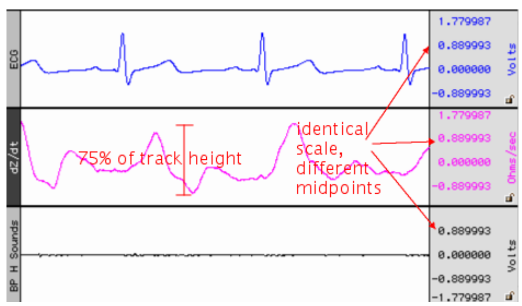


After Overlapping in Scope (red lines for illustration only)

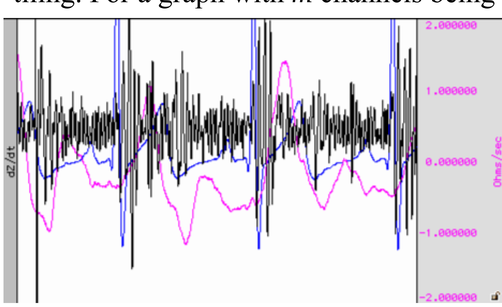
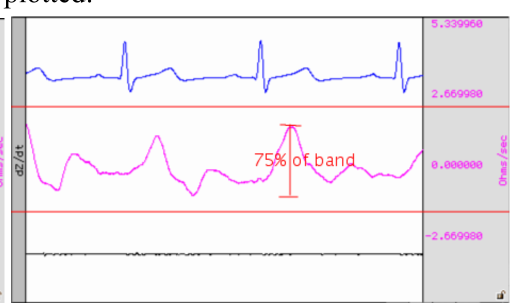
Compare Waveforms

Compare Waveforms displays all of the channels with the same amplitude scale. Compare Waveforms automatically sets the vertical scale to be the same for all channels and adjusts each channel offset so that all displayed waves are centered in the display. The scale for all the displayed channels is determined by the channel with the largest pk-pk range in the display interval. Compare Waveforms is useful for gauging the relative amplitudes of a number of channels by placing them all on the same amplitude scale and discounting the effect of waveform offset (or baseline).

➲ In Chart mode, Compare Waveforms functions on each channel in its track.

➲ In Scope mode, the channel scaling is similar but disperses the channels through the plot area similar to tiling. For a graph with *m* channels being plotted:

Autoscale Horizontal

The Autoscale Horizontal command is a convenient way to display the entire data file (in terms of duration) on the screen. When this is selected, the display will be adjusted so that the duration of the entire waveform fits in the graph window. For long waveforms, this can take some time to redraw.

You cannot undo the Autoscale Horizontal function with Edit > Undo, but you can use the Display > Zoom back command to revert to the previous display settings.

Zoom Back / Forward

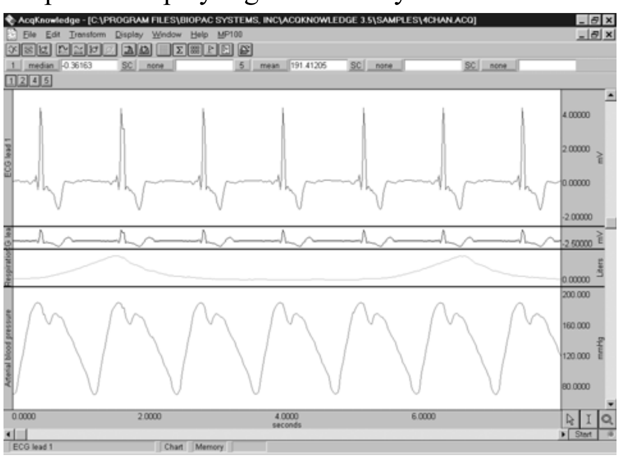
Zoom functions can affect the horizontal scale, the vertical scale, or both. Zoom restoration is functional for the Zoom tool, Autoscaling, and the Tile, Overlap, and Compare Waveform options. Zoom scales are stored until another zoom function is performed. For instance, you cannot Zoom back and then use the Zoom tool and expect Zoom back to take you back two scale levels.

- Zoom Back will restore settings one level at a time; you can repeat this selection to restore the original zoom scales. Essentially, Zoom back acts as an “undo” command for the zoom forward command and any other function that changes the amount of data displayed (either in terms of time or amplitude)
- Zoom Forward will redo a zoom function after it has been undone; you can repeat this selection to restore the latest zoom scales.

Zoom functions will work without limitation, until another Zoom is performed.

Reset Chart Display

The Reset Chart Display option will redistribute the chart displays evenly after you have changed the boundaries so that each channel’s vertical size is the same. This function, which only works in *Chart Mode*, can be useful if you need to expand a display region for analysis and then return to the original display.



Before Reset Chart Display

…and after

Reset Grid

To return to the original grid, choose "Display > Reset Grid." This will reconstruct the default, unlocked grid of four divisions per screen with solid light gray grid lines.

Adjust Grid Spacing

To modify the horizontal and/or vertical grid spacing, choose "Display > Adjust Grid Spacing." This will generate a dialog for you to modify the locked axes of the selected waveform. *See page 76 for details.*

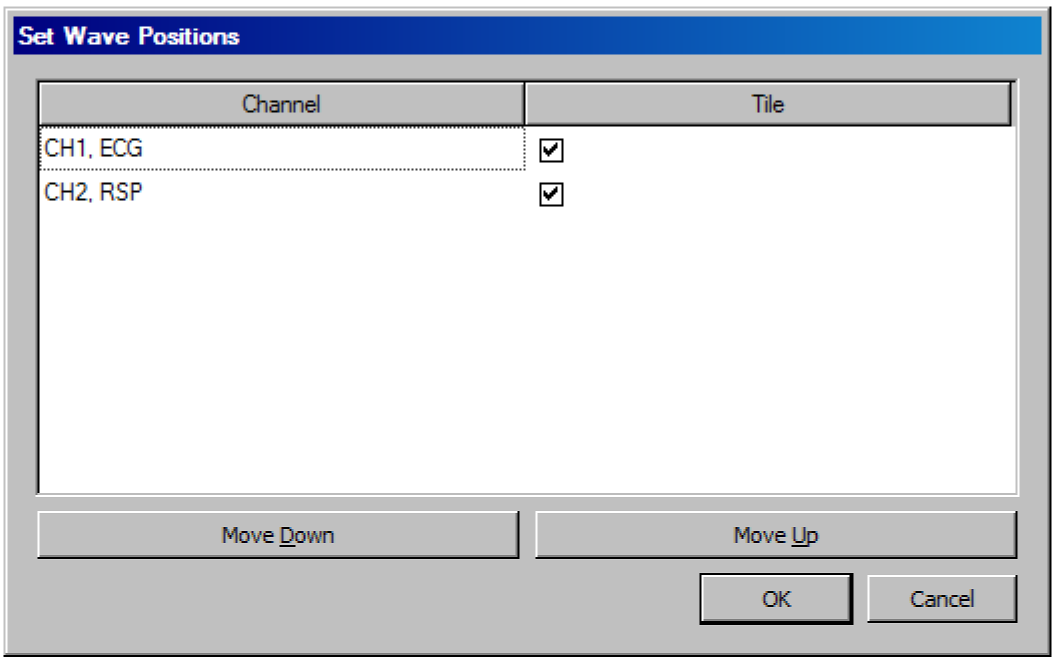
Set Wave Positions...

By default, channels are arranged on the screen based on their channel numbers, with the lower number channels being displayed at the top of the screen. You can change the ordering so that waveforms are placed in an arbitrary order.

- In chart mode this will result in vertical ordering of the individual waveforms.
- In scope mode this will result in vertical ordering of the individual waveforms after a tiling or autoscaling operation.

In addition, in the waveform positioning function, you can set any waveform to ignore the autoscaling and tiling functions. This can be important if you have some waveforms which you don't want autoscaled with others.

The waveform positioning function is selected through the Set Wave Position in the Display menu. The following dialog will then appear, with a scrolling list of all stored channels:



If you have more channels than displayed, you can scroll through the list by clicking on the vertical scroll bar at the right. The list will scroll if you move past the top or bottom when clicking and dragging the waveform positions.

The "Tile" checkbox to the left of each channel enables tiling and autoscaling for each channel when checked. Click the checkbox to toggle the enable.

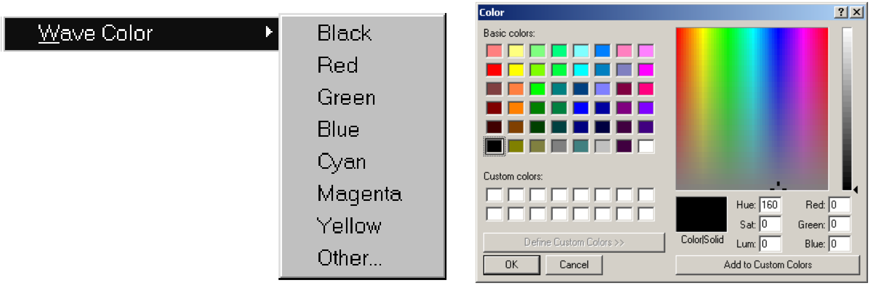
The on-screen position of the waveforms is the same as the ordering shown in the above dialog (from top to bottom). You can reposition the waveforms by reordering the channel labels as they appear in this dialog. To change the order of any waveform, select the channel label (e.g., CH1, ECG) and then click the Move Down or Move Up button. Repeat this operation until the waveforms are ordered the way you want.

- Click OK to apply your selected order to the display screen.
- Click Cancel to revert all waveform positions to those set before the dialog was opened.

Wave Color

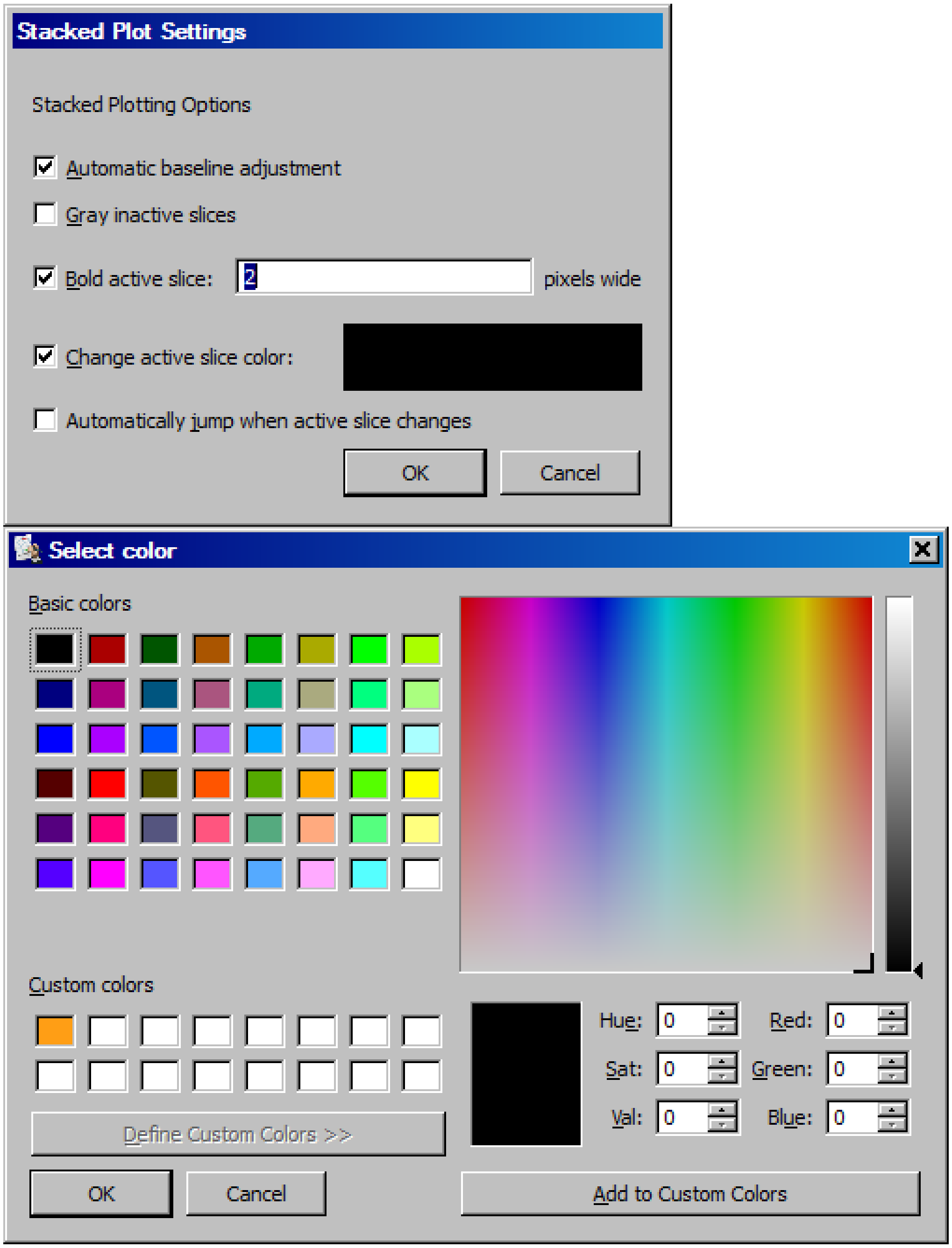
Select Wave Color and then set the desired color to discriminate between waveforms. In scope mode, the vertical scale, channel text, channel units and measurement popup menus take on the same color as the selected waveform. When adding new waveforms, Acq*Knowledge* assigns waveform colors in the following order: black, red, blue, green, cyan, and magenta.

You can assign new colors to waveforms by choosing the menu selection Display > Wave Color



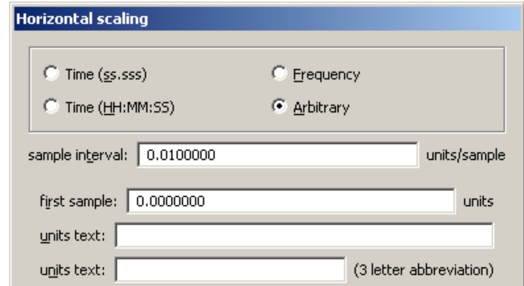
Or, you can click the right mouse button to bring up a menu, select Color, and then select the desired waveform color from the color palette menu. Depending on the type of graphics adapter on your computer, you may or may not be able to choose “Other” to display a palette of color options.

Active Slice Color



To change the Active Slice Color in Stacked Plot mode (see page 41), use Display > Show > Active Slice and then select Drawing options.

Horizontal Axis

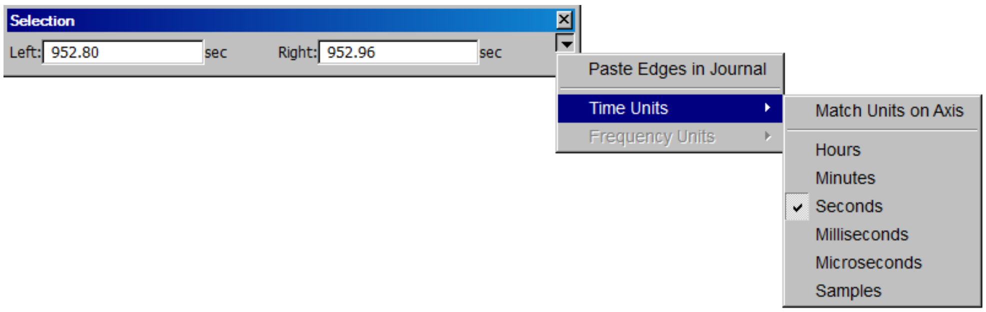


Horizontal Axis generates the Horizontal Scaling dialog. Set the axis in terms of time, frequency, or arbitrary units, and set the horizontal sample interval (the amount of time between two sample points) and the first sample (sample offset).

Time domain scaling has two options to store and display data:

- **(ss.sss)** —absolute seconds; the time scale for an event occurring 30 seconds into the record would be 30.00 seconds
- **(HH:MM:SS)** —hours:minutes:seconds; the time scale for the same event would be 00:00:30.

You can set Time Unit precision via Display > Show > Selection palette; press Enter (return) to accept changes.



Setting the horizontal **Frequency** allows output from a spectrum analyzer or plots data from a Fourier analysis or other data with a frequency base (rather than a time base). As with the time options, this feature is typically used for importing text files from other applications. For instance, if you were importing a text file with 1,000 sample points that covered a frequency range from 0 Hz to 100 Hz, you would want to set the interval to 1000 Hz/100 samples, or 0.1 Hz per sample in the box to the left of the interval text box. Similarly, if the frequency range was 20 Hz to 100 Hz, you could set the offset to 20 Hz. You can attach arbitrary base units to the data (rather than a time or frequency base). This might be useful for data collected from a gas chromatograph. When the horizontal axis corresponds to wavelength, and the data consists of 100 samples covering a range from 1 to 10 Angstroms, the interval should be 0.1 units per sample.

Arbitrary units are generally useful for changing the time base (or other horizontal scale) of data that has been imported into Acq*Knowledge* as a text file. For instance, if you want to analyze data imported from a text file that contains 30 seconds of data that was collected at 100 samples per second (100 Hz), the first step would be to open the file (following the directions on page 239).

When arbitrary units are selected, two additional text boxes appear at the bottom of the dialog. The upper Units text box is used to provide a name for the horizontal scale units (in this case, Angstroms), and the lower Units text box is used to provide an abbreviated label for the horizontal units (i.e., Ang).

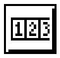
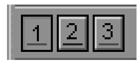
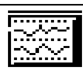
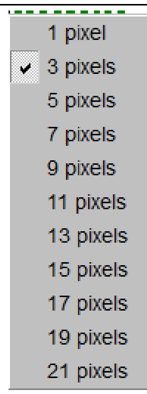
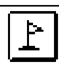
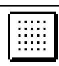
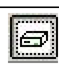
By default, Acq*Knowledge* assumes that the data was collected at 50 Hz, and would therefore plot the data so that a 60 second record was displayed that appeared to be collected at 50 samples per second. To change this to reflect the rate at which data was actually collected, you would change the sample interval box in the horizontal scaling dialog. When data are displayed on a 50 Hz time base, the sample interval will read 0.0200000 seconds per sample. This means that there is a 0.02-second "gap" between sample points in the record. To display data at 100 samples per second, change the interval to 0.01 seconds per sample.

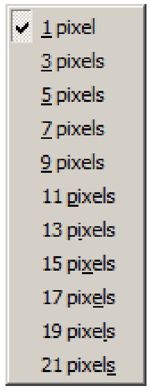
To determine the sample interval for other sampling intervals, divide 1 by the rate at which data was sampled (in terms of samples per second). Thus, a sampling rate of 0.5 Hz would translate into a sample interval of 2.00 seconds between samples, and data collected at 100,000 Hz (100 kHz) would have an interval between sample points of 0.00001000 seconds.

> TIP: To confirm that Acq*Knowledge* is storing data in the same time base it was collected in, choose Statistics from the Display menu. This will generate a dialog that describes (among other things) the sampling rate Acq*Knowledge* uses in analyzing the data. Once data has been saved as an Acq*Knowledge* file, time base information is automatically saved along with the data.

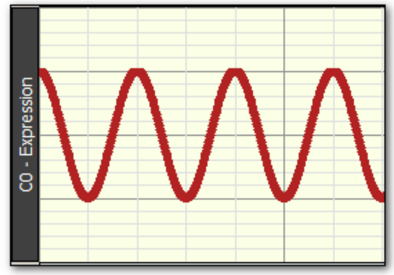
Show

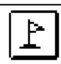
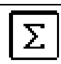
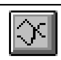
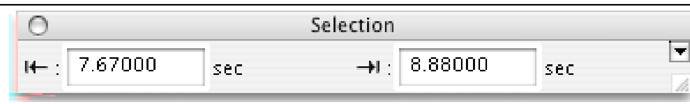
Selecting Show from the Display menu generates a submenu that allows you to control a number of data display options and what additional information is displayed in the graph window. To enable an option, select it from the submenu; a bullet (•) or checkmark appears next to the menu item when it is enabled. The three display modes and the two plotting modes are mutually exclusive, but the remaining items can be enabled independently.

Show Option	Shortcut	Explanation
Channel numbers		When the Channel numbers option is selected, the channel boxes appear just above and below the graph area.  Channel boxes with Channel 1 selected These boxes are useful for selecting channels and "hiding" channels by positioning the cursor over the channel box, holding the ALT key on the Windows or the Option key on the Mac, and clicking the mouse button.
Annotations		Toggle show/hide of text annottaions.
Chart		Activates the Chart display mode (see page 39).
Dot plot		Dot Plot allows you to view data in a "dot" format. The software will create user-defined, discrete points that map out the selected waveform. This is often useful for demonstrating the concept of discrete digital sampling by dividing the waveform up into data points or "dots."
Dot size		 Dot size is enabled after Dot Plot is selected. Dot size specifies how large each dot will be. Each dot is measured by the number of monitor pixels it occupies.
Events		Enables Event display. See page 208 for Events.
Grid		Superimposes a Grid on the graph window (see page 51). To change grid precision, use the axis scaling dialog of the horizontal or vertical axis.
Grid Options		Activates the Grid Options dialog (see page 78)
Hardware		Show/Hide Hardware "Connected to:" dialog in the graph display; includes network access.
Journal		Activates the Journal (see page 52).
Last dot only		Plots only the most recently acquired data point. This is most useful when viewing data as it is being collected and when this data is displayed in X/Y mode.
Line plot	Right-click menu	Connects each sample point with a line to create the waveform. Waveforms that are displayed in line plot mode match a true analog plot (as closely as possible). This is the default display mode for most waveforms, except histogram plots, which are displayed in Step Plot mode (see 296). You can change line options by clicking the right mouse button, which will generate a menu displaying several commonly used features.

<table>
<tr><th>Show Option</th><th>Shortcut</th><th>Explanation</th></tr>
<tr><td>Line thickness</td><td></td><td>


Line thickness is enabled when Line or Step plot are enabled. Use to specify the plot thickness in pixels. (AcqKnowledge 4.2 and higher)



Sine wave set to thickenss of 5 pixels
</td></tr>
<tr><td>Markers</td><td></td><td>Displays the marker/event region at the top of the graph window, along with any markers/events associated with the data being displayed and the marker/event tools. See page 213 for Event details.</td></tr>
<tr><td>Measurements</td><td></td><td>Displays the measurement popup menus and windows above the graph window (see pages 50 and 87).</td></tr>
<tr><td>Scope</td><td></td><td>Activates the scope display mode (see page 39).</td></tr>
<tr><td>Selection Palette</td><td></td><td>


Many of the tools within the AcqKnowledge environment are based around the selection. The selected range of data in the graph is used as the source for measurements, waveform editing, transformations, and other operations. The Selection Palette is a floating dialog that can be used to precisely enter the selection.

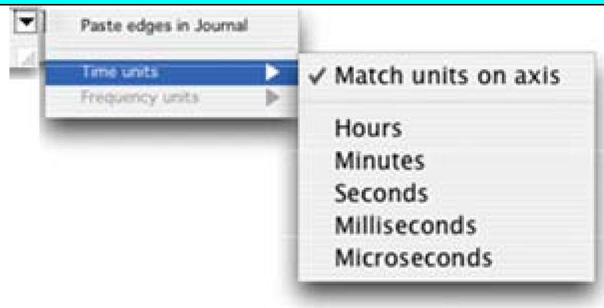
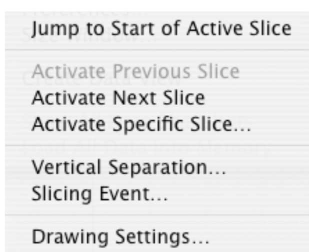
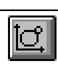
The Selection Palette can be used to adjust the selection at times when it is not possible to use the selection tool in the graph window, such as when transformation dialogs are being displayed for the graph.
The selection palette offers a way to change the selected area without having to cancel the transformation setup and lose any parameters typed in the dialog.

To display the Selection Palette, choose Display > Show > Selection Palette. This small floating dialog contains two edit fields that display the location of the left and right edges of the selection using the measurement units currently displayed in the horizontal axis. As the selection is changed, the new selection boundaries are shown.

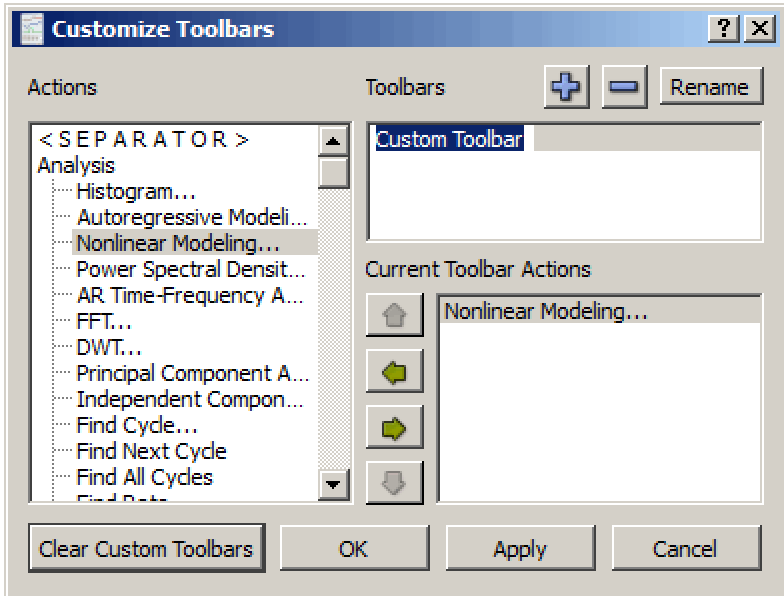
The Selection Palette also can be used to manually type in the edges of the selection. Double-clicke of the edges and type in the new horizontal position of the edge of the selection. Press “Return” to adjust the selection to that time location and update measurements and the visible display on the screen.

When a graph is displayed in X/Y mode, the Selection Palette can be used to adjust the range of data that is plotted on the screen. Limiting the time range can be useful for generating X/Y plots for different intervals of the graph that can then be compared with each other, such as examining PV loops from different time periods of a recorded signal.

Click the small arrow in the top right of the selection palette for the following additional options:
</td></tr>
</table>

Show Option	Shortcut	Explanation
		 • **Paste edges in Journal**—This option pastes a line of text into the Journal that includes the left and right edge measurements of the selection. • **Time units**—Use this submenu to change the time units used in the selection palette. The following time units are available: Match units on axis; Hours; Minutes; Seconds, Milliseconds, and Microseconds. The Time units submenu will be dimmed unless the graph displays time/arbitrary measures). • **Frequency units**— Use this submenu to change the frequency units used in the selection palette. The following frequency units are available: Match horizontal axis, Kilohertz, Hertz, and Millihertz. The frequency submenu will be dimmed unless the graph displays frequency-based measures. ***Note*** Changing time/frequency units in the selection palette can be helpful during zoom operations when the units displayed in the horizontal axis may not be the most convenient for inputting new selection boundaries.
Spectrum Analyzer Palette		Provides a dynamic display of the frequency decomposition of data, in real time or post-acquisition. See page 416 for details.
Stacked Plot Options		Displays options that can help visually distinguish the active slice from other slices being drawn in Stacked Plot mode. See page 42 for details. 
Step plot		Displays waveforms in a "step" plot, meaning that the lines connecting sample points are drawn either vertically or horizontally. Step plot is most useful for displaying histograms and similar plots, but since it displays data much as it appears to a digital processor (like the MP), it can also be useful for examining the effects of various sampling rates. NOTE: Step plot is mutually exclusive of line plot.
Toolbar		Displays the toolbar (shortcut) icons across the top of the display (see page 55).
X/Y		Activates the X/Y display mode (see page 39).

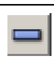
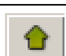
Customize Toolbars



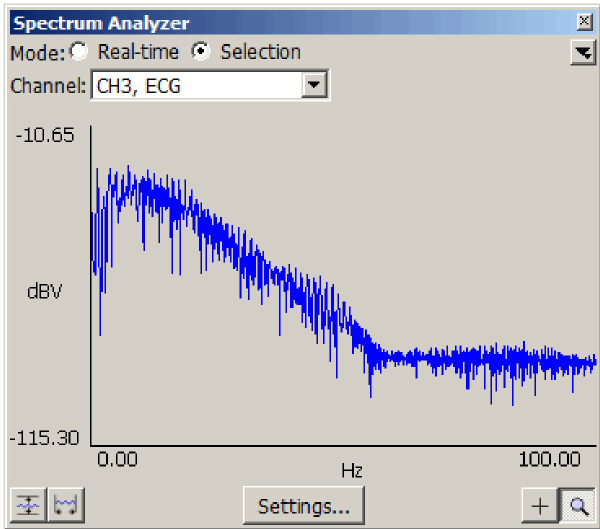
Use this feature to create custom toolbars for easy access to post-processing Analysis and Transform actions. Toolbars are dockable and custom toolbar placeholders can be named independently of toolbar actions.

- **Actions** – Menu list of available Analysis and Transform functions
- **Toolbars** – List view of custom toolbar placeholders

Current Toolbar Actions – List view of available actions from Analysis and Transform menu

Button	Function	Explanation
	Add toolbar button	Adds placeholder for new toolbar. (More than one toolbar action can be grouped under one placeholder).
	Remove toolbar button	Removes placeholder for toolbar.
Rename	Rename toolbar button	Allows existing custom toolbar name to be edited.
	Up arrow	Moves a toolbar action up the list.
	Left arrow	Removes a toolbar action from the list.
	Right arrow	Adds a toolbar action to the list.
	Down arrow	Moves a toolbar action down the list.
Clear Custom Toolbars	Clear button	Removes all toolbars from Toolbars and Current Toolbar actions list.
OK	OK button	Enforces addition or removal of toolbars from list or application toolbar region.
Apply	Apply button	Applies changes without closing Customize Toolbar window.
Cancel	Cancel button	Dismisses any toolbar changes without applying.

Spectrum Analyzer Palette



Spectrum Analyzer breaks time domain signals into their respective frequency components to provide a dynamic display of the frequency decomposition of data, in real time or post-acquisition. Spectra can be generated in real time based on the most recently acquired data or post-acquisition based on the selected area of a saved data file.

- Spectrum analyzers can be useful for locating and correcting noise sources in a system as well as other frequency domain analysis.
- The spectrum analyzer displays the FFT of a portion of data of a single channel; FFT is preferable over Power Spectral Density as the averaged periodogram approach used by PSD is effective only over larger portions of data.
- Other off-line spectral analysis tools include the FFT and Power Spectral Density transformations.

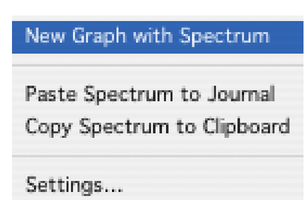
The spectrum analyzer applies to all graph windows displaying data in the time domain. Viewing the underlying time domain data at the same time as the spectral information also provides useful visual feedback with regards to signal quality. The palette allows for continuous availability of the spectrum analyzer across multiple graphs and for positioning alongside original data. The channel is always indicated by the popup menu within the spectrum analyzer itself. The graph whose data is analyzed will always be the topmost graph; this is the graph whose window is highest in the Z ordering.

Mode:

Real-time Analyzes the most recently acquired data in a graph. The analyzer generates full FFT output so, in linear units, it is the regular FFT multiplied by two. The analyzer extracts the spectrum based on a sliding window of samples at the tail end of the signal and periodically refreshes the spectrum plot during acquisition. The analyzer uses a fixed width window size. The first spectrum will be generated after the number of samples needed to fill the initial window has been acquired. If no data is being acquired, the analyzer will not display any frequency information and will appear to be off.

Selection Analyzes the highlighted section of the active channel of a saved graph (post-acquisition). Measurements derived from data on the selected area are useful tools for quickly comparing different portions of data. Choose a specific channel to analyze or “SC” to use the current active channel. Window size does not need to be specified for this mode; the closest power of two above the number of samples in the selected area will be used and padding will be applied in the method specified.

Palette popup  (upper right) Displays the spectrum analyzer palette popup menu for performing other operations on the spectrum including extracting the spectrum to a new graph window and copying spectrum data to the clipboard or journal. Options are dimmed if there is no spectrum available.



New … New Graph with Spectrum constructs a new graph window with the contents of the spectrum. This allows for more detailed examination of the spectrum than is possible with the tools in the spectrum analyzer palette.

Paste… Paste Spectrum to Journal makes a textual representation using the current Journal preferences and copies the text into the graph journal of the graph whose data is being analyzed. This will prompt to create a journal if none exists.

Copy… Copy Spectrum to Clipboard makes a textual representation using the current Journal preferences and copies the text to the Clipboard.

Settings… Displays the spectrum analyzer settings dialog. Equivalent to using the Settings button at the bottom of the palette; see Settings below for details.

Channel Indicates which channel of the hardware setup or graph is being analyzed. The “Channel” popup menu contents vary with the analyzer mode:

Real-time Channel popup menu lists active channels whose “Acquire” checkboxes are checked in MP150 > Set Up Channels. The channels will be listed as “{A,D,C}{0-16}, *chan_title*” where chan_title is replaced with the manually entered title in the channel setup window.

Selected The channel popup menu matches the channel menu of measurements in the topmost graph window. The menu starts with “SC, Selected Channel” which, when chosen, uses the data of the active channel of the graph. The remainder of the menu lists the channel numbers and labels of the channels within the topmost graph.

Plot display Plot of the spectrum of the corresponding data.

- Vertical axis units match the source channel (displays either “dbV” or linear)
- Horizontal axis displays frequency and is always displayed in “Hz.”

If there is a valid data selection that can be used to compute a spectrum, the spectrum will be displayed in this area. If there is no valid data selection, no axes will be displayed and the plot will be replaced with the text “Not Available”. The following conditions cause spectra to be unavailable:

- graphs that contain no data (either no channels or only empty channels)
- graph is being displayed in XY mode
- graph uses either frequency or arbitrary units for its horizontal axis

When operating in selected area mode, the following additional conditions also cause spectra to be unavailable:

- selection contains no data on the active waveform
- selection is a single-point selection (not enough data to compute FFT)

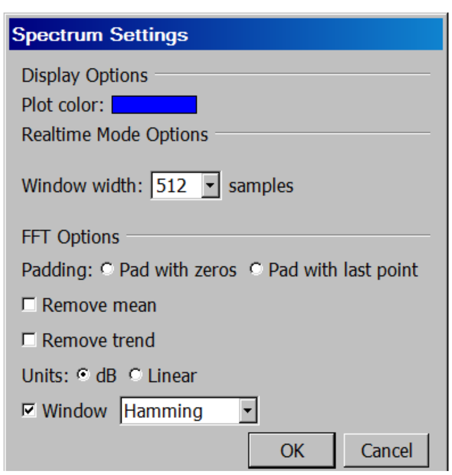
When operating in real-time mode, the following additional conditions also cause spectra to be unavailable:

- no data acquisition is in progress

Auto Vert Click to autoscale the spectrum to fit all amplitudes within the visible spectrum plotting area.

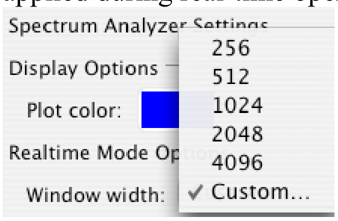
Auto Horiz Click to autoscale the spectrum to fit all frequencies within the visible spectrum plotting area.

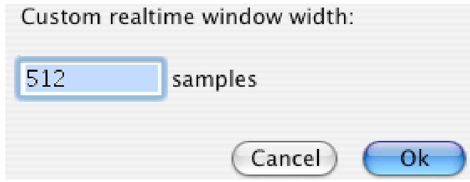
Settings



Plot color Colorwell that changes the color used to draw the spectrum in the palette. Click to display a standard color picker.

Window Width specifies the window size used when performing analyses in real-time mode. The spectrum will always reflect the frequency characteristics of the most recently acquired data of the graph, using this window size as the number of sample points to use. This popup will list various powers of two as well as a "Custom..." entry. If a custom width is entered that is not a power of two, padding will be applied during real-time operation according to the FFT Options.





FFT Options

Padding—used whenever the number of input points is not an exact power of two. Data can be padded either with zero or with the amplitude of the last data point.

Remove mean—Subtracts the mean value of the data is prior to frequency analysis. This helps remove the zero frequency component caused by DC offset.

Remove trend—Connects the endpoints of the data with a line and removes this linear trend from the data prior to frequency analysis. This can help compensate for drifting baselines.

Units—control whether the data is displayed using a logarithmic scale or a linear scale.

Window—enables the standard Acq*Knowledge* windowing options, to adjust the data to remove effects resulting from the discontinuities of data at the two edges.

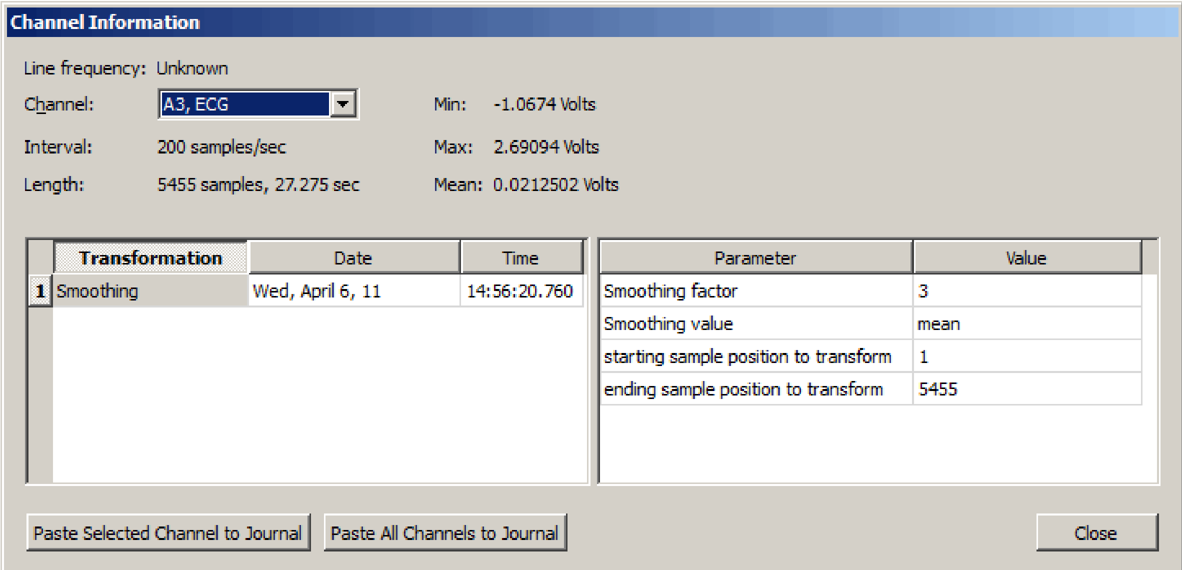
Value Click the crosshair icon to display the frequency and amplitude values of the spectrum when moved within the spectrum display. The mouse cursor will change to a crosshair when inside the spectrum plot. The frequency and amplitude values corresponding to the mouse position are displayed above the spectral plot. Hold the mouse button down to display the amplitude of the spectrum at the horizontal mouse position, along with a crosshair cursor highlighting the exact location shown on the spectrum. If the active spectrum is compressed (that is, if multiple samples exist for a particular horizontal position), the value extracted will be the maximum value displayed at that pixel position.

Zoom Click the magnifying glass to perform zoom operations. Click and drag the mouse cursor (which will change to a magnifying glass) in the plot display to select the area to zoom in on. Alternately, click either of the axes of the spectrum palette to display a dialog used to enter display ranges manually. Enter the start and end points of the desired range for each axis. There are no grids in the spectrum analyzer palette, so the axis scaling dialogs of graphs are not applicable. Note: adaptive scaling will be disabled for the spectrum display when either the zoom tool or the axis endpoint entry dialogs are used.

TIP: To zoom out, hold the Alt key (PC) or Option key (Mac) while clicking mouse over zoomed area.

Channel Information...

The Display > Channel Information command generates an information dialog for the selected channel.



Line Freq Files created with Acq*Knowledge* 4 include the line frequency (50 Hz or 60 Hz); files created in earlier versions will list "Unknown."

Channel This box displays the channel number, channel label (if any).

Interval Indicates the acquisition sampling rate. The sampling rate specified reflects the sampling interval Acq*Knowledge* uses to store the data, which is not necessarily the same rate at which it was collected. The sampling rate can be modified by using the resample function (described on page 292), by changing the interval horizontal scale (see page 411), or by pasting data collected at one sample rate into a graph containing data sampled at a different rate.

Length Indicates the overall length of the channel in samples per second and time. Generally, the waveform length information is the same for all channels, although this is not always the case. To shorten waveforms by editing out sections of the waveform (using Edit > Cut and/or Edit > Clear functions).

Min Provides the minimum value for the waveform data.

Max Provides the maximum value for the waveform data.

Mean Provides the mean value for the waveform data.

The fields below the statistical information contain transformation histories, time/date stamps, parameters, and values for selected channels.

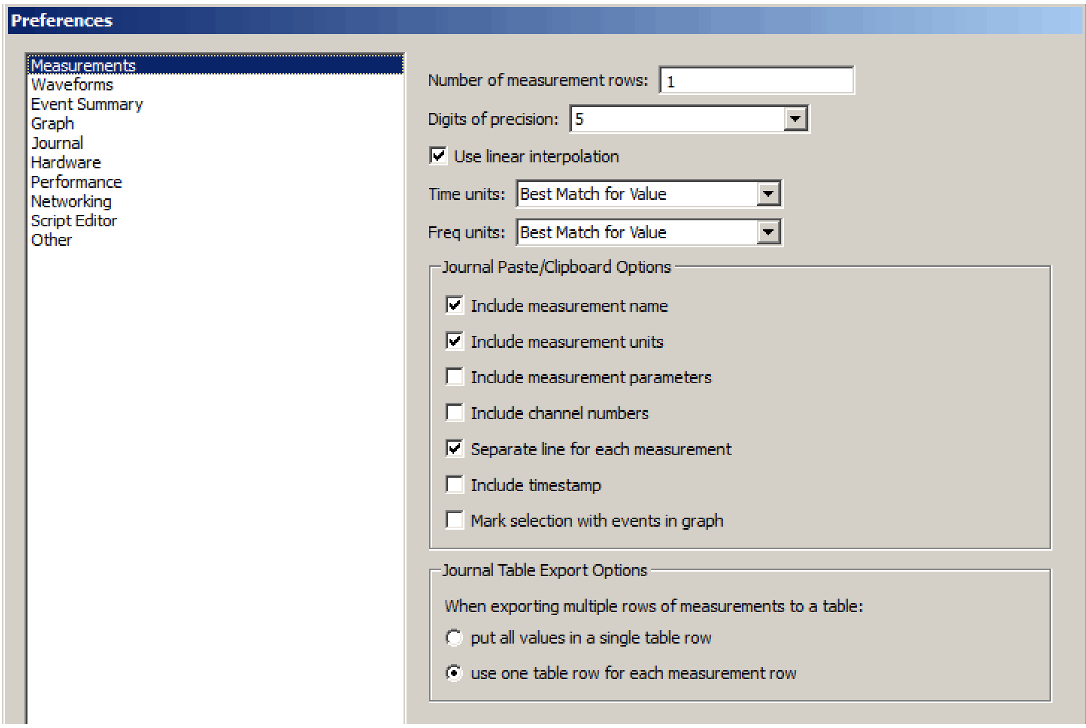
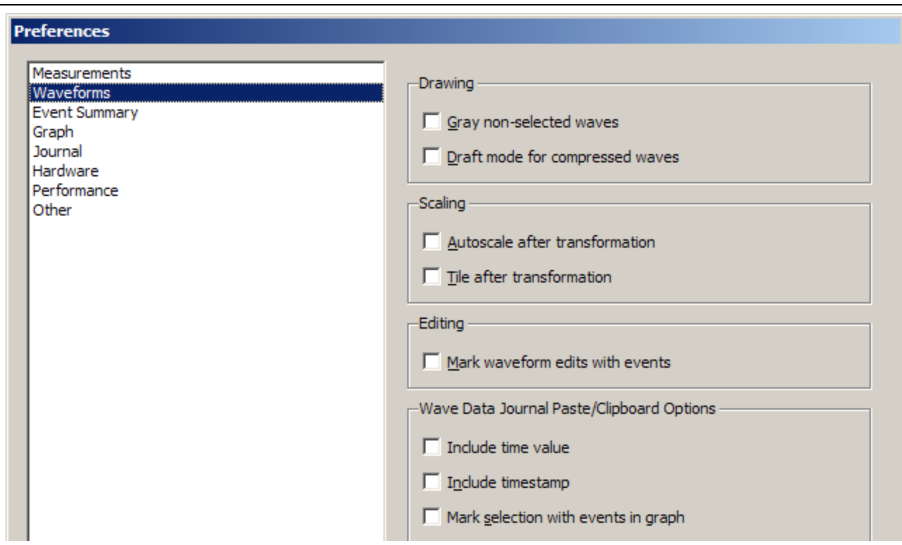
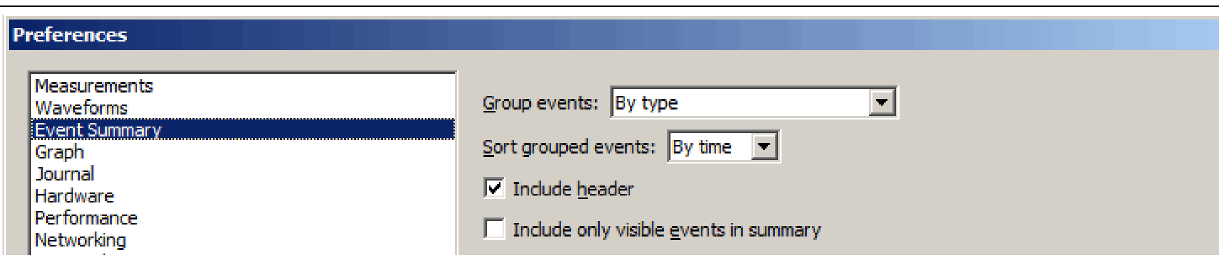
Paste Selected Channel to Journal Pastes transformation modification history for selected channel to Journal.

Paste All Channels to Journal Pastes transformation modification history for all channels to Journal.

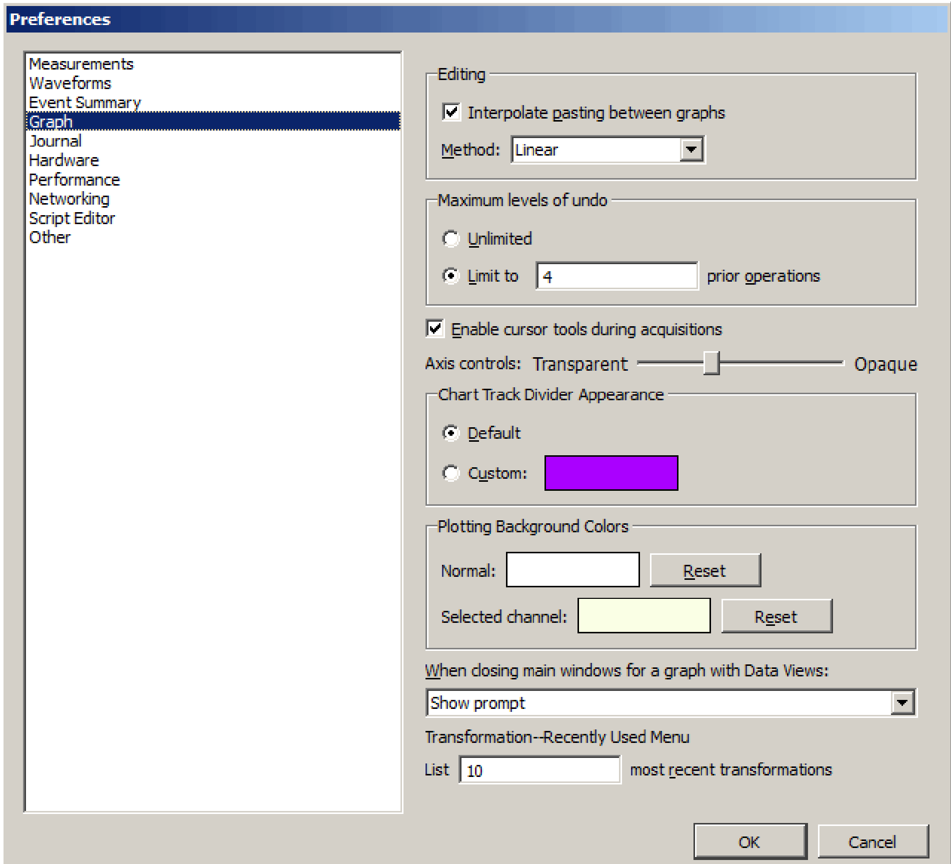
Preferences...

To generate the Preferences dialog, select Display > Preferences on Windows or AcqKnowledge > Preferences on Mac. Use Preferences to control measurement options, how waveforms are displayed, and other Acq*Knowledge* features. Select an option in the list on the left of the Preferences dialog and then set the respective preferences displayed on the right.

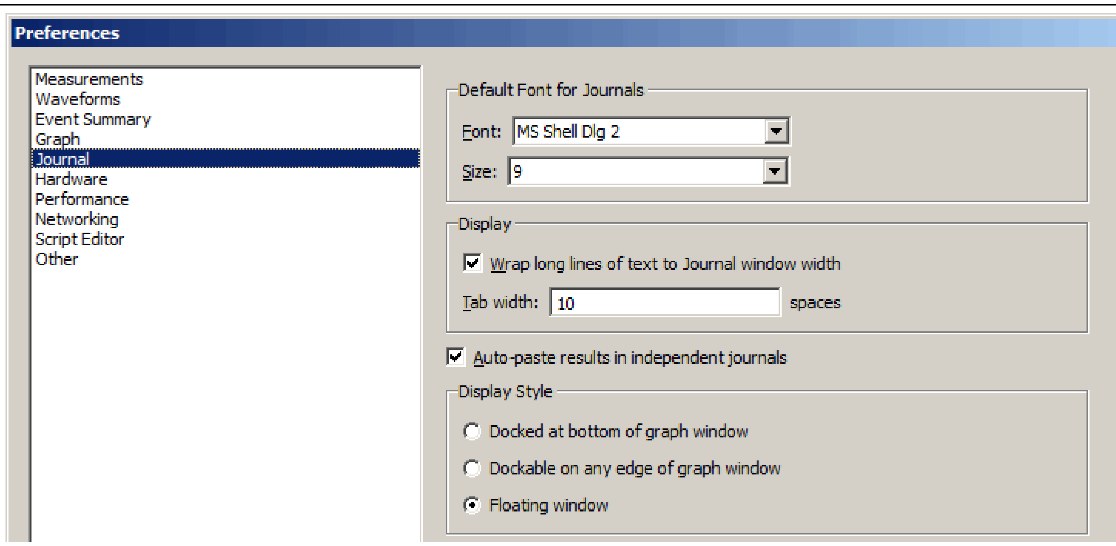
<table>
<tr><td>See page…

422</td><td>
</td></tr>
<tr><td>423</td><td>
</td></tr>
<tr><td>424</td><td>
</td></tr>
</table>

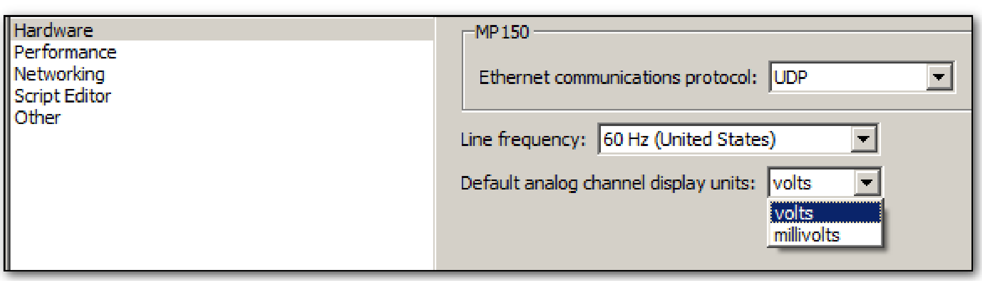
424

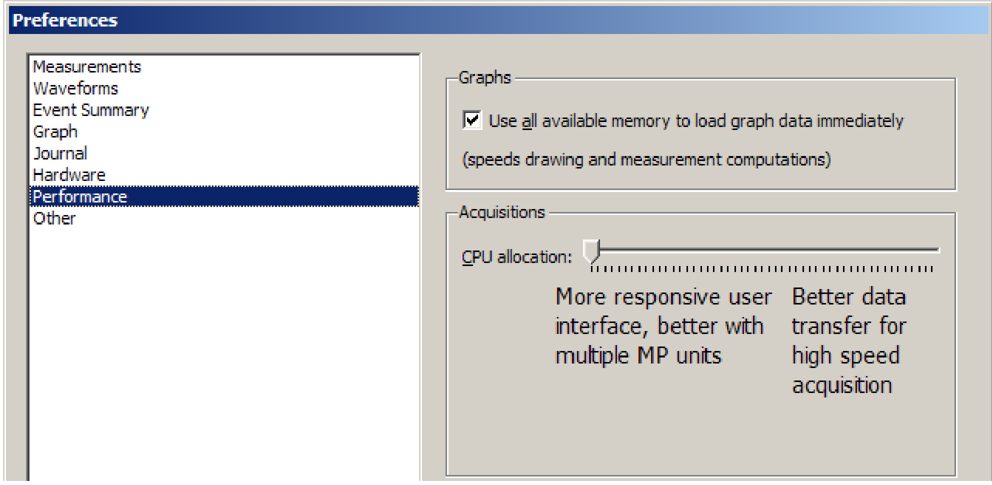

Preferences
Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Networking
Script Editor
Other
Editing
Interpolate pasting between graphs
Method: Linear
Maximum levels of undo
Unlimited
Limit to 4 prior operations
Enable cursor tools during acquisitions
Axis controls: Transparent Opaque
Chart Track Divider Appearance
Default
Custom:
Plotting Background Colors
Normal: Reset
Selected channel: Reset
When closing main windows for a graph with Data Views:
Show prompt
Transformation--Recently Used Menu
List 10 most recent transformations
OK
Cancel

425

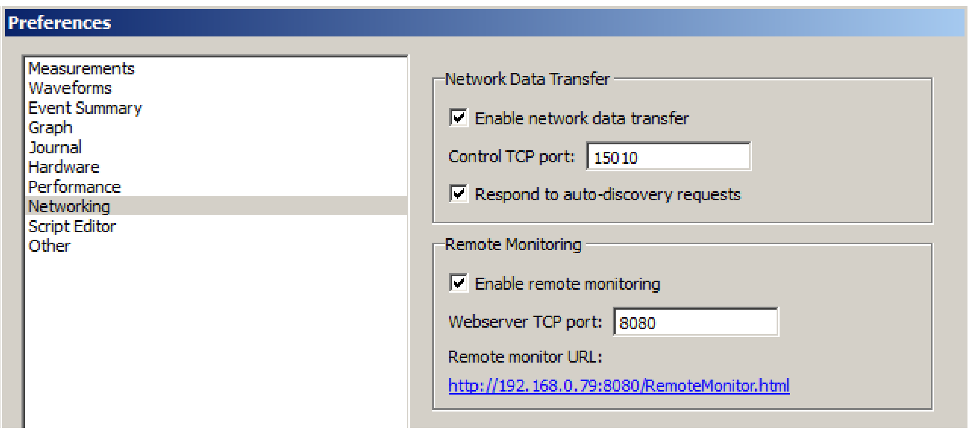

Preferences
Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Networking
Script Editor
Other
Default Font for Journals
Font: MS Shell Dlg 2
Size: 9
Display
Wrap long lines of text to Journal window width
Tab width: 10 spaces
Auto-paste results in independent journals
Display Style
Docked at bottom of graph window
Dockable on any edge of graph window
Floating window

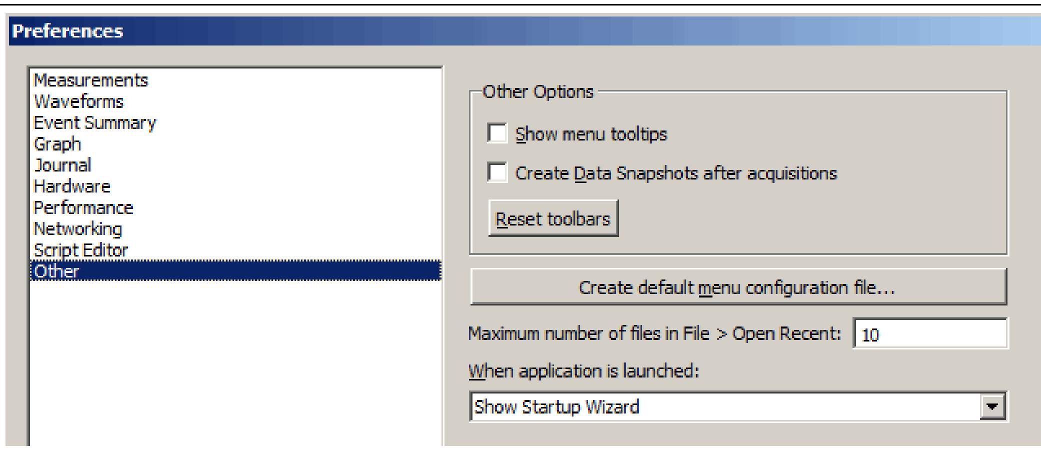
425


Hardware
Performance
Networking
Script Editor
Other
MP150
Ethernet communications protocol: UDP
Line frequency: 60 Hz (United States)
Default analog channel display units: volts
volts
millivolts

<table>
<tr><td>425</td><td>


</td></tr>
<tr><td>426</td><td>
Not supported in AcqKnowledge 4.0-4.1



</td></tr>
<tr><td>426</td><td>


</td></tr>
</table>

Measurements Preferences

- **Measurement rows**—determines how many measurement rows should be displayed at the top of the graph window.
    - o Use Display > Show > Measurements to hide the measurements; see page 412 for details.
- **Precision**—controls the accuracy of digits displayed right of the decimal (1-8) for all visible measurement results. For instance, with precision set to 3, one measurement window might show 125.187 while another reads 0.475.
- **Use linear interpolation**—toggle to enable/disable measurement interpolation.
- **Time/Frequency units**—sets the measurement unit to use for time and frequency pop-up measurements. This locks the units for the measurement result display (i.e., if seconds is selected, a result of 70 seconds will display as “70 seconds” rather than “1.16667 minutes”).

- Best match—Scales units to best match the interval for time and frequency based on the total file. For example, won't set a 3 hour file to display in msec.

- **Include for Journal/Clipboard options**
    - measurement name (i.e., BPM, Delta T, Freq, etc.) with the values.
    - measurement units (i.e., volts, mmHg, and so forth) after the numeric values.
        - *Note* The first two options cause additional text to be pasted into the journal, which can drastically reduce the amount of numeric data that can be pasted into the journal due to limitations on the maximum journal size. See page 52 for more information on working with Journal files.
    - measurement parameters used to compute the measurement function result, such as the location and operator used for Calculate measurements.
    - channel numbers at the top of each column of data.
    - timestamp—Automatically insert the time of day and the date when pasting measurements or wave data. This timestamp can be correlated with selection events to reconstruct the selected area.—useful for GLP auditing.
- **Use a separate line** for each measurement in the journal/clipboard
- **Mark selection with events in graph**—Automatically insert a pair of Global Selection Begin and Selection End events at the selection boundaries when pasting measurements or wave data. These events will be timestamped with the time of day and the date when the paste occurred. This timestamp can be matched to the result of "Include timestamp" to recreate selected areas for reconstructing measurement results or re-executing wave data exporting—useful for GLP auditing.
- **Journal Table Export Options** – Sets the options for how multiple measurement rows are displayed in a Journal table.
    - <u>Put all values in a single table row</u> – Extends multiple measurement rows horizontally into one table row.
    - <u>Use one table row for each measurement row</u> – Divides the measurements into multiple table rows in the same manner shown in the measurement toolbar.

Waveforms Preferences

In the center of the dialog are two options that control how waveforms are displayed on the screen.

- **Gray non-selected waves**—When enabled, the active wave will be drawn in a solid color and any non-selected waveforms will be drawn using lighter, dotted lines (or with lighter colored dots if dot plot is in use). This can help emphasize the selected waveform when viewing data in Scope mode.
- **Draft mode for compressed waves**—allows for some ("compressed") waveforms to be plotted in "draft" mode, which results in faster plotting time, although the display is not exact. A waveform is considered compressed when more than three sample points are plotted per pixel on the screen. For example, on a VGA display that is 640 pixels wide, a compressed waveform would be any type of waveform displaying more than 2000 samples (approximately) on the screen at any one time. Using the default horizontal scale (which plots eight seconds of data on the screen), any data sampled at more than 250 samples per second would be considered "compressed."
- **Scaling**—These two options handle the way data appears on the screen after it has been transformed (e.g., filtered or mathematically operated on). Neither option affects how data appears on the horizontal axis, although both options change how data is presented along the amplitude (vertical) axis.
    - **Autoscale after transformations** will automatically rescale all waveforms after a transformation to provide the "best fit" along the amplitude axis.
    - **Tile after transformations** tiles all visible waveforms after any transformation, and is mutually exclusive of the autoscale command. When waveforms are "tiled" they appear to be stacked on top of each other.
- **Mark waveform edits with events**—Insert an event at points where waveform edit commands have been applied.

- **Include time value**—copies the horizontal scale values along with the waveform data when data is copied to the clipboard. This means that when you paste data from the Acq*Knowledge* screen into a spreadsheet or similar application, horizontal scale information is retained.
- **Include timestamp**—Automatically insert the time of day and the date when pasting measurements or wave data. This timestamp can be correlated with selection events to reconstruct the selected area.—useful for GLP auditing.
- **Mark selection with events in graph**—Automatically inserts a pair of Global Selection Begin and Selection End events at the selection boundaries when pasting measurements or wave data. These events will be timestamped with the time of day and the date when the paste occurred. This timestamp can be matched to the result of "Include timestamp" to recreate selected areas for reconstructing measurement results or re-executing wave data exporting—useful for GLP auditing.

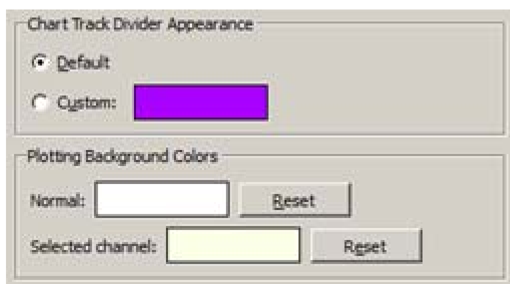
Event Summary Preferences

For the event summary that can be pasted to the journal, choose a method to group the events (i.e., type or channel), to sort the events (by time or label) and indicate whether to include all events or include only visible events in the summary. Beginning in Acq*Knowledge* 4.2, there is an option to include a header row at the top of the summary.

Access Event (Marker) preferences under MP150 menu > Set Up Events; see page 209 for details.

Graph Preferences

- **Interpolate pastings** instructs Acq*Knowledge* to interpolate/extrapolate time base information when working with data sampled at two different rates. Acq*Knowledge* will interpolate data to fit the sample rate of the destination window. When doing this, you should copy data to a higher resolution window. Although To copy data in the other direction (from high resolution to low resolution), it is not recommended since some resolution will be lost in the process.
    - *For example*, if you have one 30-second waveform sampled at 50 samples per second, and another 30-second waveform sampled at 2,000 samples per second, you can copy the contents of one window into another using the insert waveform command, and Acq*Knowledge* will interpolate one waveform so that both appear to be 30 seconds long. In this example, data would be copied from the 50 Hz (low resolution) window to the 2,000 Hz (high resolution) window.
- **Maximum levels of undo—**Set the maximum number of undo operations. Unlimited may be memory-intensive, depending on the detail of each operation.
- **Enable cursor tools during acquisition –** Allows access to cursor tools while recording is in progress.
- **Axis controls –** Controls visibility of set screen vertical axis controls.
- **Chart Track Divider Appearance –** Starting with Acq*Knowledge* 4.1, users may change the color used to draw the dividers between channels tracks The Preferences > Graph panel contains "Chart Track Divider Appearance" options.

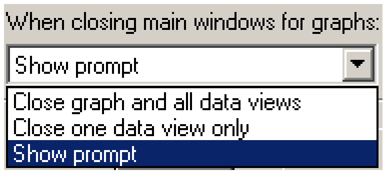


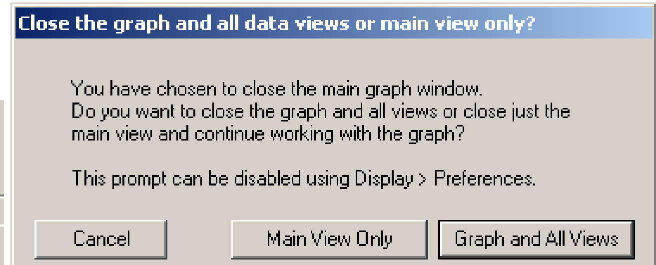
- **Default** uses operating system specific dividers, which are lighter in color (as in Acq*Knowledge* 4.0).
- **Custom** activates a colorwell, allowing a solid color to be specified for all dividers. The preference setting and color are shared by all open graphs and data views, as this is an application-level preference.

- **Plotting Background Colors** – Starting with Acq*Knowledge* 4.2, customizable background colors for individual graph channels are available.

- **Normal** activates a colorwell for choosing background color of the non-selected channels.
- **Selected channel** activates a colorwell for choosing background color of the selected channel.

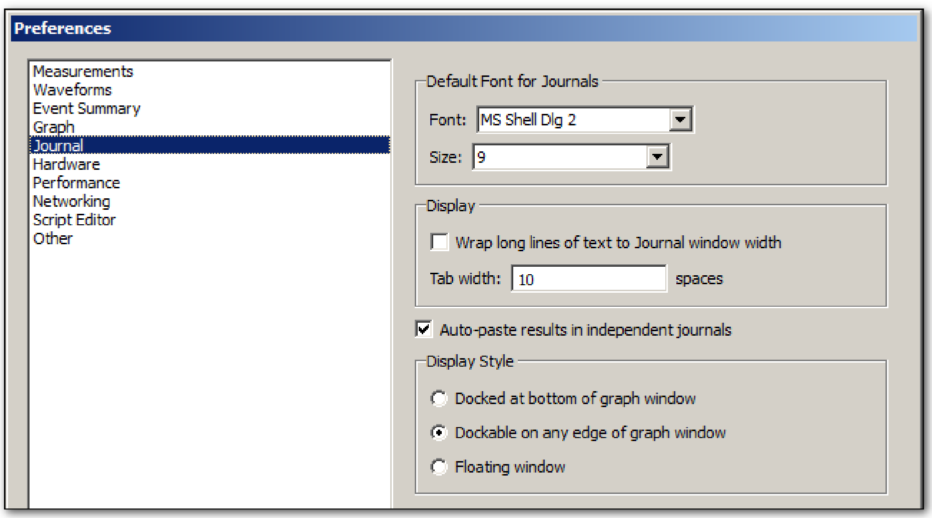
- **When closing**… determines the degree of closing and what prompts, if any, for multiple data views.





- **Recently Used—**set the number of recently used Transform and Analysis options to list in the Transform > Recently used sub-menu; provides quick access to common options. Recently used items can also be launched using keystroke the combinations appearing in this menu.

Journal Preferences



The Journal Preferences dialog has options that control the format of data when it is pasted into the journal or clipboard.

- Change font type and size to any font installed on your computer.
- Wrap Journal text—Wraps text to window size.
- Tabs: Specify the tab interval to make columns more readable when you have a high precision setting.

Auto-paste results—Toggle the checkbox to enable/disable the option to paste results to independent journals.
Display Style— Choose whether Journal window is fixed, dockable on edges of graph, or independently floating.

Hardware Preferences

- **Always work with No MP hardware connected** sets the default communication for no connection so the connection error is not displayed each time the software is launched.
- **Ethernet communications protoco**l is UDP by default; DLC is not supported in Acq*Knowledge* 4. If you cannot establish MP150 unit communication using UDP protocol, check the MP150 unit firmware (see page 478) and then contact BIOPAC for technical support.
- **Line frequency** is specified during software installation and can be changed here. Every time data is recorded, the line frequency setting is saved along with the data. If no line frequency data was saved, the line frequency setting for the installed/active version of Acq*Knowledge* will be used.
- **Default analog channel display units** – Use to set default channel units to volts or millivolts.
  - Volts – displays in Volt units, visible range +/-10V (MP150 default)
  - mV – displays in Millivolt units, visible range +/- 50 mV (MP36 default)

Performance Preferences

- **Use all available memory** instructs Acq*Knowledge* to attempt to use all the available memory for loading data. Otherwise, a variable sized buffer is used to load portions of large data files. This option works best if there is enough free memory to load the entire data file.
- **CPU allocation** sets the priority for CPU (system resource) allocation. For a data focus, move right, for a function focus, move left.

- If you are experiencing Buffer Overloads, move toward *Better data transfer for high speed acquisition*.
- To allow autoscale during acquisitions or jumping between MPs, resizing displays, or working in other programs, move toward *More responsive*.

Networking Preferences

Network data transfer and Remote Monitoring are not supported in Acq*Knowledge* 4.0-4.1.

Enable networking to allow applications running on other computers attached to the same network to gain access to data from Acq*Knowledge* as it is being acquired. Data is sent to other applications over a network using TCP (recommended) or UDP connection during acquisitions. All types of channels may be exported, including analog, digital, and calculation channels. Acq*Knowledge* will continue to function normally while data transfer is in progress, displaying the new data in the graph window and performing any autoscrolling.

Respond to auto-discovery—Toggle the checkbox to enable/disable response during network data transfer.

The network data transfer feature is not intended for strict real-time delivery. It also does not provide direct control over the MP150 unit. Perform all hardware configurations manually using the Acq*Knowledge* interface.

Enable Remote Monitoring to allow acquisitions on the computer to be viewed remotely over a network through a client/browser interface. Acquisitons can be started and stopped remotely and graph data viewed while recording is in progress. This is handy if the AcqKnowledge computer recording the experiment is in one area and the researcher monitoring the experiment is in another.

For applications that require low latencies, high-data throughput, or direct hardware configuration and control, use BIOPAC Hardware API.

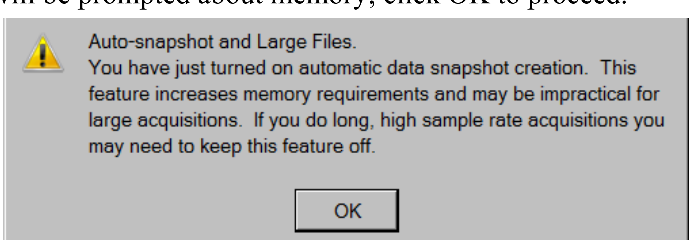
Other Preferences

- **Show menu tooltips** enables display of tooltips describing menu item functions. Tooltips appear when menu items are moused over.
- **Create Data Snapshots after acquisitions** toggles the snapshot (embedded archive) feature, which stores snapshots of original acquired data along with the graph file for easy comparison of results to original waveforms or to intermediate stages of analysis; see page 53 for details.

  IMPORTANT: Archive functions do not create a new file—they are not backup functions.
  Original data is copied and pasted to the end of the original file.
  You cannot use this feature to recover lost or damaged original data.

  When this Preference is enabled, a date-stamped archive of the data in the graph will be created each time the acquisition is stopped. In Append mode, the entire graph is backed up with each Append, old data as well as the newly acquired data.

  This is a memory intensive function; each snapshot that is added to a graph file will increase its size on disk by approximately 40%. You will be prompted about memory; click OK to proceed.

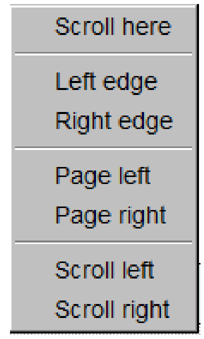


- **Reset toolbars—**Resets toolbar configuration to default setting.
- **Create configuration file—** Create default menu configuration file to customize menu display. See page 474 for customization details.
- **Maximum number of files in File > Open Recent—**Sets the number of files that will appear in the 'File > Open Recent' list.

- **When application is launched:—**Chooses between display of Startup Wizard or a new empty graph following application launch.

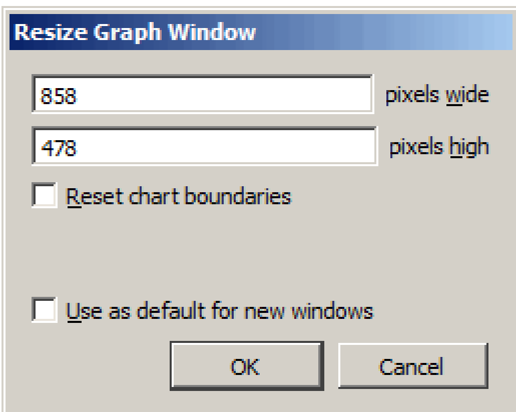
Scroll options

The Scroll option help you move through large data files. Right-click below the horizontal scroll bar to generate the contextual menu with scroll options.



Contextual menu

Size window...



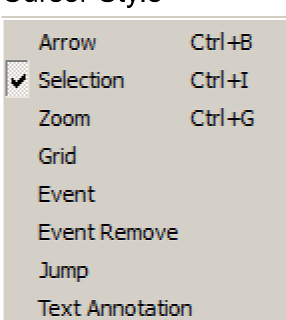
The Size Window function allows the setting of exact dimensions for the interior size of the graph window. Use this to create consistently sized windows for pasting into documents. The two text box fields are used to enter interior screen width and height, both of which are scaled in terms of pixels. Standard computer displays have 72 pixels per inch (28.3 pixels/cm), so a graph window that is 360 pixels wide by 216 pixels high would be 12.7cm tall and 7.6cm wide.

Each operating system may add additional dimensions as necessary to put in window adornments depending on the appearance configuration preference of the user (e.g. extra space for title bar of the window, any additional space put around the edges of the window frame, etc.).

When the Reset chart boundaries box is checked, the boundaries between the waveforms will be reset so that each channel "track" is the same size.

When Use as default for new windows is checked, the user-modified dimensions are applied as the default graph window size.

Cursor Style



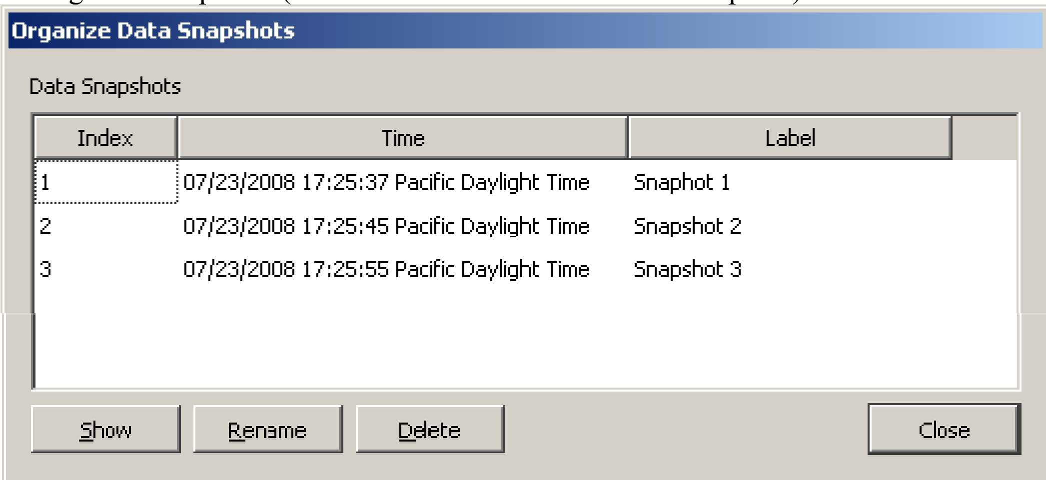
This option allows the active cursor tool to be adjusted via the Display menu. (Acq*Knowledge* 4.2 and higher)

Create Data View

Creates a new Data View for the active (frontmost) graph and names the new window "Data View of 'Filename'" For Data View details, see page 45.

Organize Data Snaphots

Arrange data snapshots (as created via Edit > Create Data Snapshot).



Show All Data Snaphots

1	Manual Archive: description and time
2	Original file
3	Auto-Archive: time only

To view the embedded snapshot(s)/archive(s) associated with a graph file, choose Display > Show Original Data/All Data Snapshots. This will open a new graph window for each archive/snapshot associated with the graph. The time portion of the Filename for each graph is from the computer clock (saved with semi-colons because you cannot save a file with colons in the filename). The “Snapshot from…” graph will open with no Start button.

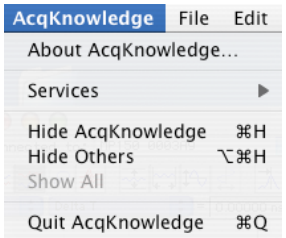
Each embedded archive is essentially a “snapshot” of the original acquired data that is stored with the graph file so you can view the archive at a later time to compare results to original waveforms or intermediate stages of analysis. Append markers are not preserved in the snapshot/embedded archive file. For details on creating snapshots/embedded archives, see page 53.

Load All Data Into Memory

Use with large files to improve plotting performance, measurement response, etc. Memory can hold up to two gigabytes of data.

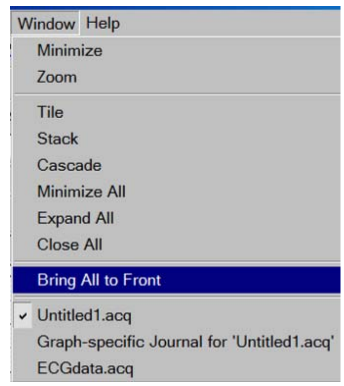
Chapter 19 Program & OS Menus

AcqKnowledge menu



Mac OS X only—System generated menu. Use for About, Quit, and Preferences.

Window menu

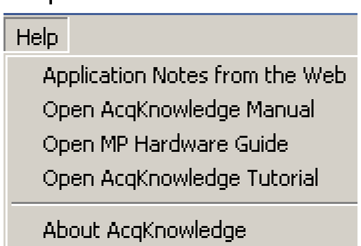


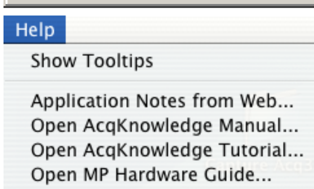
The Window menu is a standard OS function. See your Windows or Macintosh OS Guide for details.

Bring All to Front

If other programs are running, this command will bring all Acq*Knowledge* windows to the front (on top of all other application windows); this command does not change the windows size or position.

Help menu





Use the User Support System pdf files for online help with the software.

When About AcqKnowledge is selected from the Help menu, a screen is generated that provides information about the Acq*Knowledge* software being used and your system parameters, which can be useful if you need to call BIOPAC for any reason.

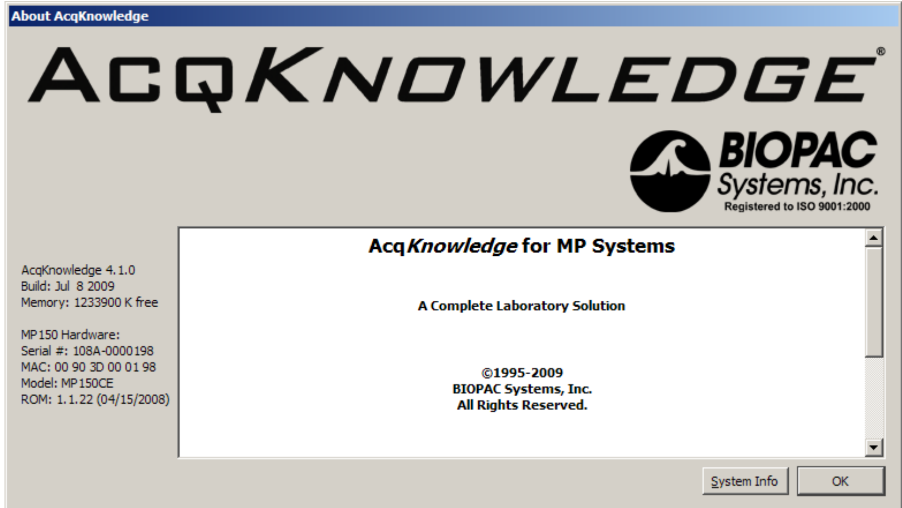
- *Mac OS X only*—About Acq*Knowledge* is under the Acq*Knowledge* menu.

Note: For information about the MP150 data acquisition unit and firmware, click MP150 menu >MP150 Info.

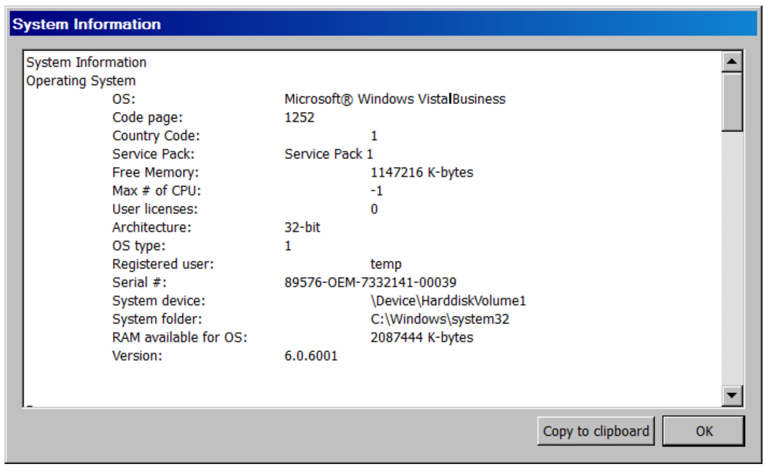
Tooltips—Tooltips is an online assistance feature to help novice users learn how to use Acq*Knowledge*. Text is generated to describe the software functionality of the item under the mouse. Unavailable items/controls will indicate why they are unavailable.

- Mac: To toggle Tooltips when you pass the cursor over an item, select Help > Show Tooltips.

Tooltips are not available for context sensitive (Ctrl-click) menus due to operating system limitations.

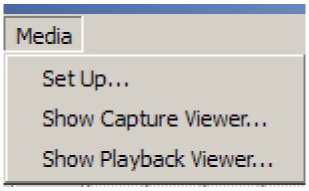


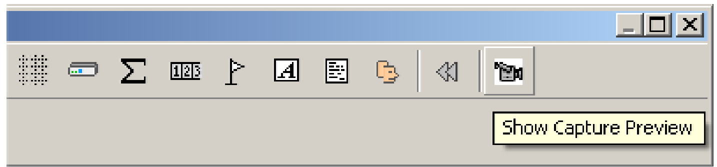
Click the System Info button for more detailed information.



The **Copy to clipboard** button makes it easy to paste system info into an email for Technical Support.

Chapter 20 Media Menu





Available in Acq*Knowledge* 4.1 and above for Windows—Media functionality allows users to capture and playback video and/or audio with a USB web cam or firewire DV device and synchronize it with physiological information from an MP device. The key functionality is a strong link between the video and data cursor when graphs are being used in post-acquisition mode; changing the selection in the graph window will automatically jump the video to the time corresponding to the cursor position. The reverse tie is also in place where erasing the video will move the data cursor to the corresponding data point in the graph.

For synchronized playback of media player with Acq*Knowledge* cursor in data view, BIOPAC recommends that the users sample the MP150 at least as fast as the video frame rate 30Hz. In this case, any measurement errors are limited to the basic frame rate error window (1/30 sec). For exact match of Video and Data samples, BIOPAC recommends frame rate 25 fps and acquisition rate 25 samples/second (or its derivatives).

Set Up Establish Sources, Output and Media parameters. Set device type for audio and or/video. Use refresh after connecting a new device to make it a selectable option. Browse using standard file open/save functionality to specify media files. If desired, set a Delay between file segments.

Show Capture Viewer Use for video signal directly from a video camera; this option is disabled (grayed) in the record mode when both the Capture video and Capture audio options in the Media Setup dialog are off.

Show Playback Viewer Use to play back media from the disk (stored media files); this option is disabled (grayed) if there is no media assigned to the file.

Show Capture Preview This Media Toolbar icon toggles the preview window display state (show/hide); this option is disabled (grayed) in the record mode when both the Capture video and Capture audio options in the Media Setup dialog are off.

Video Playback and Capture preview include a right-mouse contextual menu item "Grab bitmap" which, when selected, generates a Save As dialog to save the current displayed frame as a *.bmp image.

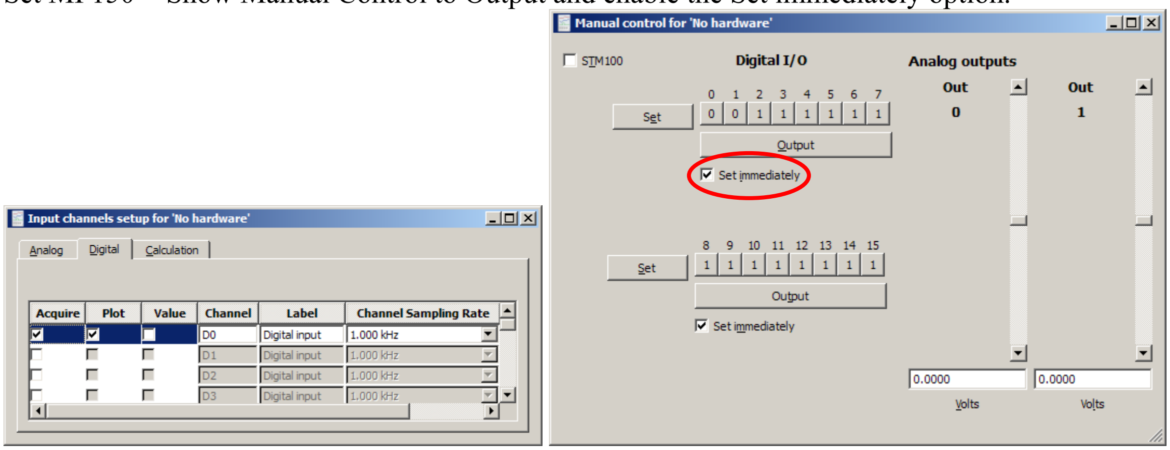
Media Notes

- :: Media capture performance is improved under Windows 7 or Vista OS. If the selected webcam drops frames because of poor performance/low quality, the degree of synchronization will be compromised. Testing indicated the Microsoft Lifecam NX-3000 gave reliable performance with no dropped frames.
- :: Several Acq*Knowledge* files can point (link) to the one media file.
- :: Acq*Knowledge* files can link to media files created by other programs. If the media file is shorter or longer than the Acq*Knowledge* files, just align the two files at the start.
- :: Acq*Knowledge* files alignment precision with the media file is user-controlled through the use of a delay function that allows a forward or backward time shift.
- :: Acq*Knowledge* files store the location (path) of the media file. This path is editable, so the Acq*Knowledge* file can link to other media files too.
- :: Media functionality does not support the *Autosave file* acquisition mode.

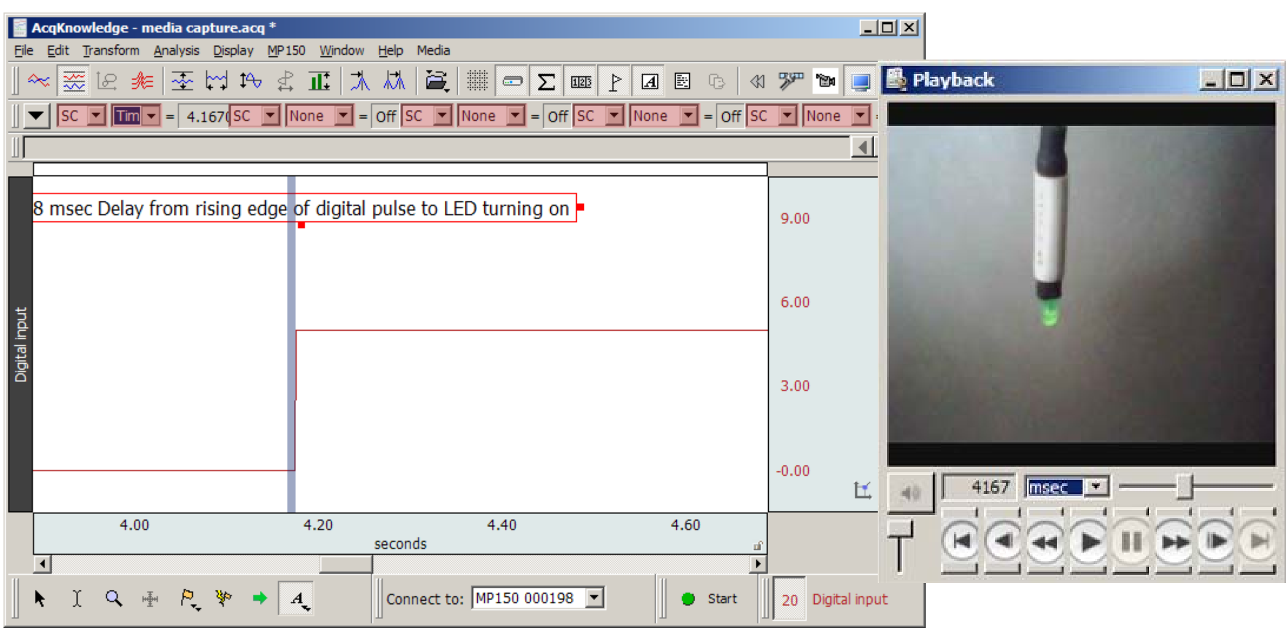
Synchronization Tip

To optimize synchronized playback of the media and the physiological record, use the OUT103 LED and a digital channel to determine the delay between the media and the data. The LED must be in view of the video camera and the LED channel must be recorded.

1) Setup LED Output:
    a. Connect CBL102 to an analog input channel and CBL106.
    b. Connect the other end of CBL106 to a Digital I/O channel and GND D on the rear of the UIM100C; additional interface required for the MP36R.
    c. Piggyback the OUT103 with the CBL106 on the rear of the UIM100C.
    d. Use MP150 > Set Up Channels to acquire and plot the Digital I/O channel the LED is connected to.
    e. Set MP150 > Show Manual Control to Output and enable the Set immediately option.



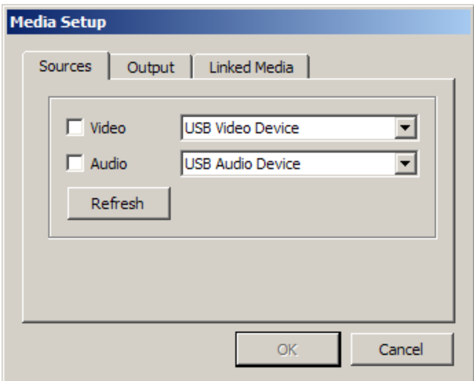
2) Start the acquisition in Acq*Knowledge*.
3) Click "0" on the appropriate channel in the Manual Control dialog.
4) Once the LED has illuminated and you can see the square wave in the file, you can hide the channel.
5) After the recording is complete, use the I-beam selection tool to measure the offset between the LED illumination and the leading edge of the digital impulse. Use a Delta T measurement to determine the delay information; Delay may be positive or negative based on camera performance. Delay should be entered in the Linked Media row for each segment—see page 433.

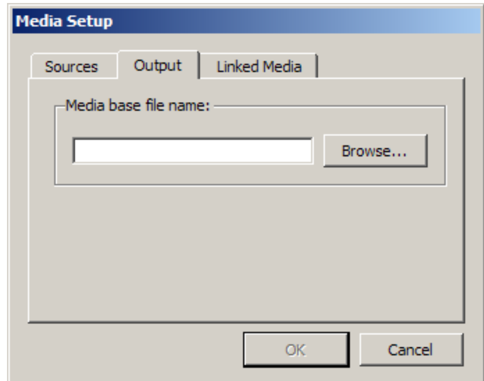


Source

Use this dialog to select media source and select audio and video to record. Click Refresh to update the list if a video or audio device is connected after the dialog was opened. When video/audio for capture is selected, an output file must also be slected. Input file name and click OK; this will close the Media Setup dialog and automatically open the media window if the Capture option is ON.

All video camera, audio (microphone) input parameters can be setup by user with the UI provided by camera manufacturer.



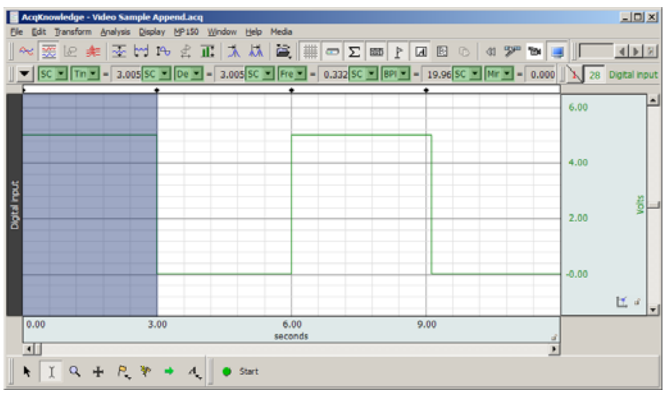


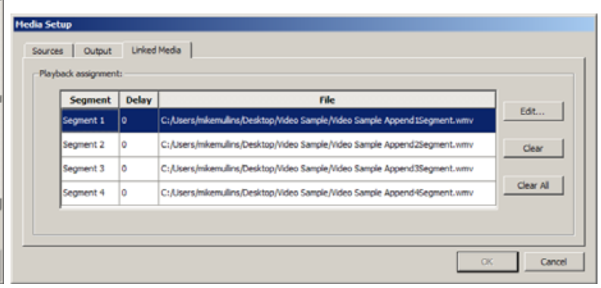
Output

Video/audio capture requires a media file specified with full name with disk location. *.avi or *.wmv file formats are supported. Users can save Acq*Knowledge* data and media streams onto separate hard drives.

Linked Media

IMPORTANT An Acq*Knowledge* data file must be opened before linking to a media clip.



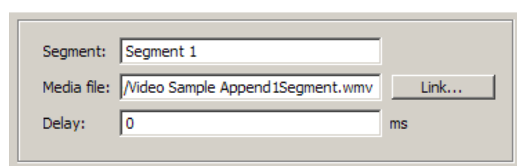


If media was captured with the data file, the Linked Media dialog will display a row for each appended segment in the Acq*Knowledge* data file and will list the file location of the corresponding media for each segment. The samples above show four Acq*Knowledge* data segments and four linked media Files.

Click anywhere in the row (or choose the Edit button) to set a delay to synchronize the media file with the physiological data. Delay range: Min= 1 millisecond, Max = segment duration.

- See Synchronization Tip on page 432.

If media was not captured with the data file, click the appropriate row and click "Link" to browse to the desired media file from that segment.



Delay—Eash segment can have a distinct delay. Click in the Delay cell or click Edit to generate the dialog for Delay entry.

"+" Delay places start of video file after graph start

"-" Delay places start of video file before graph start

The best possible synchronization can't be better than the the video frame rate (usually1/30 of a second).

Media > Capture

Use Set Up to assign a Source and Output to enable the Capture menu option. There are no Preview window controls and the size reflects default video camera resolution.

Playback Preview

As the media file is manually scrolled or automatically played, the Acq*Knowledge* cursor keeps moving to reflect the corresponding location in the Acq*Knowledge* graph. If the Acq*Knowledge* cursor is moved, the media file is automatically scrolled to keep time sync with the data file.

In Acq*Knowledge* 4.2 and above: Media files linked to appended data segments are loaded in sequential order. After playback of the first media segment, the cursor will automatically advance to a still-frame view marking the beginning of the next segment. The Play button must be pressed in order to play back subsequent segments.

Audio Mute button and level slider

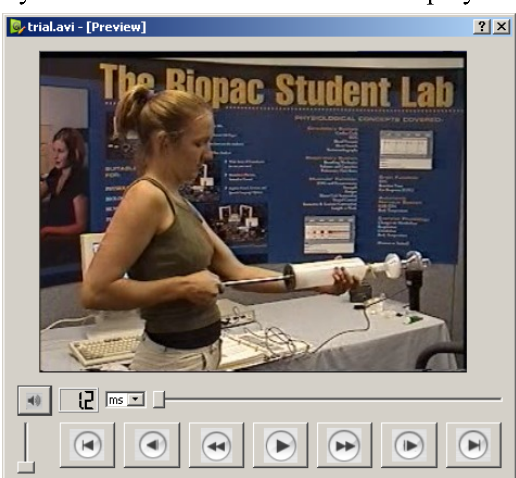
Video Digital indicator (time in milliseconds or frame number for the segment clip) and Horizontal slider (progress bar) to navigate the media file. The start point can be set from either the media clip or the data file. For precise selection, hold the shift key and use the forward or backward arrow keys on the media player or the keyboard to move single video frame (mostly 1/30 seconds) or data point.

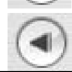
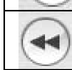
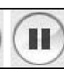
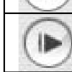
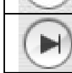
Use the scroll bar to navigate to different frames. Synchronization should be maintained with data in the graph window. This should result in a single sample selection cursor shown at the time closest to the displayed video frame.

The media window displays the text "No media assigned" in Playback Preview when the media window is visible but there is no video/audio file assignment for given data segment.

During the capture or playback of audio only, the media window will be displayed with a static musical note image as shown at right.

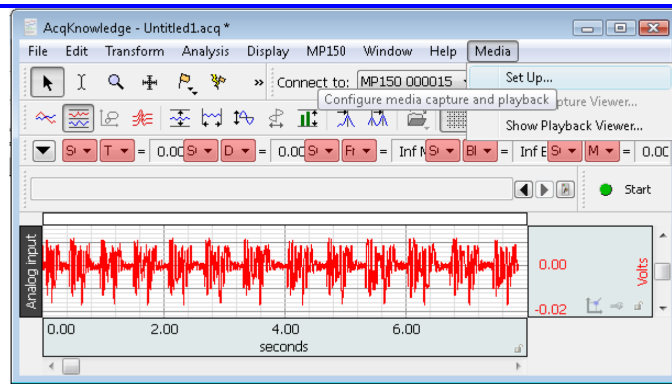
The Playback viewer uses standard media player controls.



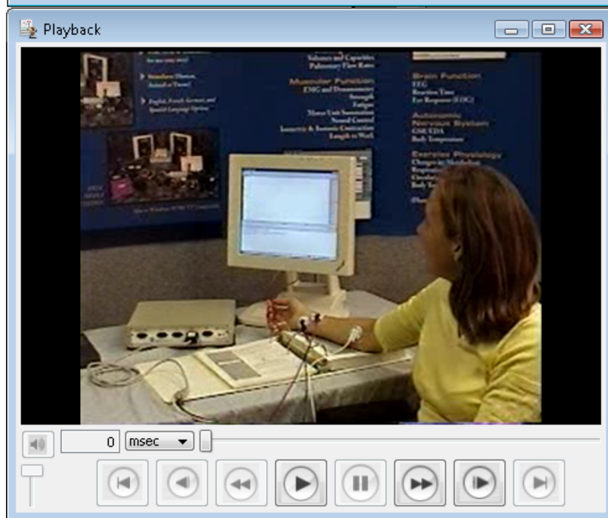
	Go to previous segment / go to beginning of segment
	Step backward a frame/sample
	Fast backward / reverse rewind
 	Play/ pause
	Fast forward
	Step forward a frame/sample
	Go to following segment
	Mute sound

Media Playback Example

1. Launch Acq*Knowledge* 4.1
2. Open a saved acquisition file.

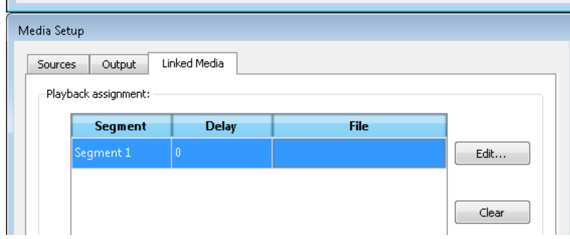


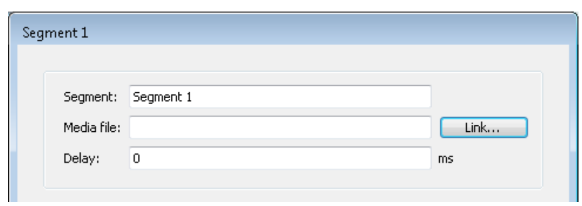
3. Select Media > Show Playback Viewer.
4. Here you can play with contents:
   - Select I-beam cursor on graph and push "Play" button on the player.
   - Change selection with I-beam on graph and see the video.

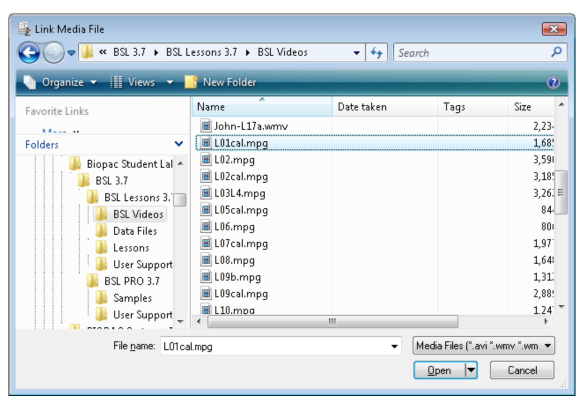


IF media is not assigned, locate the video clip for the appropriate segment:

a.) Select Media > Set Up
b.) Select the "Linked Media" tab
c.) Select Segment 1 and click "Edit.
d.) Click "Link" and select a saved media file.







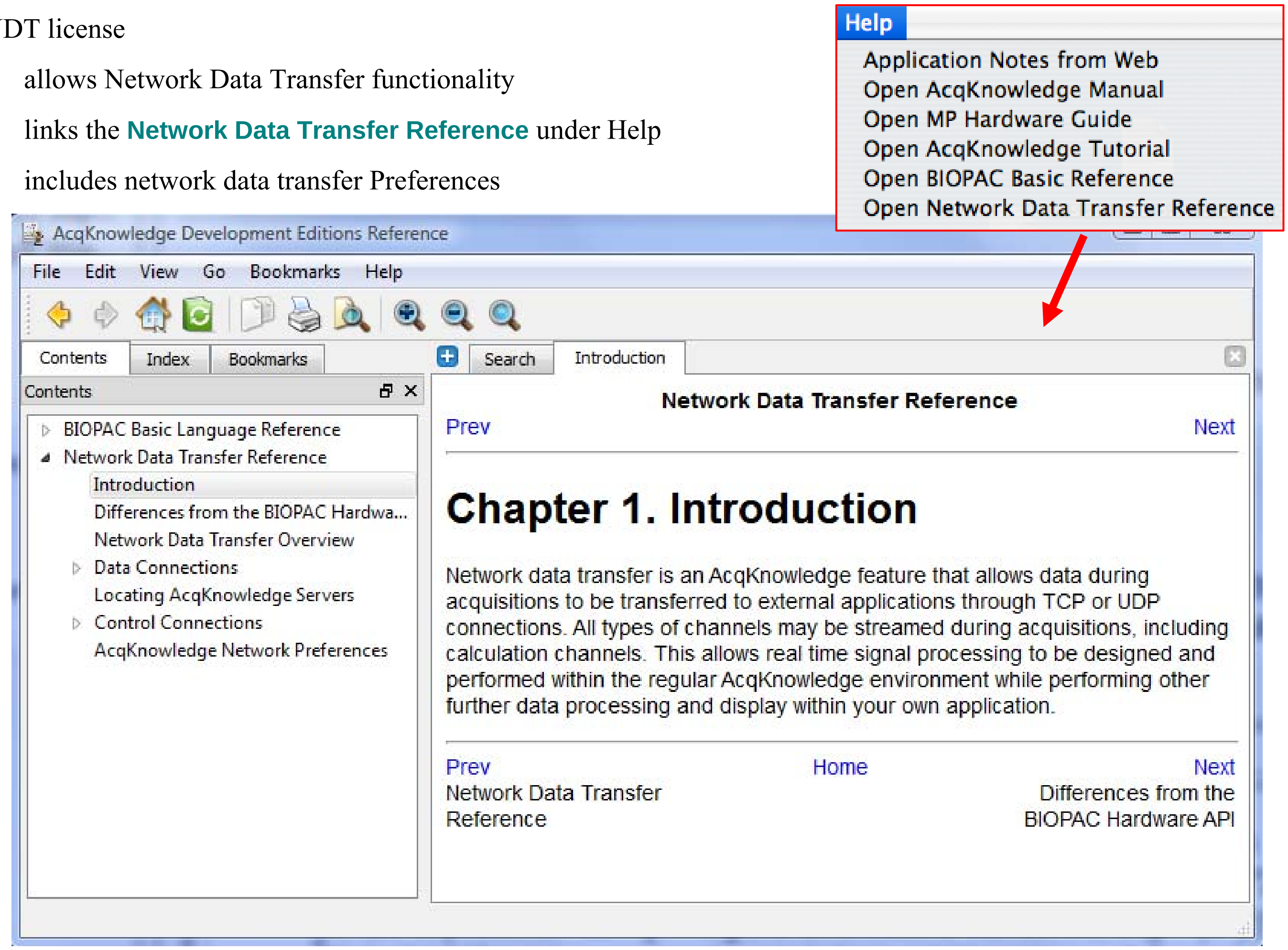
Chapter 21 Licensed Functionality: Network Data Transfer

Network Data Transfer (NDT) functionality is available through an optional license available with Acq*Knowledge* 4.1.1 or above.The license must be authorized to access NDT functionality. To add an NDT license to an existing MP System, please contact BIOPAC.

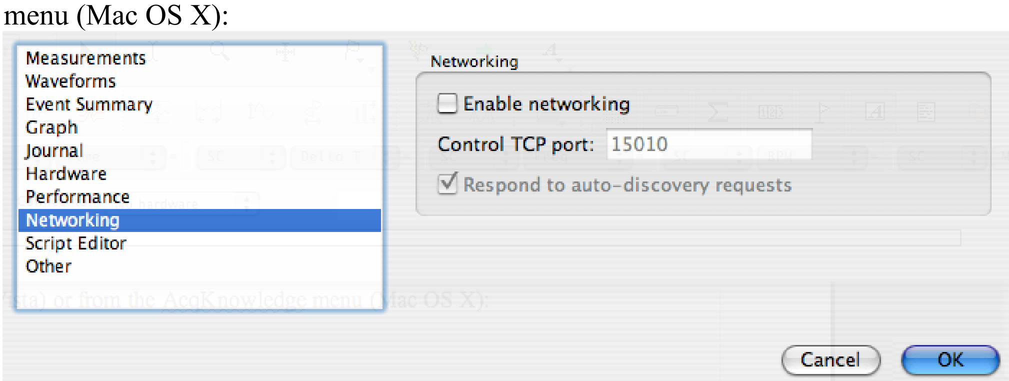
Network Data Transfer (NDT) is a real-time data transfer system that allows access to the data being acquired into a graph by Acq*Knowledge* for use in an external application; the Acq*Knowledge* process and the custom application may run on the same computer.
Make TCP or UDP connections to external applications and stream binary data during acquisitions.

The NDT license

- allows Network Data Transfer functionality
- links the **Network Data Transfer Reference** under Help
- includes network data transfer Preferences



Most of the settings for the network data transfer functionality are set by clients through control connections. Several settings for the Acq*Knowledge* server may be set directly in the Acq*Knowledge* preferences. Versions of Acq*Knowledge* that include network data transfer functionality have an additional "Network" group of settings underneath their Preferences. These Preferences are accessed from the Display menu (Windows 7/Vista) or from the Acq*Knowledge* menu (Mac OS X):



NDT is a basic method for allowing third party applications to tap into the data stream being generated by both the MP unit and Acq*Knowledge* during data acquisitions. NDT provides

- networking facilities that allow for integration into a distributed application environment
- basic control facilities to allow external applications to query and control the Acq*Knowledge* application state.

The NDT system is split into two separate types of connections: data connections and the control connection.

A. Data connections deliver data from Acq*Knowledge* to external applications during acquisitions.

B. Control connections are made from external applications to Acq*Knowledge* to query application state and adjust data connections.

The *server* refers to the Acq*Knowledge* process and the computer on which it is running. The *client* refers to the custom application that is to receive data from Acq*Knowledge* and the computer on which it is running.

All connections should be made using standard network protocols, either TCP or UDP. Single system image architectures should make connections using the loopback interface. It is assumed that network implementations have appropriate IP networks in place with routing between machines that can be identified either by IP address or by hostname. Firewalls must be properly configured to allow network communications between the client and server. Appropriate network configuration is the user's responsibility.

Data Connections

Data connections are used to deliver data from the Acq*Knowledge* server to the client application. Data connections stream both data acquired from an MP unit and computed data from Acq*Knowledge* calculation channels. Data connections are available in a variety of formats and can be configured to meet the needs of the client application and bandwidth requirements.

Data connections are created only at the start of acquisitions. It is not possible to "attach" to data acquisitions that are already in progress.

XML-RPC calls for retrieving data are also described in this section. These connections are not persistent and not established from server to client, but rather a request made from client to server. The recommended mode of operation is regular TCP or UDP operation.

Variable Sampling Rates

Acq*Knowledge* uses variable sampling rates that allow different channels of data to be acquired at different sample rates. This allows fast moving signals (such as EMG) to be acquired at high sampling rates while simultaneously recording slow moving signals (such as respiration) at lower sampling rates. The primary use of variable sampling rate is to optimize storage requirements by minimizing space spent retaining slow moving data.

In addition to the storage optimizations, variable sampling rates are also used to optimize data connections. Channels that are sampled at lower rates require less network bandwidth to transfer from client to server. If channels of data cannot be disabled and overall bandwidth is limited, variable sampling rate can be used to lower the bandwidth required to move data between the server and the client.

The use of variable sampling rates requires the client to be aware of downsampled channels and handle data accordingly. Variable sampling rate may also affect the interpretation of the incoming data connection stream, as indicated below.

Transfer Types

Clients may choose between two different transfer types:

- **single connection** uses one data connection between the server and the client to deliver all data
- **multiple connection** uses multiple data connections delivering data simultaneously

Single Connection

The single connection transfer type uses a solitary connection between the server and the client to deliver data. When multiple channels of data are being delivered, all data is sent over the single connection in an interleaved format. The interleaved format mingles the data of all channels in order. For example, an interleaved representation of two samples from three channels of data would be: C1 C2 C3 C1 C2 C3. This is equivalent to two sample frames where a *frame* contains the data at a particular sample location for all of the channels, in this case "C1 C2 C3". Frames are delivered sequentially over the data connection.

The single connection transfer type allows for all data to be processed from a single location and uses only one network connection resource. Single connection transfer has drawbacks including the need for the client to demux the data stream as well as account for variable sampling rates.

Variable Sample Rate Considerations

When variable sampling rate is being used, the single connection transfer type has the characteristic where not all frames have the same size. If a frame occurs at a sample position where a channel is not being sampled, that channel will not be included in the frame.

All downsampling within the Acq*Knowledge* variable sampling rate environment occurs at integer divisions of the base sampling rate. Only frames with indexes (zero-based) that are evenly divisible by the downsampling divider will contain data for that channel.

It is the responsibility of the client to compute and retain the frame index and to properly check channel dividers against the frame index to determine which channels are represented in that frame.

Frame 0 always contains a data point from every channel.

For example, consider a three channel acquisition. Channels 1 and 3 have a downsampling divider of 1, that is, they are being acquired at full speed. Channel 2 has a downsampling divider of 2, that is, channel 2 is being acquired at half speed. The first five frames of data in the single connnection transfer type will appear as follows:

C1 C2 C3 | C1 C3 | C1 C2 C3 | C1 C3 | C1 C2 C3

Note how frames 1 and 3 are shorter as they occur at positions where channel two is not defined.

If variable sampling rate is being used, clients are required to perform proper frame indexing in order to demux the interleaved data stream. If clients cannot handle variable sampling rate correctly and are using the single stream transfer type, clients should check all of the downsampling dividers using the control connection to Acq*Knowledge* and warn the user if the configuration cannot be supported with that client.

Multiple Connection

The multiple connection transfer type uses a single connection from server to client for each channel of data that is being delivered. Using multiple connections offers the benefit of avoiding the client having the need to demux all of the data from each sample. If the client is operating in a high-load environment, the elimination of the demuxing may be useful in reducing processor overhead. It also allows client code to be simpler if variable sampling rate is being used.

The primary disadvantages of using the multiple connection transfer type are the usage of more network ports and the client assuming responsibility for synchronization of data across multiple channels. The data immediately available on one network connection may not be guaranteed to be the identical sample index of data being received for another channel. The client must keep track of sample index on an individual channel basis to properly synchronize data across multiple channels.

Variable Sampling Rate Considerations

Using variable sampling rate in a multiple connection transfer type is significantly easier. Each individual channel's connection delivers data at that channel's sampling rate. On a given connection, all samples have an identical length.

Clients still must be aware of variable sampling rates. The sampling rate of information on a downsampled channel connection is different than the sampling rate of information on an upsampled channel connection. If the client is performing any time domain measurements or other computations involving the sample interval, the difference in inter-sample-interval must still be taken into account.

XML-RPC

The XML-RPC transfer type allows clients to explicitly request data from the server. Instead of data being automatically pushed to clients, the client must post an XML-RPC function call to the server. This allows the client to query the server for the most recently acquired data sample value for a particular channel. Clients that do not require continual data streams or interact with only slow moving data may wish to use this method communication method. This method returns values only; no information about sample indexes or lengths is returned.

XML-RPC has significant overhead for both client and server, so this transport method cannot handle more than a few requests per second. If faster response time is required, the client should implement either the single connection or multiple connection streaming methods.

XML-RPC is not a true data connection as it does not involve the server constructing a streaming connection to the client.

Transport Protocol

Data connections offer a choice of using either TCP or UDP as the transport protocol for delivering data to the client. Choice of protocol depends on application requirements. When a client is receiving data, it is assumed that all data connections are using the same transport protocol.

TCP/IP

TCP is the preferred transport protocol. As TCP guarantees reliable, ordered delivery, all data is simply transferred from the server to the client without any additional information. Data is streamed continuously as it becomes available. TCP is recommended for all clients that require a guarantee of receiving all information. It is also recommended for any configuration using up to two computers. The port number used for data connections is specified by the client using the control connection prior to the start of acquisition. Once a client passes along port information, the client should begin listening for connections on that port.

When using TCP data connections, the start of acquisition is signaled to clients by the establishment of a connection on an appropriate port to the client. The end of an acquisition is signaled by the termination of the connection.

UDP

UDP is a connectionless protocol that does not guarantee either delivery or properly ordered reception of packets by clients. Data connection is allowed to be switched to UDP delivery mode. The primary benefit of using UDP datagrams is that a single data stream can be multicast to a number of computers. Multicasting is not offered implicitly by the Acq*Knowledge* data connection protocol but can be achieved implicitly by requesting a data connection be bound to a broadcast address.

UDP delivery used fixed size datagrams. The default size is 512 bytes. Clients can modify this size to any fixed number of bytes prior to the start of acquisitions. The UDP packet size is stored in the template and is different for each graph. UDP clients that require a specific packet size should set that packet size prior to the start of each acquisition.

Each datagram will contain the following:

Field	*Data Type*	*Offset*	*Description*
Starting sample index	unsigned long (four bytes, network order)	0 byte	This indicates the starting sample position of the first sample of data contained in the packet. This number is always monotonically increasing and can be used to reassemble datagrams that are received out of order. This field is always stored in network order. Usage of htonl()/ntohl() should convert from network order into host endian.
Length of data section in bytes	unsigned long (four bytes, network order)	4 bytes	Total number of bytes in the data section. Data is sent by Acq*Knowledge* as it is available, so not all data packets will contain the same amount of data. This field is always stored in network order. Usage of htonl()/ntohl() should convert from network order into host endian.
Data section	(type and endian specified by client)	8 bytes	Data section containing the binary data that was acquired. The data is converted into the appropriate data as configured by the client.

All of the data delivery is performed as data is available from the MP unit. The actual size of the data section in packets that get delivered to the client is dependent on the speed of data acquisition and other activity on the host computer. If variable sampling rates are being used, frames will not be split up. All of the data for the final frame is contained in the UDP packet. If a frame will not fit in the amount of space in a packet, it is sent in the next packet.

There are no provisions for clients to request retransmissions of packets from the server. Clients should be aware that data may not be delivered when using UDP and should be prepared to examine sample indexes at the beginning of each packet and handle missing data accordingly (padding, warning user, etc.).

The port on which datagrams is delivered is specified by the client prior to the beginning of acquisition on the control connection. Once the client specifies its port, it should begin listening for datagrams delivered to that port. The start of acquisition is signaled by the first datagram that is sent to that port. The sample index of the first datagram corresponds to the first hardware sample of data acquired by Acq*Knowledge*. If the graph is initially empty, the index is zero.

Unlike TCP connections which get explicitly disconnected at the end of acquisitions, there is no direct messaging for UDP delivery indicating the end of acquisitions. Datagrams will not be sent to the client after the end of acquisition. Clients requiring explicit termination notification should either use TCP or implement a timeout mechanism combined with an XML-RPC getAcquisitionInProgress call on the control connection to locate the end of acquisitions.

XML-RPC

The XML-RPC “get most recent data sample” call will use standard XML-RPC connection semantics involving the client making an HTTP POST request to the server and interpreting the response as appropriate. Handling of XML-RPC can be performed by a library in the client's appropriate implementation language.

Real-time Delivery Guarantees

No delivery time guarantees exist for any data connection. Data is delivered to the client as it becomes available. The overall latency of the system from physical sample time to data delivery is dependent on a number of factors including network load, Acq*Knowledge* overhead (which is variable due to calculation channel processing time, user interface activity, thread scheduling, and other operations), system load, and other factors. The actual sampled data itself is guaranteed to be accurate; the sample time of a signal acquired into the MP unit is always accurate. It is only the time between the physical time corresponding to a sample and its delivery to the client application that is variable.

Clients that require strict real time guarantees or more predictable latencies should investigate using the hardware API on their local machine.

Data Formats

It is assumed that the data transfer feature is used in a mixed host environment, potentially with clients running in environments that have restricted data types. The sampled information delivered by a data connection is allowed to be controlled to appear in a variety of different formats for the client:

- 64 bit floating point – This format will always be available for all channels and may be delivered in either big endian byte order or little endian byte order. This is equivalent to a C style double data type.
- 32 bit floating point – This format will always be available for all channels and may be delivered in either big endian byte order or little endian byte order. This data type is not native to Acq*Knowledge*, so the precision of received data may differ from data as recorded by Acq*Knowledge*. This is equivalent to a C style float data type.
- Signed 16 bit integer – This format is available only for analog data channels. It may be delivered in either big endian byte order or little endian byte order. This is equivalent to a C style short data type. Clients receiving data in 16 bit integer format should use the control connection to determine appropriate floating point scaling factors that need to be applied to the data to convert into actual units.

Data formats should be specified by the client prior to the start of acquisition. If left unspecified, the default data format depends on channel type:

Channel Type	Default Data Type
Analog	16 bit signed integer, little endian
Digital	16 bit signed integer, little endian
Calculation	64 bit floating point, little endian

XML-RPC get most recent sample requests will always return the double type of XML-RPC (in ASCII notation).

Default Data Connection Settings

If the client does not modify any data connection settings, the following is used:

- Single connection transfer type
- TCP/IP transport protocol
- Port 15020 for single connection
- For multiple connections, each channel type (16 channels per type) is set as follows: analog channels [15020-15035], digital channels [15040-15055], calculation channels [15060-15075].
- Default data formats for each channel type as indicated in the “Data Formats” section

Note that no channels are enabled for delivery by default. Both data connection delivery and get most recent sample tracking are disabled. Clients will still need to enable channels in order to receive data.

Locating Acq*Knowledge* Servers

It is possible that clients and servers may be located on networks with dynamic IP addresses or other features that make establishing the connection between machines difficult. In this case, a simple UDP broadcast mechanism can be used to locate known servers.

Acq*Knowledge* will listen for incoming UDP packets on port 15012. If the UDP packet contains the sequence of ASCII characters “AcqP Client” and only that sequence, it will send a broadcast packet containing “AcqP Server Port:” followed by the port number on which the server is listening for control connections. The port number is expressed in base 10 ASCII notation.

It is possible to configure Acq*Knowledge* to not acknowledge discovery requests for security purposes.

Control Connections

Clients connect to an Acq*Knowledge* server using control connections. A control connection allows the client process to control how data is going to be delivered to it, query settings, modify settings, and perform other basic operations without requiring graphical interaction with the Acq*Knowledge* environment.

On the start of an acquisition, all data connections are established to the client that most recently established a control connection unless the client has modified the destination by using the changeDataConnectionHostname command.

It is possible to configure Acq*Knowledge* to not respond to any control connections for security purposes.

The majority of all control connections use XML-RPC. The XML-RPC specification can be located at http://www.xmlrpc.com/spec. XML-RPC consists of an HTTP POST request being assembled by the client along with data content expressed in the XML-RPC notation. The remote procedure call will then return with an appropriate response to the caller. By design, XML-RPC is client and platform agnostic.

XML-RPC implementations exist for a number of languages. If there is no implementation in the client's language, hardcoded requests can be embedded or a small helper application or shared library can assist in providing the control connection interface.

The URI that should be used when connecting to the server is the recommended “/RPC2” for XML-RPC. For example, a URL for localhost control connections would be “http://localhost/RPC2”.

TCP Port

Only one control connection may be opened by a client to a server at a time. The server will listen on port 15010 by default. As this port may conflict with other network services or may need to be modified for firewall accessibility, Acq*Knowledge* will allow the server port to be modified by the user in the Display > Preferences panel. Clients should be aware that control connection port numbers are not fixed and should either allow users to change the port number from the client or use the dynamic discovery mechanism for locating Acq*Knowledge* servers.

Control Procedure Calls

Control procedure calls are remote procedure calls with a set method name and response. All method names and strings are case sensitive. The available control calls are roughly split up into querying acquisition parameters, configuring data delivery, and limited calls for modifying acquisition parameters and affecting application state.

Channel Index Parameter Structures

Some procedure calls take a *channel index structure* as a parameter. This is an XML-RPC structure that consists of the channel type and index. The channel type is a string member named "type" that is one of the following strings: analog, digital, calc. The channel index is an integer member named "index" and contains a zero-based index indicating the channel. For example, the following channel index parameter structure can be used to refer to calc channel 2 (recall, in Acq*Knowledge* calc channels are indexed from zero):

```
<struct>
    <member>
        <name>type</name>
        <value><string>calc</string></value>
    </member>
    <member>
        <name>index</name>
        <value><int>2</int></value>
    </member>
</struct>
```

Querying Acquisition Parameters

The calls for querying acquisition parameters are intended to allow clients to request information required for them to fill out appropriate parameters and to verify that previous control requests have been properly applied. The following control calls are recognized:

getMPUnitType

Method name: acq.getMPUnitType
Parameters: None
Return value: int

Retrieves the type of MP unit to which the server is connected. This may be zero (indicating no unit is connected, e.g. "No Hardware" mode), 150 (for MP150), or 36 (for MP36R).

The client can use this value to decide between appropriate templates to download or other channel settings.

getEnabledChannels

Method name: acq.getEnabledChannels
Parameters: string
Return value: array populated with int

Retrieves the channels that are available for acquisition and data delivery over a data connection to the client. The type of channels that are to be returned are specified in the string parameter. The string parameter may be one of the following: analog, digital, calc. The type must be lowercase. "analog" returns information about analog channels, "digital" digital channels, "calc" calculation channels.

The enabled channels are returned as an array of channel indexes, zero-based. These are the indexes that can be validly used in calls for configuring data connection parameters.

getChannelScaling

Method name: acq.getChannelScaling
Parameters: channel index parameter structure
Return value: struct containing scaling

For channels that can be delivered in short integer format, the channel scaling provides the scale factor and offset used to convert the short into physical units using the formula: sample*scale+offset. The scaling is returned as a structure containing two double-valued members: “scale” contains the multiplication factor, “offset” contains the offset factor.

Channels that cannot be delivered as short integers cannot be scaled. If this method is called with an invalid type of channel, a fault response is returned.

getSamplingRate

Method name: acq.getSamplingRate
Parameters: None
Return value: double

Returns the current sampling rate expressed in Hz. This is the rate at which data is sampled for a channel whose downsampling divider is 1.

getDownsamplingDivider

Method name: acq.getDownsamplingDivider
Parameters: channel index parameter structure
Return value: int

Retrieves the downsampling divider for a particular channel. A channel is sampled at the base sampling rate divided by this factor. This factor is also used to determine which frames contain samples for this channel.

Data Connection Configuration Commands

While it is possible to configure data connection parameters using Acq*Knowledge*, frequently clients may need to alter data connection configurations based upon dynamic information regarding the machine on which they are running (e.g. port collisions with other services, unexpected endian changes, etc.). The following commands may be used to configure how data is delivered to the application.

getDataConnectionMethod

Method name: acq.getDataConnectionMethod
Parameters: none
Return value: string

Returns the method currently being used for data connections between the server and client. The string value is either: single, multiple. “single” corresponds to a single data connection being made between the server and the client with all data interleaved over that connection. “multiple” corresponds to opening an individual connection to the client for each channel.

changeDataConnectionMethod

Method name: acq.changeDataConnectionMethod
Parameters: string
Return value: 0 on success, or fault code

Changes the method used to deliver data to the client. The parameter is a string that is one of the following: single, multiple. “single” opens up a single data connection and sends data in an interleaved fashion. “multiple” opens up an individual data connection for each channel.

getDataConnectionHostname

Method name: acq.getDataConnectionHostname
Parameters: none
Return value: string

Returns the currently set hostname for data connections. When data connections are established on the start of acquisition, the IP address associated with this hostname is sent the data. Hostnames must properly resolve in order for data connections to be made; DNS configuration is outside of the scope of the network data transfer feature.

If this hostname is empty, data connections is made to the most recently connected client application. This is the default setting.

Hostnames are unique on a graph by graph basis and are saved in templates and graph files. Clients redirecting data to another machine should check and set the data connection hostname as appropriate prior to the start of acquisition.

changeDataConnectionHostname

Method name: acq.changeDataConnectionHostname
Parameters: string
Return value: 0 on success, fault on error

Changes the destination machine for data connections, the recipient of the network delivered data. If the parameter is an empty string, data connections will automatically be made to the most recently connected client. The empty setting is the default.

If non-numeric hostnames are specified as parameters, they must be resolvable. If a hostname cannot be resolved, a fault is returned. Proper DNS configuration of the server is beyond the scope of the network data transfer feature.

getTransportType

Method name: acq.getTransportType
Parameters: None
Return value: string

Retrieves the transport type that is being used to deliver data from the server to the client. The transport type is a string that is one of the following: tcp, udp. Note that the XML-RPC data delivery method may be used in addition to this transport type if channels are enabled.

changeTransportType

Method name: acq.changeTransportType
Parameters: string
Return value: 0 if successful, else fault code

Change the transport type that is used to deliver data from the server to the client. The transport type is a string that has one of the following values: tcp, udp. XML-RPC last value data delivery may be used in addition to this type provided channels are enabled properly.

getUDPPacketSize

Method name: acq.getUDPPacketSize
Parameters: None
Return value: int

Returns the current size in bytes of UDP packets that is delivered to clients. Datagrams are always this fixed byte length although each individual datagram may contain varying amounts of data.

setUDPPacketSize

Method name: acq.setUDPPacketSize
Parameters: int
Return value: 0 on success, fault on error

Changes the size in bytes of UDP packets that are delivered to clients. Each individual datagram will always be this fixed length although the amount of data sent in specific packets may vary.

getUDPBroadcastEnabled

Method name: acq.getUDPBroadcastEnabled
Parameters: None
Return value: boolean

Determine if UDP packets are sent only to the client or are broadcast to the broadcast IP of the network. Broadcasting is supported only when the transport type is UDP.

changeUDPBroadcastEnabled

Method name: acq.changeUDPBroadcastEnabled
Parameters: boolean
Return value: 0 if successful, fault code on error

Modify whether UDP packets are sent only to the client or are broadcast to the broadcast IP of the network. Broadcasting is supported only when the transport type is UDP.

getSingleConnectionModePort

Method name: acq.getSingleConnectionModePort
Parameters: None
Return value: integer

Returns the port number on which the server will connect to the client to deliver data. This port is used only when the connection mode is set to "single" which interleaves all data over a single connection.

changeSingleConnectionModePort

Method name: acq.changeSingleConnectionModePort
Parameters: integer
Return value: 0 on success, else fault code

Modifies the port on which the server connects to the client to deliver data. This port is used only when the connection mode is set to "single" which interleaves all data over a single connection.

getDataDeliveryEnabled

Method name: acq.getDataDeliveryEnabled
Parameters: channel index parameter structure
Return value: boolean

Query whether a channel is enabled for data delivery. Channels must be enabled for data delivery in order for their data to be delivered to the client. Not all channels that are being acquired are required to be delivered to data delivery.

changeDataDeliveryEnabled

Method name: acq.changeDataDeliveryEnabled
Parameters: channel index parameter structure, boolean
Return value: 0 for success, else fault code

Change whether or not data delivery is enabled for a particular channel. Data delivery can only be changed prior to the start of an acquisition. Changes to data delivery enabling are only applied on the next start of acquisition.

getMostRecentSampleValueDeliveryEnabled

Method name: acq.getMostRecentSampleDeliveryValueEnabled
Parameters: channel index parameter structure
Return value: boolean

Query whether a channel is enabled for most recent data sample requests. If a client wishes to use the XML-RPC calls to fetch the most recent value of data acquired of a channel, the channel must be enabled for this functionality prior to the start of acquisition.

changeMostRecentSampleValueDeliveryEnabled

Method name: acq.changeMostRecentSampleDeliveryValueEnabled
Parameters: channel index parameter structure, boolean
Return value: 0 for success, else falut code

Change whether or not a channel is enabled for most recent data sample requests. When a channel is enabled, XML-RPC calls can be used during an acquisition to return the most recent sample of data acquired (or computed) for the channel. Any changes to the enabled state of a channel is applied on the start of the next acquisition. If a client wishes to use XML-RPC calls to read the value of a channel, that channel must be enabled prior to the start of the acquisition.

getDataConnectionPort

Method name: acq.getDataConnectionPort
Parameters: channel index parameter structure
Return value: int

Retrieves the port on which the the server will deliver the data for the channel specified in the parameters to the client. Per-channel data connections are only used if the data connection method is set to "Multiple".

changeDataConnectionPort

Method name: acq.changeDataConnectionPort
Parameters: channel index parameter structure, integer
Return value: 0 for success, else fault code

Changes the port on which the individual connection is made by the server to the client to deliver the data for the channel specified in the parameters. This style of connection is used only if the data connection method is set to "Multiple".

getDataType

Method name: acq.getDataType
Parameters: channel index parameter structure
Return value: structure

Returns the data type that is being used in the binary data streams for the channel's data. The return value is a structure with a type and endian member. The type member, named "type", is a string and contains one of the following values: short, double, float. These strings correspond to their matching C-style data types. The endian member, named "endian", is a string and contains one of the following values: little, big. "little" corresponds to little endian byte order, big endian bit order. "big" corresponds to big endian byte order, big endian bit order.

changeDataType

Method name: acq.changeDataType
Parameters: channel index parameter structure, type structure
Return value: 0 on success, or fault code

Changes the data type that is used for binary data streams of the channel's data. The type structure is a struct containing two members. The "type" member is one of the following strings: double, float, short. Each string corresponds to the matching C-style data type. The "endian" member is one of the following strings: little, big. Each corresponds to the matching byte endian. Bit order within a byte will always be big-endian.

Not all channels may be able to support all data types. If the channel cannot be transmitted in the requested data type, a fault code is returned.

setDataConnectionTimeoutSec

Method Name: acq.setDataConnectionTimeoutSec
Parameters: integer of new timeout in seconds
Return value: 0 on success, or fault code

Changes the timeout in seconds after which the data connections is closed when acquisitions complete. Clients may need to set this keep-alive timeout in order to receive the trailing data at the end of acquisitions. The default value is “0” seconds which terminates all data delivery connections immediately when the final sample of data is acquired.

Reading Data During Acquisition

Normally data is delivered to clients during acquisitions using data connections. Data connections are either TCP or UDP connections established from the server to the client over which the server streams the incoming data. In some languages and environments however, it may not be possible to handle continuous data streams. The following XML-RPC commands are offered to assist these types of clients. Due to the large overhead of processing connections and XML-RPC requests, this data transfer type is not recommended and TCP/UDP should be used wherever possible.

getMostRecentSampleValue

Method name: acq.getMostRecentSampleValue
Parameters: channel index structure
Return value: double, or fault code

This procedure allows clients to read the most recent data value of a specific channel during acquisitions. In order for this call to be successful, a data acquisition must be in progress and the channel must be enabled for most recent sample value data delivery. Issue a changeMostRecentSampleValueDeliveryEnabled call prior to acquisition to allow this procedure to be used.

getMostRecentSampleValueArray

Method name: acq.getMostRecentSampleValueArray
Parameters: none
Return value: array of structures with channel info and values, or fault code

This procedure allows clients to retrieve the most recent data values of all channels during acquisitions in a single call. If clients are interested in the values of multiple channels, using this method is more efficient than performing consecutive getMostRecentSampleValue calls (which require an individual POST request per call).

Only channels that are enabled for most recent sample value data delivery is returned. Issue a changeMostRecentSampleValueDeliveryEnabled call for each desired channel prior to acquisition in order for this to return the value for a channel.

The return value is an array of structures, one per channel. Each structure contains two members. The “channel” member will contain a channel index structure with members set to appropriate type and index information for the channel. The “value” member is a double that contains the most recent sample value of the channel specified in the “channel” member.

This procedure cannot be called unless there is an acquisition in progress and there is at least one channel enabled for most recent sample value delivery.

Other Control Connection Commands

Control connections will also allow for the following additional commands to be used by clients:

loadTemplate

Method name: acq.loadTemplate
Parameters: base64 encoded binary AcqKnoweldge graph template
Return value: 0 on success, or fault code

Attempts to open the passed template within the Acq*Knowledge* environment. The parameter is a base 64 encoded Acq*Knowledge* “gtl” graph template file. Only templates in PC Acq*Knowledge* 3.7.1 or Mac Acq*Knowledge* graph templates are allowed to be used with this command. The parameter must include the entire contents of the template file.

The parameter in the XML-RPC call should be a base64 parameter with the raw binary contents of a graph template file. When this parameter is decoded, it should correctly provide the contents of a template file on disk.

This function will return 0 on success, otherwise a fault code if the template could not be loaded. Once a template is loaded, the hardware settings contained within that template is used for subsequent data acquisitions. Templates for ACQ 3.9.2 and higher will retain any data connection settings that have been specified by clients. After loading a template, clients should re-send any configuration information for ports and data connection methods if they do not match the new settings from the template.

If the template data is corrupted or is incompatible with Acq*Knowledge*, user interaction may be required on the server computer to dismiss any error messages when attempting to load the template. If user interaction is required on errors, this call may not return until the user interaction has completed. Clients who are using XML-RPC bindings that offer timeout services may wish to use them with this function.

getAcquisitionInProgress

Method name: acq.getAcquisitionInProgress
Parameters: none
Return value: boolean

Query whether data acquisition is currently in progress or not. A value of true is returned if data acquisition is occurring in any open Acq*Knowledge* graph window.

toggleAcquisition

Method name: acq.toggleAcquisition
Parameters: none
Return value: 0 on success, else fault code

Toggles data acquisition in the frontmost graph. If data acquisition is in progress, it is halted. If none is in progress, data acquisition is started in the graph.

Note that this function invocation may block if physical user interaction is required to start the acquisition in the graph, such as dismissing an overwrite warning, warnings on incompatibilities between different MP unit types, specifying a save location for acquisition to disk, etc. If the implementation of the XML-RPC binding used by the client supports timeout capabilities, it is highly recommended to enable timeouts for this function.

setOutputChannel

Method name: acq.setOutputChannel
Parameters: channel index structure, float output value
Return value: 0 on success, else fault code

Changes the voltage on the specified output channel of the MP device. For analog outputs, the value should be in the range (-10, 10) for the voltage level. For digital outputs, a value of 0 will turn the specified line off, a non-zero value will turn it on. The latency of when the output line is changed is variable and non-guaranteed. Additionally, the output channel may be modified by other areas of the software including control channels, manual user intervention, configured stimulators, etc.

The valid output channels are dependent on the type of MP device that is connected.

- MP150 units allow analog 0, 1 and all digital output channels
- MP36R units allow no analogs and digital 0-8.

Chapter 22 Licensed Functionality: Vibromyography

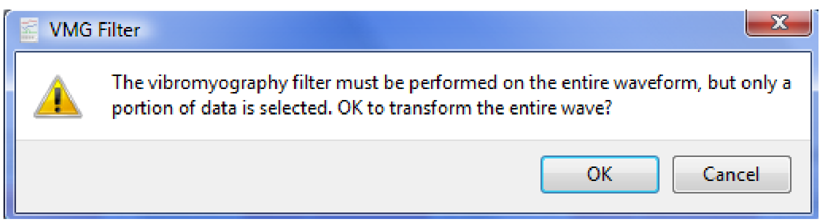
VMG functionality is available through an optional license available with Acq*Knowledge* 4.1.1 or above. The VMG license must be authorized to access VMG functionality. To add a VMG license to an existing MP System, please contact BIOPAC.

The vibromyography transducer (TSD250) uses an accelerometer to measure surface vibration during activity which is directly correlated to muscle activity; this allows for muscle force and balance to be assessed without using surface electrodes or needle probes. The VMG license allows access to software processing algorithms that are incorporated into Acq*Knowledge* to perform data reduction for analysis of data collected from a VMG system.

The VMG license:

- adds “Vibromyography” Calculation channel Preset with required scaling and calibration
- adds “Vibromyography Filter” option under the Analysis menu
- includes Quick*Start* Q45 Vibromyography (.gtl format)—the journal of the file introduces VMG and the hardware settings use Module Setup to add a “VMG Transducer” to analog channel 1 and analog channel 2 of an HLT100C module. Two calculation channels are set to the “Vibromyography” preset using analog channel 1 and analog channel 2 as the respective source channels.

A side-effect of the VMG analysis is that the sampling rate of the channel is lowered by a factor of 32. In the Acq*Knowledge* software, all data in an individual waveform must share a single sampling rate divider; it is not possible to mix sampling rates within a channel. As such, the analysis must be performed on the entire data signal. Traditionally, if there is only a single point selected (0 width selection), the entire data channel is transformed. If there is a selected area, the application will check if it encompasses the entire waveform. If the entire waveform is selected, the entire waveform will be transformed. If only a portion of the channel is selected, the following warning will be displayed:



When OK is clicked, analysis will be performed on the entire waveform. The selected area will be maintained but the waveform regions outside the selected area will still be transformed. This matches the “Transform entire wave” checkbox operation of other transformations. Cancel exits without modifying the data.

Sampling Rate Restrictions

The Vibromyography Filter is designed to process data acquired at 2 kHz sampling rate only. If the correct sampling rate is not used (via MP menu > Set Up Acquisition), results may be unpredicatable.

Transducer Setup

The TSD250 VMG transducer is a MEMS accelerometer transducer used for recording vibromyography signals from major muscle groups.

- MP150: Activating the VMG license adds the “VMG Transducer” option to the MP150 module setup; it is an HLT100C high level transducer.
- MP36R Support—the MP36R system may be useful for VMG analysis as four channels allows for comparison of muscle balance between two muscle groups. No custom preset is included for VMG transducers and any filters, offsets, and calibration/scaling will need to be configured manually—contact BIOPAC for support.

Post-analysis Selection Adjustment

After the analysis completes, the waveform sampling rate of the selected waveform will be reduced by a factor of 32. As this reduction occurs, the selected area or zero-width cursor location will be adjusted to snap to the nearest samples of data in the processed VMG channel.

Data Modification History Name

This operation will be displayed in data modification logs (Display > Channel Info) as "VMG Analysis."
It will not have any parameters.

VMG Calculation Channel Preset

The Vibromyography calculation channel preset uses the VMG channel as its source channel. The calculation channel preset automatically applies a downsampling divider of 32 based on the acquisition sampling rate.

- A hardware calculation channel preset can only have a fixed divider of the acquisition sampling rate. This calculation channel preset requires the source channel to be acquired at the acquisition sampling rate. If a user changes the channel sampling rate of the source channel, the calculation channel will not be updated and must be manually adjusted—the user will be required to set the calculation channel to the channel sampling rate of the source channel divided by thirtytwo.

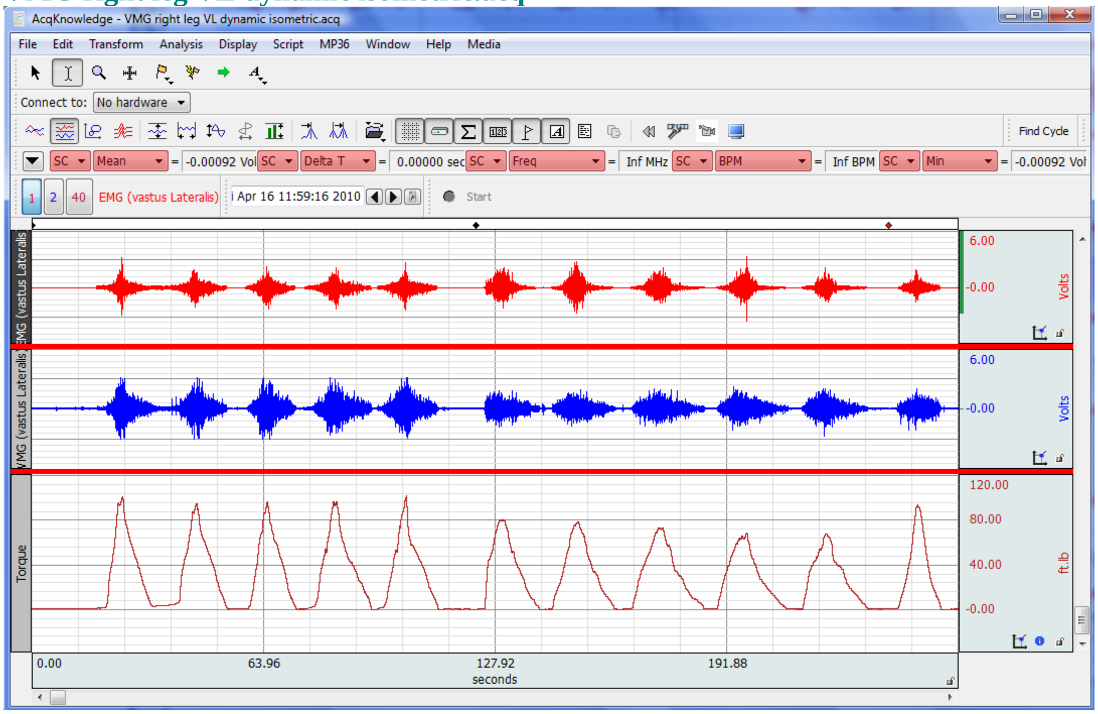
At the end of an acquisition, the Vibromyography preset automatically performs the following steps:

1. Check if VMG Analysis is available. If VMG analysis is not available, display a warning dialog that the VMG license needs to activated (or purchased from BIOPAC).
2. Check if acquisition is running in append mode and, if so, check that the destination channel waveform sampling rate divider will apply the correct reduction factor of 32 compared to the selected/source channel divider. If there is a mismatch, a warning prompt is generated advising users that additional segments will no longer be able to be acquired into the graph and asking them to confirm that VMG processing should proceed.
3. Perform Vibromyography Analysis filtering; this reduces sampling rate by 32.
4. Adjust selection to highlight only the most recently acquired data segment. If not in append mode, all data will be selected.
5. Copy the processed data to the clipboard.
6. Select the destination calculation channel.
7. Paste processed data from clipboard over the zero valued data for the appended segment (or entire channel if not in append mode).
8. Remove the duplicated channel created in step 3 to allow further data segments to be acquired.

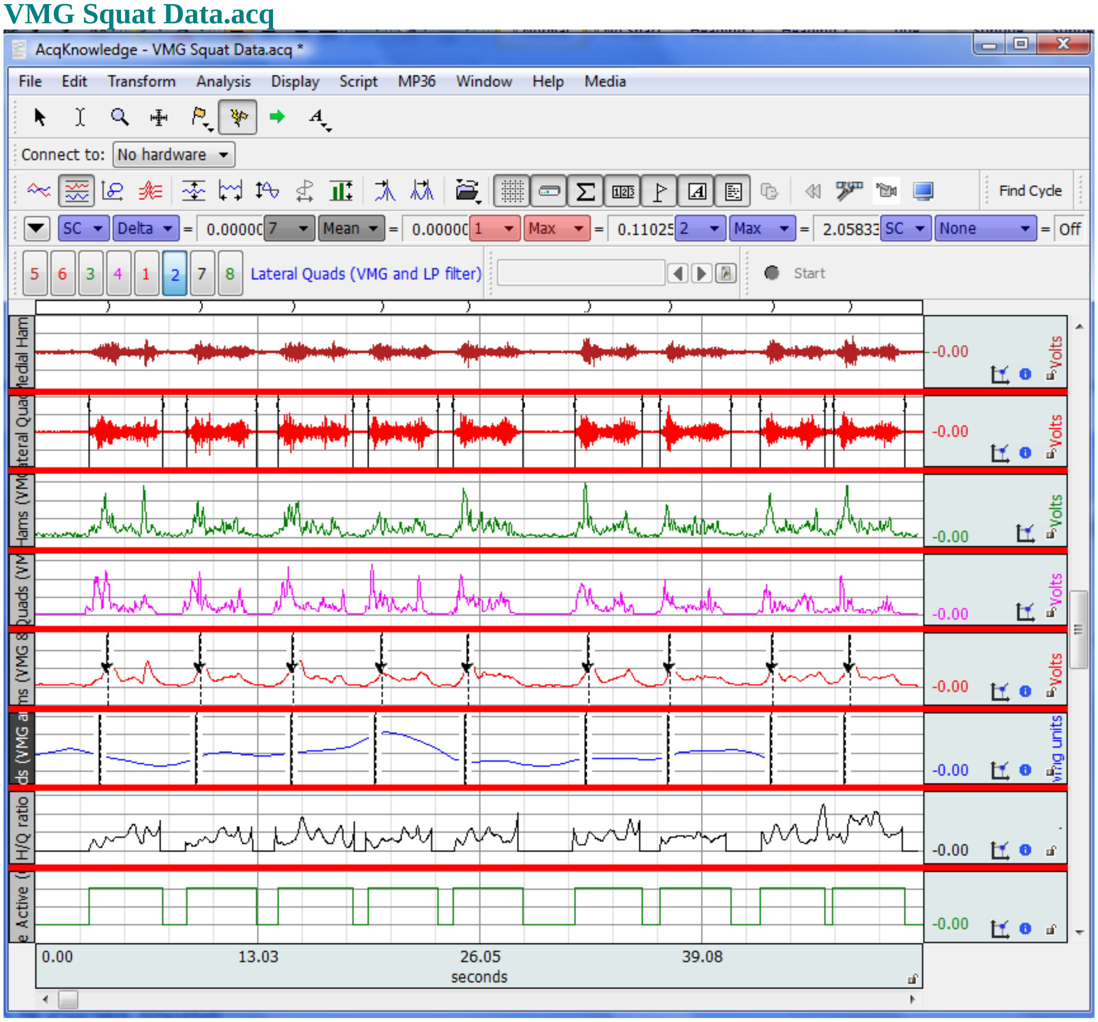
VMG Sample Data Files

Two sample data files illustrating basic VMG data and analysis results are included:

- **VMG right leg VL dynamic isometric.acq**



- **VMG Squat Data.acq**



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Chapter 23 Licensed Functionality: Scripting

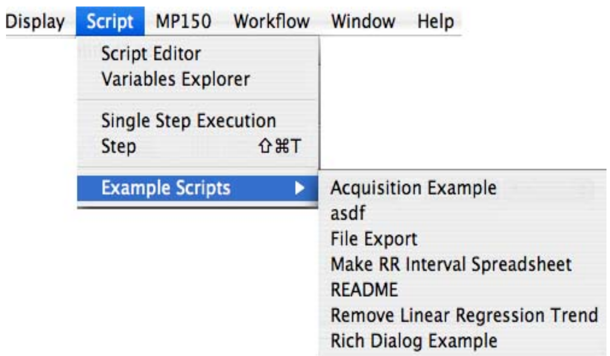
Scripting functionality is available through an optional license available with Acq*Knowledge* 4.1.1 or above. The Scripting license must be authorized to access Script functionality for executing, authoring, and debugging BIOPAC Basic scripts. To add a Scripting license to an existing MP System, please contact BIOPAC.

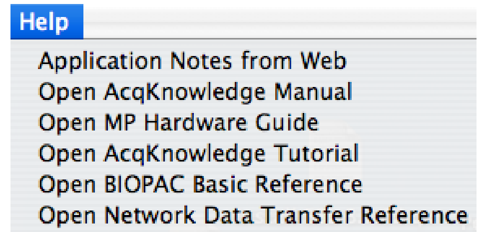
Scripting is available for Windows Vista and Mac OS X 10.5 or above and also requires Qt SDK 4.5.0 or higher for rich dialog development.

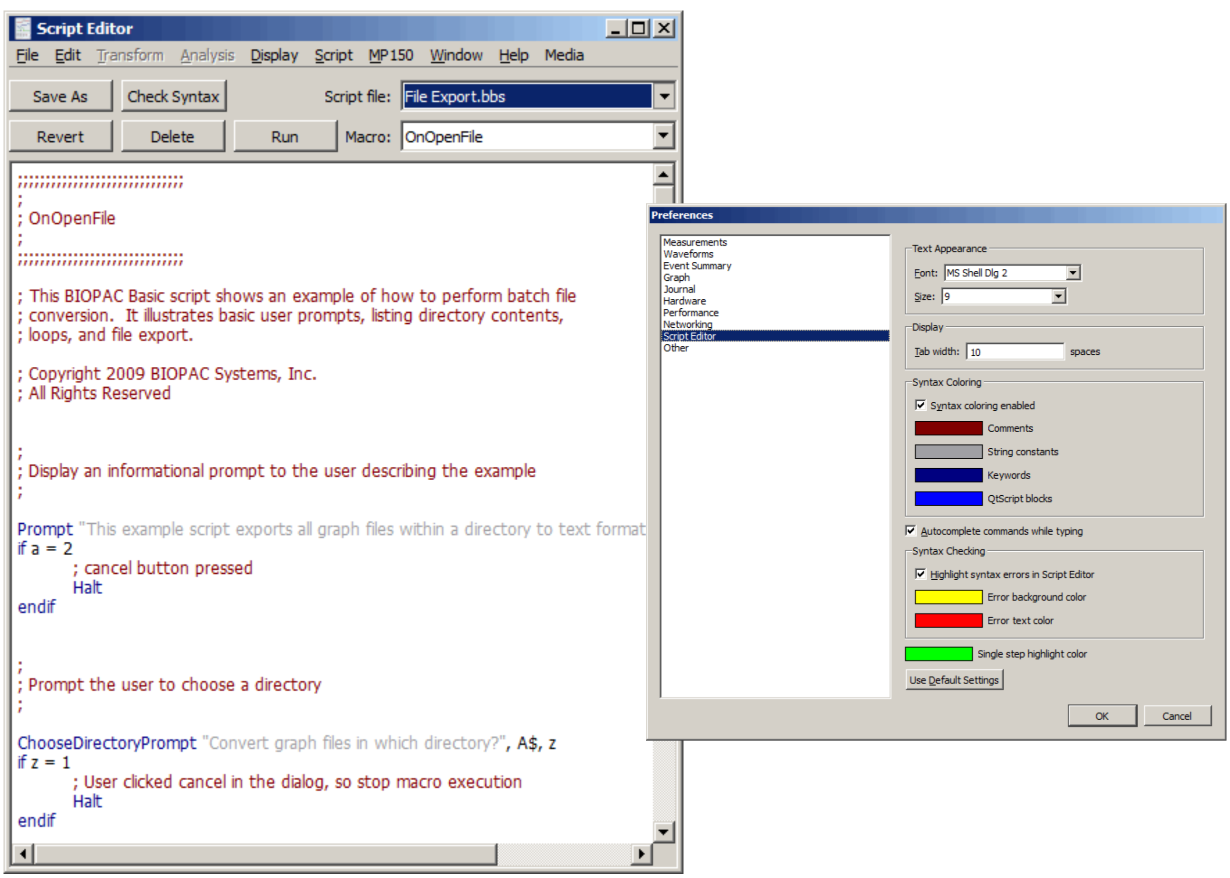
BIOPAC Basic Scripting is a scripting language development option for Acq*Knowledge* 4.1 that allows for viewing of runtime variables, creating new script files and editing existing script files, triggering of individual script functions for testing and single step functionalities. Only users that have licensed the BIOPAC Basic feature may run user-generated scripts; if the feature is not available only digitally signed BIOPAC scripts may be executed.

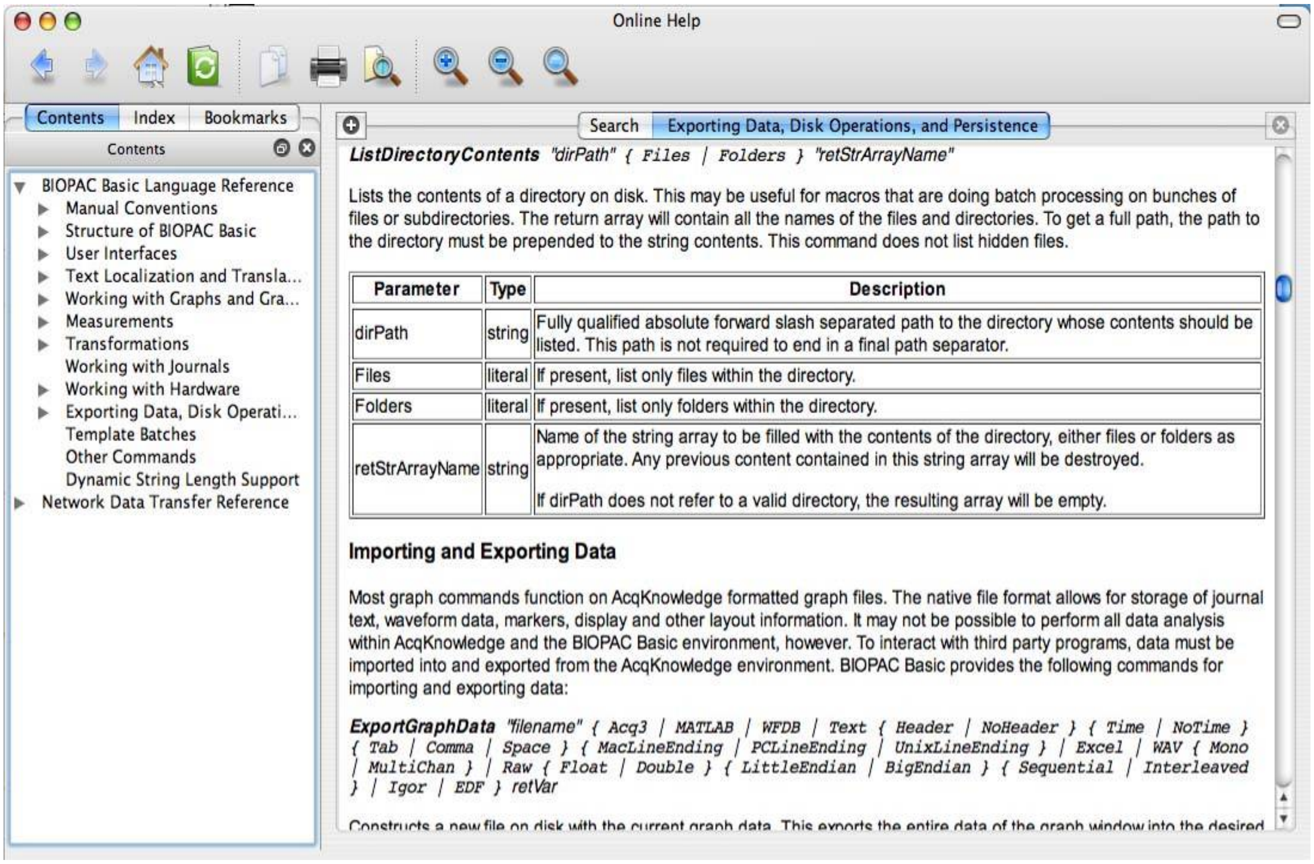
The Scripting license

- enables the Script menu
- adds the Calculation channel Preset "Run Macro"
- links the **BIOPAC Basic Reference** under Help
- adds Preferences for Scripting









The "Run Macro" Preset enables automatic post-processsing at the end of acquisition.

Single Step Execution mode halts execution after each individual line of a macro, which allows for stepping through macros line by line for debugging and development purposes.

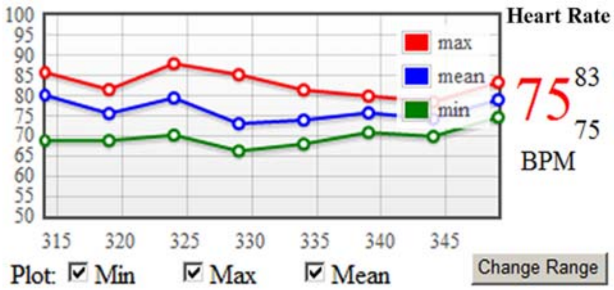
The Variables Explorer window shows the contents of the scripting language variables.

Note

- Inserting an extra End in the middle of the macro creates a second macro upon saving. The second macro starts immediately after the inserted End.
- Calculation channels for Run Macro created in the licensed version will be converted to Integrate if opened in a copy of Acq*Knowledge* that does not have a Scripting license.

Chapter 24 Licensed Functionality: Remote Monitoring

Remote Monitoring functionality is available through an optional license available with Acq*Knowledge* 4.2 or above.The license must be authorized to access Remote Monitoring functionality. To add a license to an existing MP System, please contact BIOPAC.



New! Remote Monitor

Simplified user interface to view subject data on another computer or mobile device – 'bedside monitor' display.

Track the welfare of the subject with alarms to warn when signals fall out of range. The system will work on any device that has access to the same IP based network as the MP150.

Acq*Knowledge* MP devices are generally tethered to specific computers where data acquisition is performed. In some laboratories, this computer may not be in the same location as the researcher performing the experiment. In MRI situations, for example, the data acquisition computer may be in the MRI control room but the researcher may be in a separate area. Acq*Knowledge* Remote Monitoring offers researchers the capability of checking on critical parameters from an alternate location.

Remote Monitoring is a client/server application capable of locating and connecting to computers running Acq*Knowledge* on the same network. It consists of a simple browser interface, from which acquisitions can be started, stopped and remote data viewed during and post-acquisition.

About Remote Monitoring

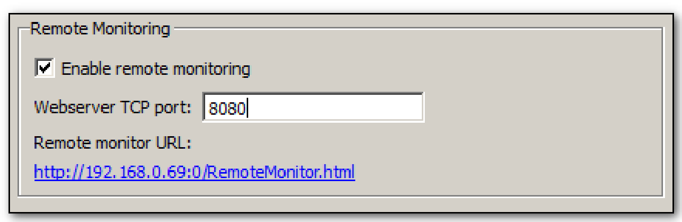
- Remote Monitoring is licensed functionality and must be activated by BIOPAC.
- Remote Monitoring is for viewing of data only. Transformation and specialized analysis of graph data is not supported within the Remote Monitoring interface.

The Remote Monitoring web interface consists of three primary pages:

- A list of open graph windows
- Configuration settings for an individual graph
- The data monitoring page.

Remote Monitoring in AcqKnowledge Networking Preferences

Remote Monitoring is enabled by default in Acq*Knowledge* Networking Preferences (Display > Preferences > Networking > Remote Monitoring). The **Enable remote monitoring** checkbox option activates the local machine on the network, making it visible to other local network machines also running Acq*Knowledge* Remote Monitoring.



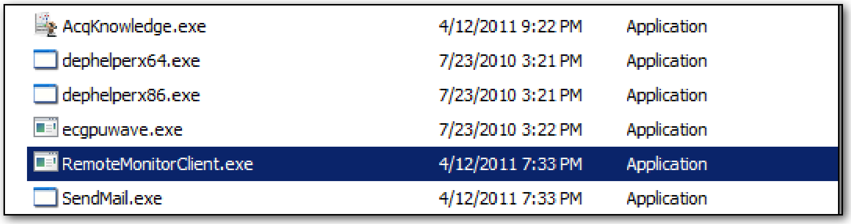
The **Webserver TCP port** is the numerical port on which Acq*Knowledge* listens for remote requests. (This port is set to 8080 by default.) The **Remote monitor URL** is a clickable link that opens Remote Monitoring in the local machine's default web browser. **This view will display acquisitions running on the local machine only**. (This is actually an easy way to become familiar with Remote Monitoring). To view acquisitions running on machines in other network locations, the stand-alone **Remote Monitoring Client** application must be used. For further details, see the Remote Monitoring Client section on the following page.

NOTE If a Remote Monitoring preference or port setting is changed, the new preference will not be applied until the subsequent Acq*Knowledge* application launch.

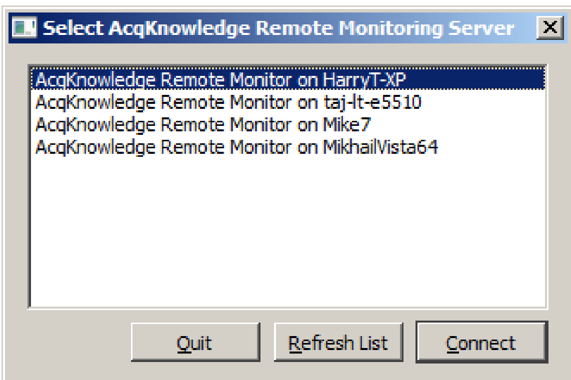
Remote Monitoring Client

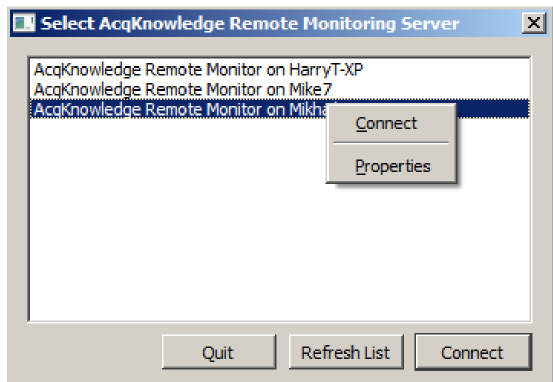
The Remote Monitoring Client is a stand-alone application residing in the Acq*Knowledge* program folder. This application facilitates the remote connection to other computers running Acq*Knowledge* acquisitions on the local network. Acq*Knowledge* does not need to be running on the local machine in order to use the Remote Monitoring Client to observe remote acquisitions in progress. To launch the Client, browse to the following directory:

Main Drive:\Program Files\BIOPAC Systems, Inc\AcqKnowledge 4.2\RemoteMonitorClient.exe



Double-click on the **RemoteMonitorClient.exe** to launch the application. After launching, the first presented item is the **Remote Monitoring Server** list. This is a list of other Acq*Knowledge* computers on the network that have Remote Monitoring enabled.





Quit Exits Remote Monitoring Client

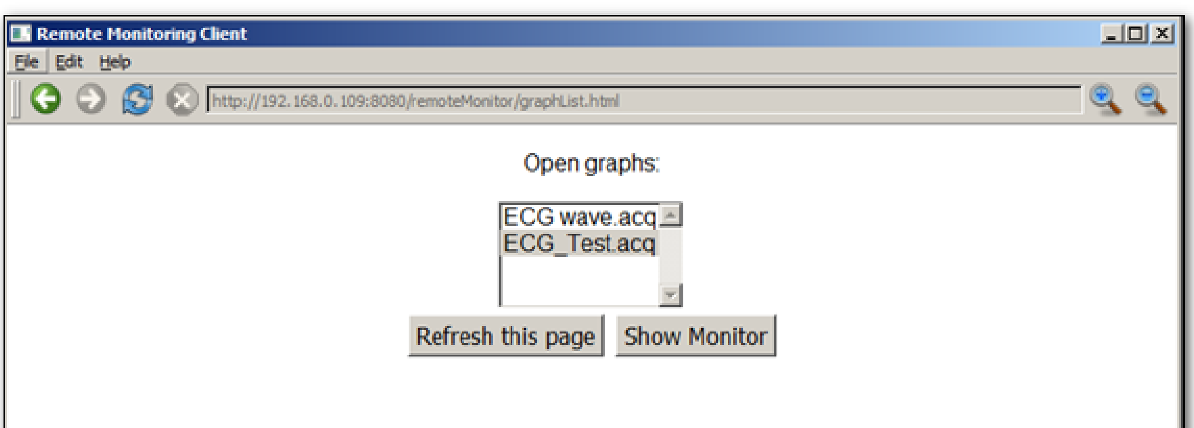
Refresh List Updates list of available Acq*Knowledge* Remote Monitor computers on network

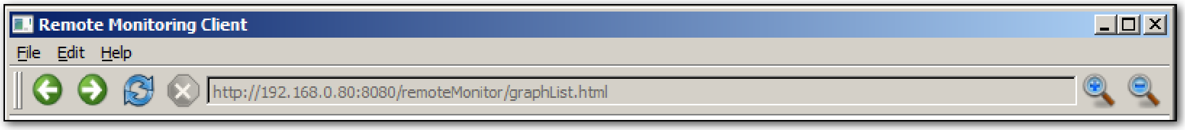
Connect Connects to the computer selected in list

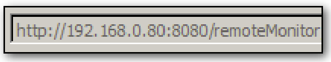
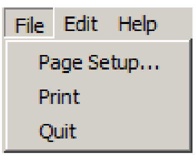
The above-right figure shows a right-click contextual menu available within the Remote Monitoring Server List, which allows an alternate means of connecting to a selected computer. The Properties option displays the Acq*Knowledge* application status, along with network and hardware information about the selected computer.

Remote Monitoring Client Browser

Selecting a computer from the list launches the Remote Monitor Client browser interface. The navigation buttons operate in the same manner as most Internet browser controls. See the following page for details on the Remote Client browser buttons.

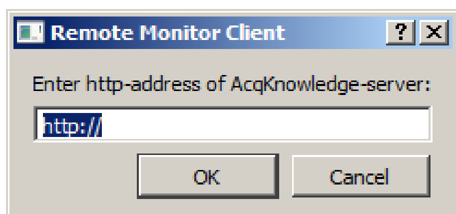




Icon	Button Function	Explanation
	Back	Moves browser back one page
	Forward	Advances browser ahead one page
	Refresh	Reloads the current page
	Stop	Stops loading of current page
	Address bar	Displays I.P. address of currently-connected computer
	Zoom in	Master control for enlarging size of browser content
	Zoom out	Master control for decreasing size of browser content
	File, Edit, Help menus	**File** contains Page Setup and Print controls for Remote Monitoring chart displays. Quit exits the Remote Monitor. **Edit** contains a Copy option. (Copy function not supported in Windows version) **Help** displays "About" information for the current version of Remote Monitoring Client*

NOTE for Windows only:

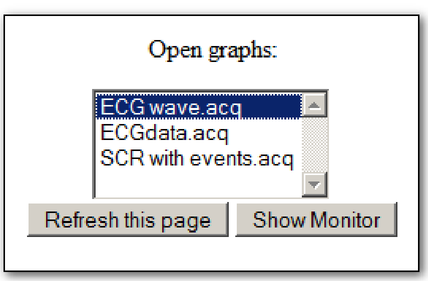
In order for the Remote Monitor Client to properly display the server list of additional Acq*Knowledge* computers on the network, Bonjour Service for Acq*Knowledge* must be installed. (The option of installing Bonjour Service is presented during the licensed Acq*Knowledge* 4.2 application installation). If Bonjour is not installed, the following dialog will be presented upon launch of the Remote Monitoring Client:



The I.P. address of the desired computer can be entered into the http-address field. If the address is valid, clicking OK will connect the Remote Monitoring Client to this computer. An acceptable entry should include the server IP address and UDP port number. (Example; http://192.168.1.76:8080)

Open Graphs Page

When the Remote Monitoring Client browser is launched, a scrollable list of all graph windows currently open on the selected remote machine is presented. Only one graph may be selected at a time.

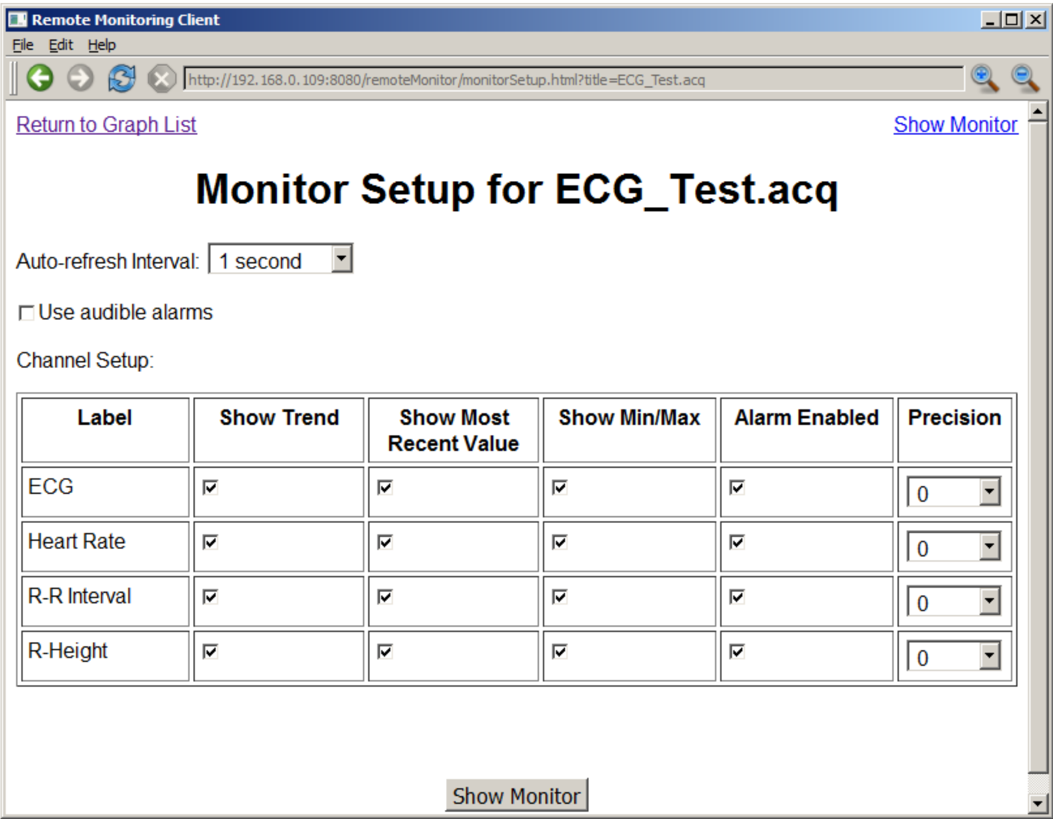


Refresh this page Reloads the page and refreshes the list of available graphs.

Show Monitor Advances the browser view to the selected file's setup page.

Configuration Settings Page

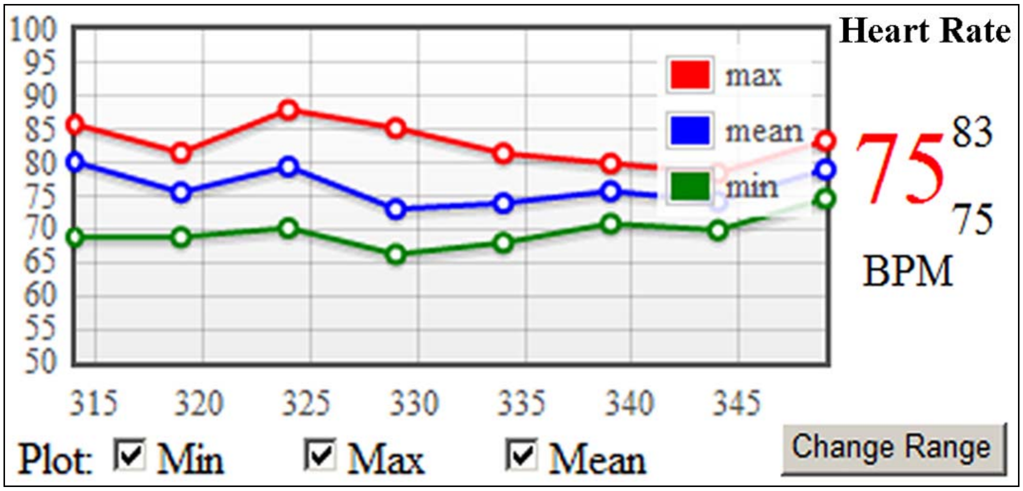
After selecting a graph and clicking **Show Monitor**, the following Monitor Setup page is displayed. This page contains configurable options for data display and other viewable parameters in the Remote Monitor graph. Note that all available options are set individually per channel.



Control	Description
Return to Graph List	Returns browser to list of currently-open graphs. Serves the same function as the browser's 'back' button.
Show Monitor	Saves the selected setup and advances the view to the data monitoring page. ('Show Monitor' button at bottom of screen duplicates this link's function)
Auto-refresh interval	Chooses the interval at which the monitored data is being refreshed over the network. The increments range from 1-sec. to 5 minutes.
Use audible alarms	When enabled, an alarm will sound if the Remote Monitoring graph data display exceeds its maximum or minimum visible ranges. The audio sound is a one-second beep followed by one second of silence. This audio playback is supported only on HTML5 compliant browsers.
Label	Displays assigned label of the AcqKnowledge data channel
Show Trend	Displays a graphical plot of the currently monitored data.
Show Most Recent Value	If checked, the most recent value of the channel data is displayed in a large font. If unchecked, textual display of this value is omitted.
Show Min/Max	Displays minimum and maximum value of currently monitored data.
Alarm Enabled	If the channel value exceeds the current trend display range, the alarm changes the color of the textual display to red and optionally plays audio.
Precision	Sets number of decimal places following channel display values.

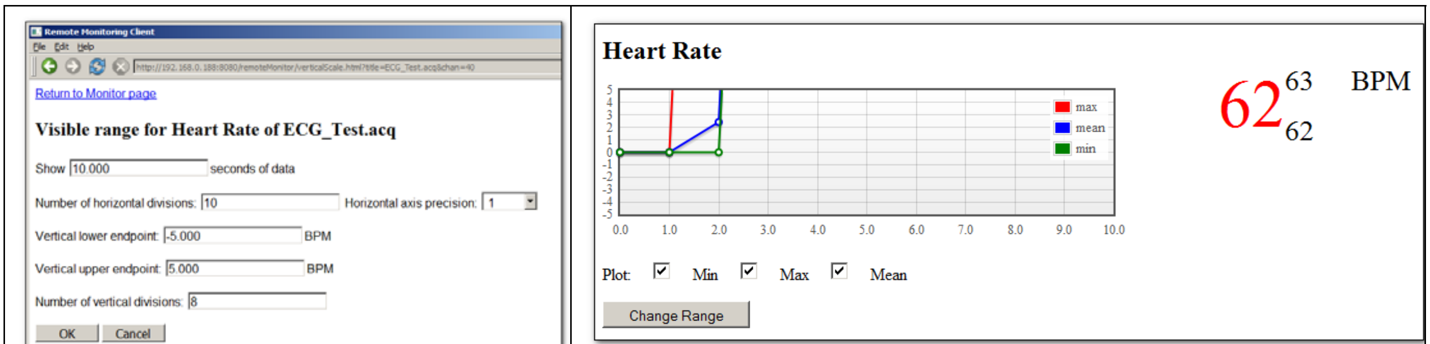
Data Monitoring Page

After the desired channel setup parameters are selected, choosing **'Show Monitor**' will advance the view to the data monitoring page.

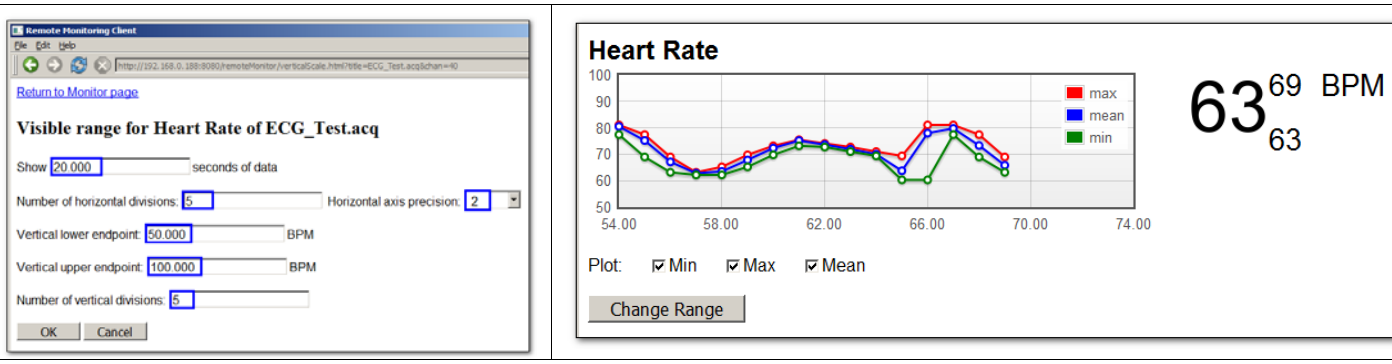


If an Acq*Knowledge* acquisition is already in progress and data being plotted, the screen will appear similarly to above, with the graph plot tracing at intervals determined by the Monitor setup auto-refresh rate. If the acquisition has not been started prior to launching Remote Monitoring; the **Start** button will be displayed in this screen. (Remote acquisitions can be easily started or stopped from within this data monitoring page).

Control	Description
Return to Graph List	Displays scrollable list of all currently-open graphs.
"-" and "+"	Controls for decreasing and increasing size of the input values display font.
Reset	Resets size of input values font display to default setting.
Show Monitor Settings	Returns to the "Monitor Setup" page for adjusting refresh rate, display options, and other monitoring parameters.
Start/Stop	Toggles between starting/stopping acquisition in Remote Monitoring graph.
Refresh Now	Updates data and controls on Monitoring page.
Stop Alarms	Halts any audio alarms that may be playing. Active only if Audio Alarm option is enabled.
Plot	Controls visual display of Min, Max and Mean values display of current graph
Change Range	Allows adjustment of visible ranges of the chart, similar to the vertical and horizontal scale dialogs found in the Acq*Knowledge* application. This is useful for viewing data that may otherwise appear out of range of the default scaling. Change Range only affects the data display in the Remote Monitoring window, not in the actual Acq*Knowledge* graph data. (See below for Change Range example and further details).



Default Visible range. (Note BPM data from this graph is 'out of range' in the above chart)



Visible range is modified via 'Change Range' to include entire data set. Horizontal time scale and vertical divisions were also modified.

Controls in Visible Range (Change Range) dialog

Control	Description
Return to Monitor page	Clickable link for paging back to the Monitoring screen.
Show seconds of data	Determines visible horizontal time scale in chart display.
Number of horizontal divisions	Sets the number of horizontal divisions in chart.
Horizontal axis precision	Sets number of decimal places following horizontal time values.
Vertical lower endpoint	Determines low end of vertical graph scale.
Vertical upper endpoint	Determines high end of vertical graph scale.
Number of divisions	Sets the number of vertical divisions in chart.

NOTE: **Remote Monitoring** plots are only updated in the data monitoring window while an acquisition is in progress. Once a Remote Monitoring acquisition is stopped, the graph will remain visible only as long as the browser page is displayed. After navigating away from the page, the plot will not be retained or reconstructed. To save a Remote Monitoring plot for future reference, printing a hard copy or printing to a PDF file is recommended.

*For Remote Monitoring technical support, contact BIOPAC Systems, Inc at (805) 685-0066 or support@biopac.com

Chapter 25 Licensed Functionality: B-Alert

B-Alert functionality is available through optional licenses* available with Acq*Knowledge* 4.2 or above (B-Alert wireless headset hardware is also necessary).

* B-Alert Headset integration: must be authorized to access basic B-Alert functionality.

* Cognitive States Analysis: must be authorized to access this enhanced functionality.

To add licenses please contact BIOPAC.

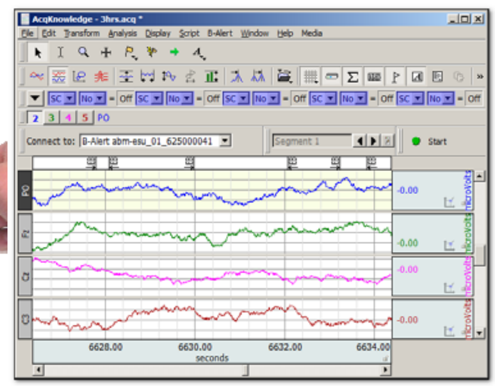
The B-Alert Hardware Data Acquisiton license adds:

- Basic wireless recording of up to nine channels of raw or decontaminated EEG data

The Cognitive States Analysis Software license adds:

- Functionality described above, plus the ability to create individual baseline recordings for each subject
- Additional analysis software and specialized calculation channels

Data Acquisition and Analysis with B-Alert™

B-Alert™ X10 is a Bluetooth wireless system and sensor headset integrated with Acq*Knowledge* software to record up to 9 channels of monopolar EEG, plus one optional channel of ECG data. **B-Alert** data can be acquired simultaneously with BIOPAC MP150 Hardware, if additional graphs are used.

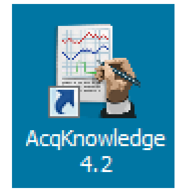
IMPORTANT NOTE: In Acq*Knowledge* for B-Alert:

- **B-Alert** is licensed functionality and must be activated by BIOPAC
- Analog channels can be toggled on/off but not modified
- Digital channels are not supported
- **B-Alert-**specific calculation channels are available when the optional Cognitive States Analysis software license is applied (Acq*Knowledge* calculation channels C8 and higher can be used if configured manually)
- Data acquired with **B-Alert** is outputted in standard BIOPAC *.acq format

B-Alert™ users should refer to the **B-Alert X10 User Manual** for complete hardware setup instructions.

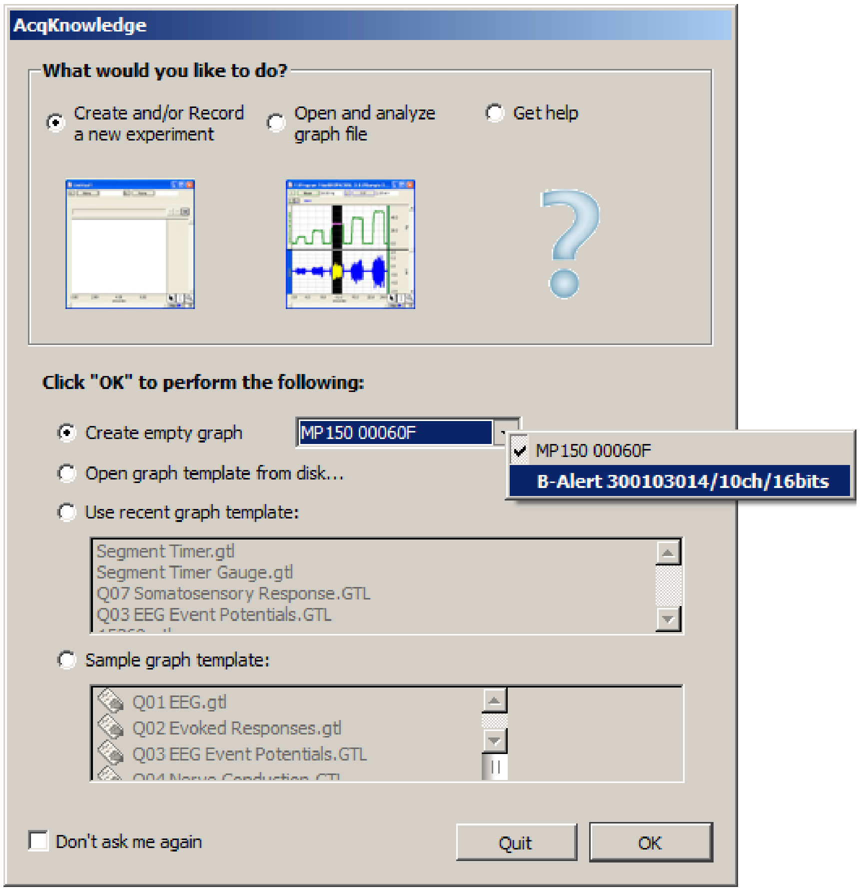
- For step-by-step direction, request **B-Alert X10 User Training Videos** from support@biopac.com.

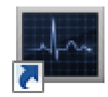
Acq*Knowledge* software is used to view, record and analyze data acquired with the B-Alert unit.



To launch software with B-Alert hardware:

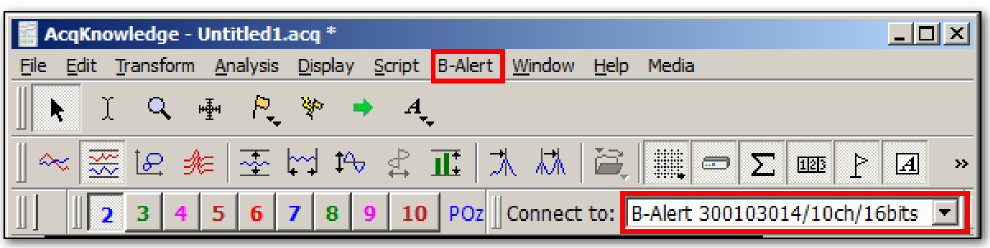
1. Connect the **B-Alert** USB dongle and turn the X10 headset unit's power switch ON.
2. Choose **B-Alert** device from the Acq*Knowledge* Startup Wizard Hardware menu.
3. Use the **B-Alert** menu options for acquisition and channel settings.



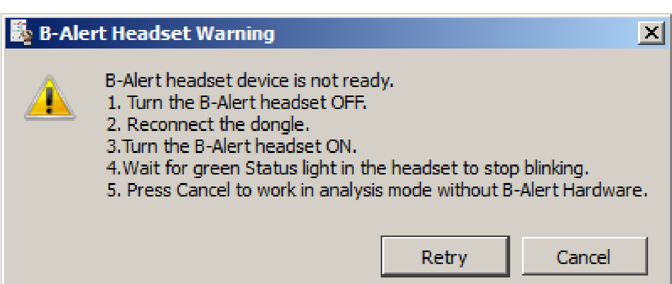


With the optional Cognitive States Analysis License activated, an additional B-Alert shortcut icon will appear on the Desktop. For complete details about B-Alert Cognitive States software, see the **B-Alert Software Manual**.

When Acq*Knowledge* launches in B-Alert mode, the MP menu will be replaced by the B-Alert menu and the B-Alert device ID will appear in the Acq*Knowledge* graph "Connect to" menu.

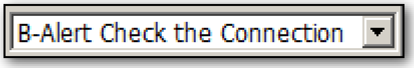


If the B-Alert device cannot be located or is disconnected, the following dialog will appear:



Click 'Retry' in the B-Alert Headset Warning dialog to initiate a refresh of the hardware connection.

Click ‘Cancel’ in the B-Alert Headset Warning dialog to launch the Acq*Knowledge* software in analysis mode, identified in the “Connect to” menu as “B-Alert Check the Connection.” (This operates similarly to MP150/36R “no hardware” mode, for which data can be analyzed and transformed but not recorded).



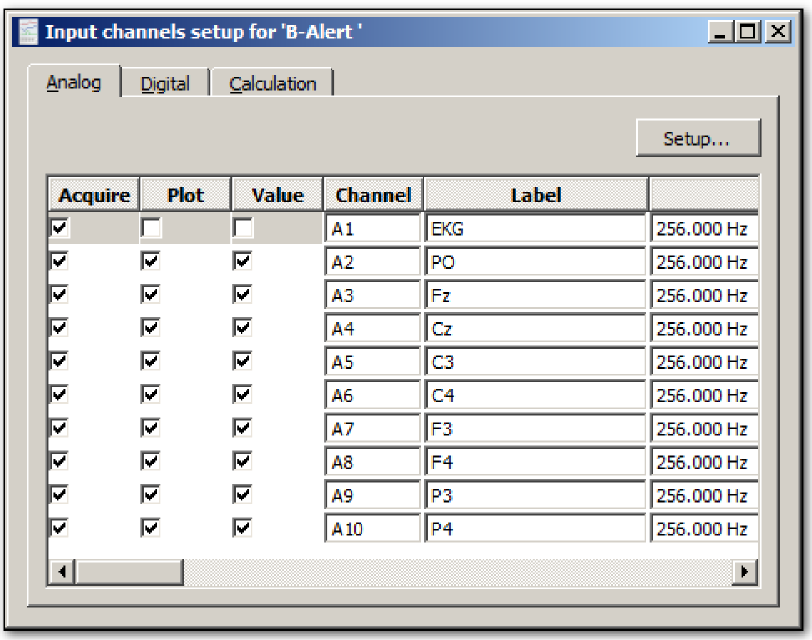
Acquisition Setup

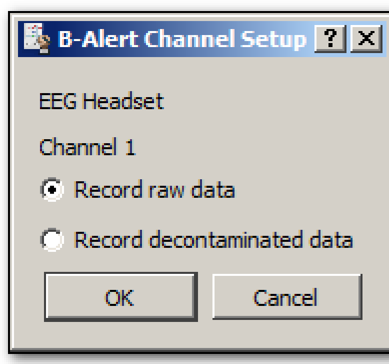
Standard recording modes found in MP150/MP36R hardware (with the exception of Averaging) are supported in B-Alert but the acquisition sample rate is limited to 256 samples per second. Dependent upon licensing level, there are two additional checkbox options in the B-Alert acquisition setup dialog:

- **Record EEG artifacts as events:** When checked, recorded EEG artifacts are translated into visible events (eye blinks, EMG interference, etc.). When unchecked, artifacts are discarded and only data is acquired.
- **Use B-Alert Definition File:** When checked, enables use of a subject’s baseline Definition File. This option is only available if the Cognitive States Analysis license is applied. See page 465 for a detailed explanation of Definition File setup in Acq*Knowledge*.

Channel Setup

Nine analog input channels of monopolar EEG data are enabled by default in B-Alert, along with one optional ECG (EKG) channel. Channels are configurable as desired. In the standard B-Alert setup, calculation channels C8 – C15 remain available for additional online transformation/filtering of data (for C0-C7, see page 465). Digital channels are not supported in B-Alert hardware.



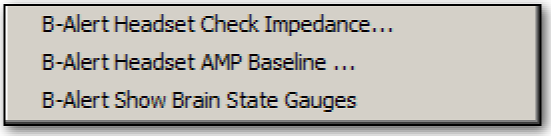


Under the standard **B-Alert** license, the Input channel setup contains options for recording raw or decontaminated EEG data. These parameters are set individually per channel. It is possible to record raw data on one channel and decontaminated data on another.

- **Record raw data**: records unfiltered data. Any further filtering must be applied through calculation channels or transformations. (Default setting)
- **Record decontaminated data**: filtered data will be recorded for the channel. This setting applies algorithms to minimize artifact resulting from eye blinking or other small involuntary movements.

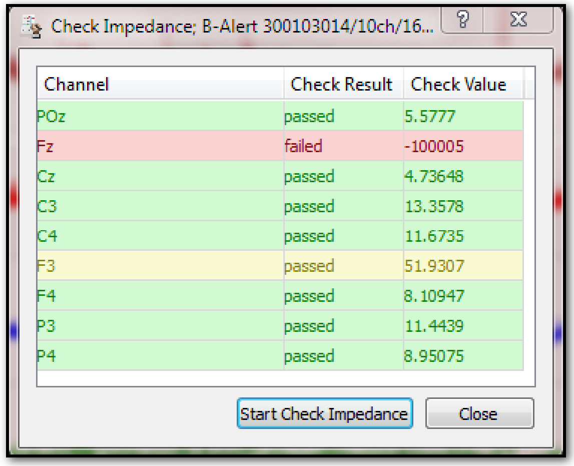
The optional **B-Alert** Cognitive States Analysis license offers additional functionality, such as creation of a baseline “Definition” file (based upon a subject’s responses to some simple cognitive tests), and access to pre-configured calculation channel setups.

B-Alert-specific Hardware Menu Options



B-Alert Headset Check Impedance

This item is found in the B-Alert menu, (which replaces the MP menu in B-Alert hardware configuration) and is used to initiate an impedance check to verify the headset's electrode contact quality. Results and resistance values are displayed in the dialog when the check is complete. If any of the channels fail the impedance check (as shown on Channel Fz on the right), verify that electrodes are firmly attached and making good contact, and then rerun the check.



B-Alert Headset Amp Baseline

Requires Cognitive States Analysis license activation

Use to set up an "Alertness Memory Profile" (AMP) Baseline recording of a subject's EEG definition file.

Subject: Field for 4-digit identifier unique to subject being recorded.

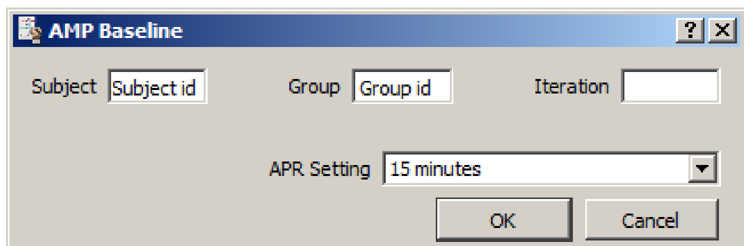
Group: Field for single-digit identifier used to distinguish a group number.

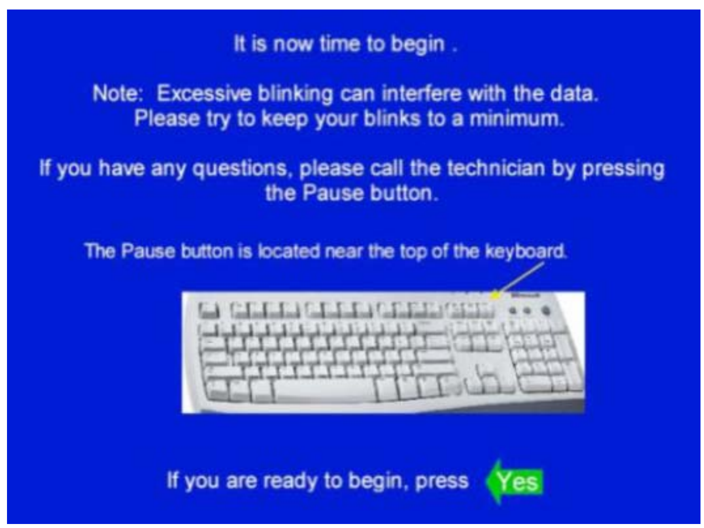
Iteration: Field for single digit identifier identifying the session, if additional Baseline sessions are recorded for a subject.

APR Setting: Choose the type and length of the baseline recording. Recording lengths of 15, 30 and 45 minutes are supported. Refer to the **B-Alert** Software Manual for further details.

After setting up the required fields, click OK to launch the baseline recording user interface, similar to the example at right. A series of step-by-step instructions will follow.

For more details about the baseline recording user interface and additional software controls, refer to the AMP Baseline section of the **B-Alert** Software Manual.

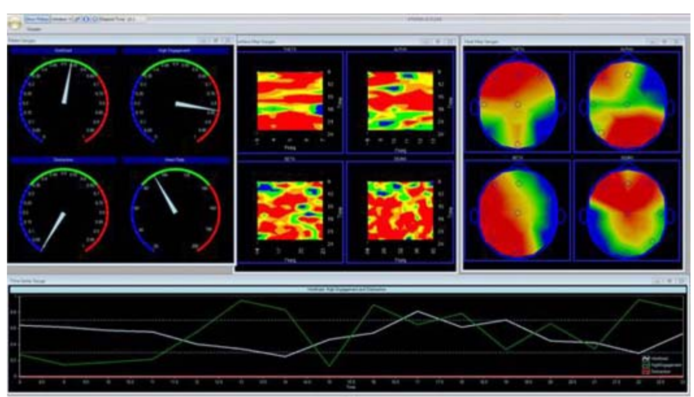




B-Alert Show Brain State Gauges

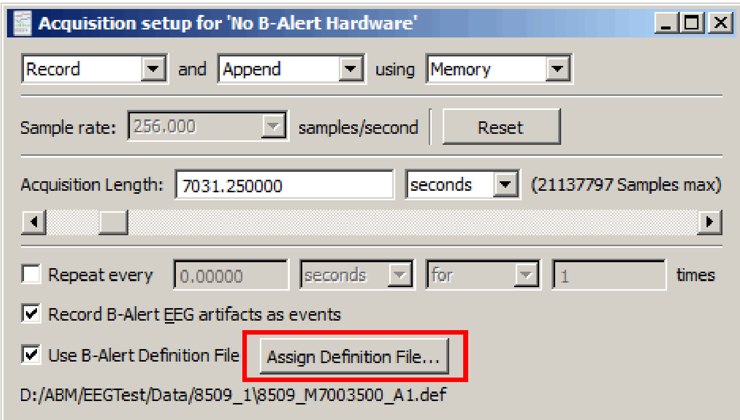
Requires Cognitive States Analysis license activation

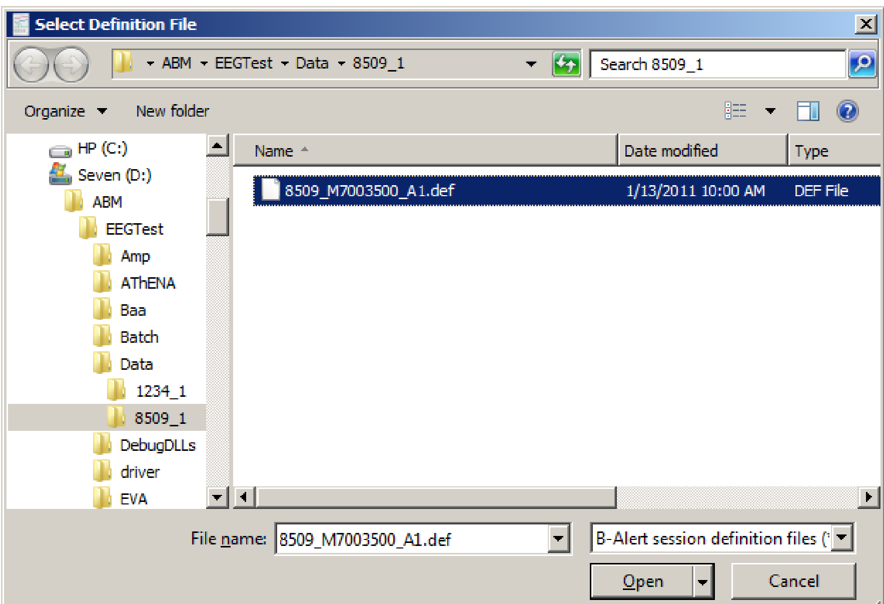
Displays real-time views of B-Alert headset data as it is being acquired. Information includes Meter Gauges gauges (*Top Left*) with Engagement, Workload and Drowsiness (along with Heart Rate). Time Series (*Bottom)* Heat maps (*Top Right*) display EEG power spectral densities (PSD) in both spatial and temporal maps for the traditional Hz bands (Beta, Alpha, Theta, Sigma).



Assign Definition File

Requires Cognitive States Analysis license activation

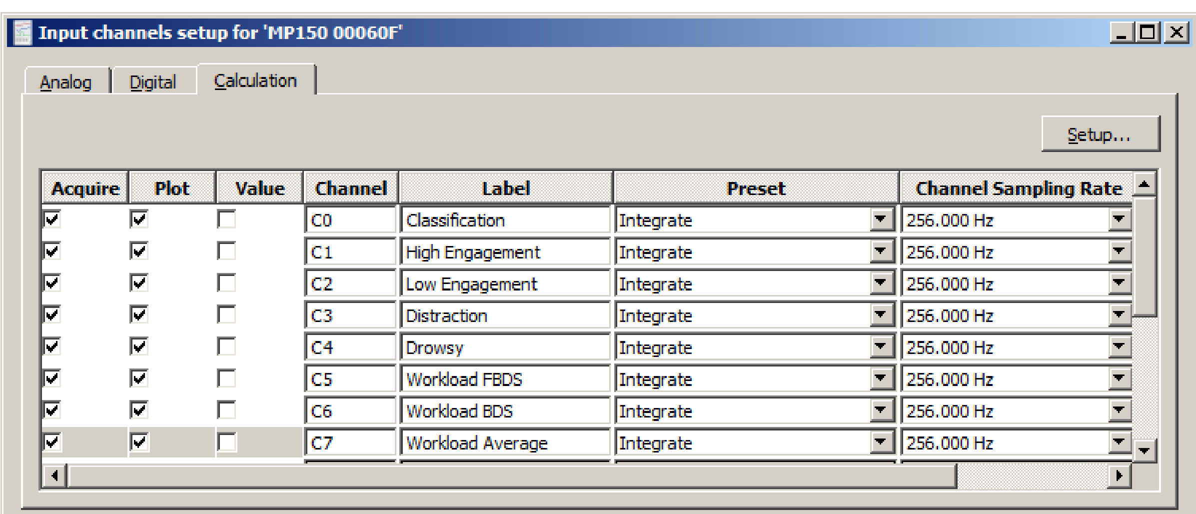




The Definition File is created when the subject undergoes an initial baseline EEG recording while responding to some simple onscreen tests. (Definition File setup is configured in the B-Alert Headset Amp Baseline dialog referred to on the previous page). The file is saved to a directory containing the subject's B-Alert profile folder. Once created, a subject's Definition File will always be referenced for subsequent recordings and analysis.

Cognitive Analysis Calculation Channels

Pre-configured calculation channels C0 – C7 become available when a subject's B-Alert Definition File is active. These signals are mapped from the Definition File and extract cognitive workload, high/low engagement, distraction and drowsiness data. The channel setups and presets are not editable but can be enabled or disabled as desired.



For specific information on additional B-Alert GUI software controls, see the **B-Alert** Software Manual.

Data Output

The following data is collected during a B-Alert experiment and merged into a standard Acq*Knowledge* *.acq file:

Real-Time Output file name	Description
Data file	
.edf	European data format containing nine raw and nine decontaminated EEG channels, raw ECG channel, plus derived heart rate, head movement value and head movement level
_Impedance.csv	Lists the values obtained for each channel each time impedance was measured
Automatically Generated during Acquisition – for all EEG Channels	
_Ref_Raw.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands labeled by channel (no edge-effect window)
_Ref_Class.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands labeled by channel (with Kaiser window)
Automatically Generated during Acquisition – Derived Signals	
_HR_beat.csv	Presentation of heart rate based on beat-to-beat interval
_HR_epoch.csv	Beat-to-beat heart rate interpolated to sec-by sec value
Optionally Generated with B-alert Cognitive State Classifications	
_Classification.csv	Probabilities for sleep, distraction, low and high engagement, cognitive state from DFA with greatest probability, probability of high workload based on forward and backward digit span (FBDS), backward digit span (BDS), and average of FBDS and BDS
_Diff_Raw.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands for differential channels: FzPO,CzPO,FzC3,C3C4, and F3Cz (no edge-effect window)
_Diff_Class.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands for 5 differential channels FzPOz, CzPO, FzC3, C3C4, F3Cz (with Kaiser window)
_Zscore_class.csv	Updates and applies mean and standard deviation with each new second to provide z-scores for B-Alert cognitive states (sleep onset, distraction, low and high engagement, three workload measures)
_Zscore_psd.csv	Updates and applies mean and standard deviation with each new second to provide z-scores for PSD for all channels requested in initialization process

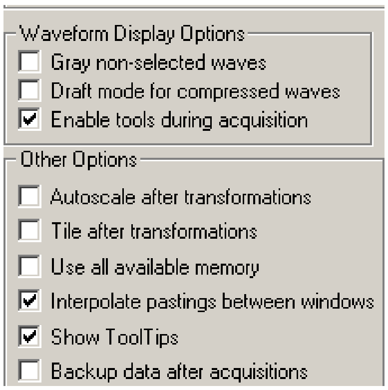
Part D—APPENDICES

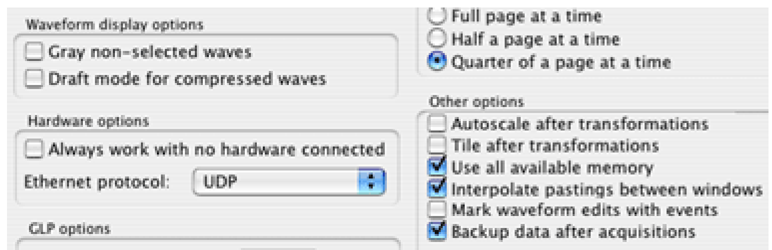
Appendix A - Frequently Asked Questions

Q: *I have a large data file and it seems to take a long time to redraw the screen. Is there anything I can do to speed it up?*

A: Yes. You can choose from several remedies for this.

(1) The simplest solution is to check the Draft mode for compressed waves and Use all available memory boxes in the Preferences dialog (shown below). Checking these two boxes will cause Acq*Knowledge* to plot data faster (at the expense of some precision) and use as much available memory as possible.





(2) You can reduce the time interval per division, which causes less data to be displayed on the screen at one time, and should reduce plot time.

(3) If the data still takes too much time to redraw and you have a color monitor, try reducing the number of colors displayed.

(4) If you have a high-resolution video card (one capable of displaying many thousands of colors), you may want to reduce the resolution to speed up plotting time.

(5) Load all data into memory; see page 428 for details.

Q: *Can I use other software with the MP System (MP150 or MP36R)? Can I use* Acq*Knowledge to control other data* Acquisition *hardware?*

A: No. The MP System (MP150 or MP36R) was designed to work with the Acq*Knowledge* software. However, the software can read in previously acquired text files generated by Acq*Knowledge* or any other software.

Q: *I have a device that outputs an RS-232/RS-422 signal. Can I connect this to the digital I/O lines?*

A: No. These types of digital output devices have their own communication protocols and are more complex than the digital pulses that the MP System (MP150 or MP36R) can accept as inputs.

Q: I imported a text file and the time scale is wrong. What happened?

A: When a text file is imported, Acq*Knowledge* assumes (by default) that the data was sampled at 100 Hz or 100 samples per second. This is arbitrary, and there are two ways to adjust this. Both methods involve Calculating the interval between sample points. To calculate the sampling interval, you need to know the rate at which the data was originally sampled. The sampling interval is calculated by dividing one by the sampling rate. You can adjust the sampling interval to the appropriate value via the File > Open dialog before the data is read in, or if the data is already present, change the time scale in the Display > Horizontal scale dialog.

For instance, if 20 minutes of data was originally collected at 2Hz and is read into Acq*Knowledge* as a text file, the software will interpret this as data collected at 100 samples per second. To set the time scale to accurately reflect the data, change the sampling interval from 0.01 to 0.5 seconds per sample.

To change this setting before data is read in, click the Options button in the File > Open dialog and change the value in the Sampling Interval dialog. To change the time scale after data has been read in, adjust the units per division in the Display > Horizontal axis dialog. If the data are time-domain data, you can adjust the seconds/sample interval at the bottom of the dialog. This value defines the interval between sample points, and can be changed to fit the rate at which the data was originally acquired.

Q: I have the fastest computer available. Why can't I acquire data to the computer any faster than 11,000 Hz on one channel?

A: The bottleneck occurs in two places:

1. The first occurs when data is transferred between the MP150 data acquisition unit and the computer. While the MP System (MP150 or MP36R) can acquire data as fast as 70,000 Hz when data are stored directly to the MP150 data acquisition unit memory, the maximum rate drops considerably when data is acquired to the computer memory, and even more so when data is acquired directly to disk.
2. The second bottleneck occurs within the computer itself, and has to do with the time it takes to transfer and process incoming data. Faster computers can perform these tasks more quickly, which is why the maximum possible sampling rate for a Pentium (storing to memory) is faster than a 386SX. With a large number of channels, the aggregate sampling rate can climb to a theoretical maximum of 16,000 samples per second.

To resolve the sampling limitation, use an MP System (MP150 or MP36R).

Q: I just filtered a waveform and now my data file is huge. Why is that?

A: When Acq*Knowledge* performs any type of transformation on a waveform (e.g. digital filtering, waveform math), it converts the entire waveform from integer format (two bytes per sample) to floating-point format (eight bytes per sample). Since each sample point in the waveform now takes up four times as much space, the file should be approximately four times as large. Acq*Knowledge* still saves the file as compactly as possible, and since some of the information stored describes the time base, the file size will not increase by exactly a factor of four.

Q: My MP data acquisition unit seems to be connected, but I can't acquire data. What should I do?

A: This can be caused by one of several conditions:

(a) Check to make sure that the MP data acquisition unit is ON and, if so, that all the connections to the MP data acquisition unit were made properly. When the MP data acquisition unit is powered up, a light on the front panel of the MP data acquisition unit will illuminate. If the power light will not illuminate, check to make sure the proper power supply is connected. The power supply that comes with the MP data acquisition unit is rated at 12 VDC @ 1 Amp, and using other power supplies may result in damage to the MP data acquisition unit.

(b) If the proper power supply is connected but the power light still does not illuminate, disconnect the power supply and check the fuse in the back of the MP data acquisition unit. The fuse is a standard 2.0 Amp fast blow fuse, and can be changed by unscrewing the fuse cap and replacing the fuse.

(c) If the power light does illuminate, the next step is to see if the busy light (next to the power light on the front panel of the MP data acquisition unit) illuminates when the MP data acquisition unit is powered up. When the MP data acquisition unit is powered up, the busy light should illuminate for three or four seconds and then extinguish.

NOTE: The busy light is normally off (except at startup), but it will remain on while data is being acquired and will illuminate for the duration of each trial when data is being acquired in averaging mode. If the busy light does not illuminate when the system is powered up or does not turn off after a few seconds, contact BIOPAC at one of the locations listed in Appendix A.

Q: I Set Up the channels but I only seem to be acquiring noise. What's wrong?

A: A number of phenomena can cause this. Check to make sure that the settings in the Set Up Channels dialog correspond to the channel switch settings on the amplifier modules and/or direct analog connections to the UIM100C. When a direct analog input is set to the same channel as an amplifier, the resulting data will appear quite noisy or erratic. You should also check to see that no two amplifiers are set to the same channel.

Another possible cause is that the gain settings on the amplifiers are too low and should be increased. You may also want to select Autoscale waveforms from the Display menu. This will automatically adjust the waveforms to provide the "best fit" in terms of scaling the data to fit in the available window space.

It is also possible that the electrodes/transducers themselves are the source of the noise. Proper electrode adhesion techniques involve abrading the skin and securing the electrode in place to reduce movement artifact.

*Q: What is the storage and operation accuracy of Acq*Knowledge?

Acq*Knowledge* performs all internal calculations to the accuracy defined by the IEEE format for double precision flointing point numbers and stores the results of those calculations in double precision floating point format. This format assigns 8 bytes to all numbers involved in calculations or resulting from calculations. The 8 bytes (64 bits) are assigned as 52 bits to mantissa, 1 bit to sign, and 11 bits to exponent. The effective decimal accuracy for calculation operation or storage will be defined as [2 to the 52] power or approximately 4.5 E15. Accordingly, the effective decimal accuracy will be between 15 and 16 digits.

Appendix B - Filter characteristics

Filter types

Acq*Knowledge* employs two types of digital filters:

(a) Finite Impulse Response (FIR) perform post-acquisition filtering

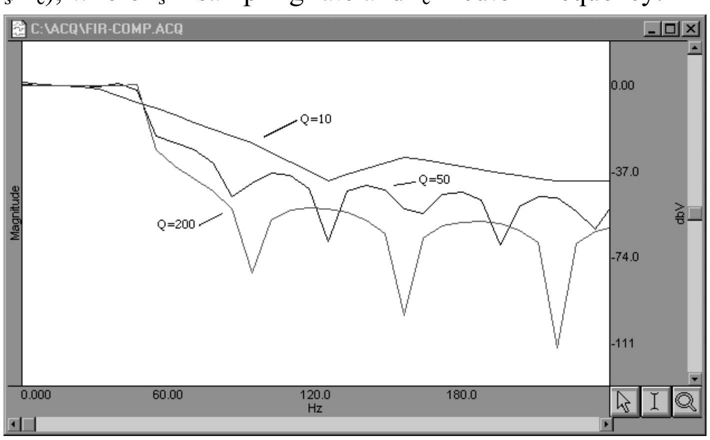
(b) Infinite Impulse Response (IIR) perform filtering calculations online (during an acquisition) or post-processing (after an acquisition)

Although the similarities between the two types of filters outweigh the differences, some important distinctions remain.

1. First, IIR filters are typically more efficient than FIR filters, which means that IIR filters can filter data faster than FIR filters, which is why IIR filters are used for online Calculations.
2. Second, IIR filters tend to be less accurate than FIR filters. Specifically, IIR filters tend to cause phase distortion or "ringing." When the phase of a waveform is distorted, some data points on a waveform are shifted (either forward or backward in time) more than others. This can result in the intervals between events (such as the Q-R interval or the inter-beat interval in an ECG waveform) being slightly lengthened or shortened compared to the original signal. In practice, however, the effect of this distortion is usually minimal since the frequencies which are most distorted are also attenuated the most. By contrast, FIR filters are phase linear, which means that the interval between any two sample points in the filtered waveform will be exactly equal to the distance between the corresponding sample points in the original waveform.
3. Third, IIR filters have a variable Q setting that defines the filter response pattern, but FIR filters do not have a Q component. The optimal Q of an IIR filter is 0.707, with lower values resulting in a flatter response and higher values resulting in a more peaked response. The default Q for all IIR filters is 0.707 (except for Band pass filters where Q defaults to 5), which is appropriate for nearly all filter applications.

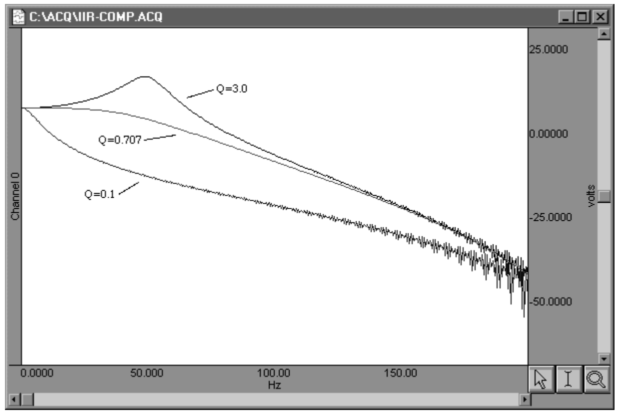
In the examples on the following page, the filter responses of several different types of filters are compared. All of the filters are 50 HZ low pass filters operating on the same data.

The first graph shows how the number of filter coefficients in FIR filters (Q) affects the filter's frequency response. Note that as the number of coefficients (Q) increases, the filter becomes more accurate. A good rule of thumb is to set $Q \geq 2(f_s / f_c)$, where f_s = sampling rate and f_c = cutoff frequency.



FIR filter performance as a function of number of coefficients (Q)

The next graph shows how the pole or zero locations of the filter, as related to filter "peaking" (specified by Q), affect the frequency response of the filter. The "Q" in this case is not to be confused with the Q from the FIR filter. Note how increasing "Q" in the IIR filter case affects filter "peaking."



FIR filter performance as a function of changes in pole or zero locations

Coincidentally, the FIR (Q = 10) and IIR (Q = 0.707) filters have very similar responses in this case.

Technically, the coefficient setting for FIR filters determines the number of multiplies performed by the filtering algorithm. In practical terms, it determines how "steep" the frequency response of the filter is. Filters with a large number of coefficients have a steep roll-off, whereas the frequency response of filters with a smaller number of coefficients is not as steep.

Window Functions

Window functions are used for two purposes in Acq*Knowledge*. Windows are applied to the impulse response in the (FIR) digital filtering functions, and can optionally be applied as part of the FFT function. In either case, a window refers to a computation that spans a fixed number of adjacent data points.

Typically, window functions are used to eliminate discontinuities that may result at the edges of the fixed span of points of the digital filter function (FIR filters) or the data points of the FFT.

Digital filtering. When a window is used in digital filtering, the impulse response of the filter (rather than the data itself) is modified. When the impulse response smoothly approaches zero at both the beginning and end of the data, this works relatively well. When the impulse response is not so well behaved, edge effect occurs. Edge effects can be minimized by windowing, or forcing the edges of the impulse response to smoothly approach zero. The exact process depends on the window selected (see below).

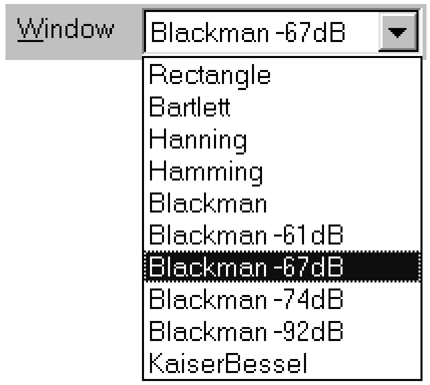
Another way to minimize edge effect with an FIR filter is to increase the number of coefficients used to transform the data.

FFT. The FFT function also windows data, although the nature of the windowing function is somewhat different in the sense that the window operates on the data. One of the assumptions of the FFT is that the input data is an infinitely repeating signal with the endpoint wrapping around. In practice, the endpoints are almost never exactly equal. You can check this by choosing the Delta measurement item from the measurement popup menus, which returns the amplitude difference between the first selected point and the last. To the extent that the endpoints differ, the FFT output will produce high frequency components as an artifact of the transformation.

- Acq*Knowledge* displays only the positive coefficients of an FFT. In this FFT presentation, there is an implicit negative frequency component for each positive frequency component, so if you are looking at amplitude levels in a linear FFT you need to multiply by two (negative frequency can only be created with positive frequencies in the real world).

By windowing the data, the effects of this phenomenon are greatly diminished. When data are windowed, a window is moved across the data, much as the smoothing function moves across the data. Whereas the smoothing function simply takes the average of a specified number of points, each type of window weights the data somewhat differently.

The Window pull down menu offers the following options:



Bartlett implements triangular windowing and Rectangle does not window the data. The “shape” of the other windows is defined by the following formula, where $n = \overset{N-1}{\underset{0}{n}}$ and A, B, C and D are constants:

$$A - B\cos\frac{2\pi n}{N} + C\cos\frac{2\pi 2n}{N} + D\cos\frac{2\pi 3n}{N}$$

The table below details the different parameter values for each type of window.

Type of Window	Parameter Values A	B	C	D
Bartlett	n/a	n/a	n/a	n/a
Blackman	0.42000	0.50000	0.08000	0.00000
Blackman -61	0.44959	0.49364	0.05677	0.00000
Blackman -67	0.42323	0.49755	0.07922	0.00000
Blackman -74	0.40217	0.49703	0.09392	0.00183
Blackman -92	0.35875	0.48809	0.14128	0.01168
Hanning	0.50000	0.50000	0.00000	0.00000
Hamming	0.54000	0.46000	0.00000	0.00000
Kaiser-Bessel	0.40243	0.49804	0.09831	0.00183
Rectangle *Windows/PC only*	n/a	n/a	n/a	n/a

Appendix C - Hints for Working with Large Files

It is not uncommon for users to generate large data files (on the order of several megabytes) through some combination of (a) high-speed acquisitions, (b) long acquisitions, and (c) multi-channel acquisitions. Users frequently encounter system limitations (such as storage space limitations) and find the files are difficult and slow in loading to memory.

The software that comes with your MP System (MP150 or MP36R) stores the data in as compact a format as possible. Each sample takes up roughly two bytes of storage space. When a waveform (or a section of a waveform) is transformed (i.e., filtered or integrated) each data point takes up roughly eight bytes of storage space. As a result, file size can change drastically after transforming one or more waves.

Note Acq*Knowledge* data files greater than 2GB can be opened, but edit, transformation and analysis operation cannot be performed.

The following tips can help you get the most out of your MP System (MP150 or MP36R) when working with large data files.

- Use virtual memory

  Since Acq*Knowledge* runs under Windows® XP or Mac® System 7.0 or better, most computers are able to take advantage of the virtual memory feature. While this is slower than conventional memory, it will at least make it possible to load some files that might otherwise be impossible to load.

- Remove waveforms

  Since each waveform adds to the total size of the file, try removing (or copying to another file) some of the waveforms from a multi-channel file. This is especially true if you would like to perform transformations of some sort on at least one of the waves.

- Sample slowly

  Theoretical and methodological concerns will, to a large extent, dictate sampling rate. However, if you can reduce the sampling rate, choose to do so. Or, use Transform > Resample (page 292) to resample data after collecting it.

- Set preferences

  Check the "Use all available memory" and the "Draft mode for compressed waves" options under the Preferences menu item. This should decrease the time it takes to redraw waveforms and allow the software to access all available memory for storage.

- Store to disk

  Although slightly slower than storing to RAM, acquiring data directly to disk allows you to recover data in the event of a power loss to the MP System (MP150 or MP36R). Furthermore, much larger data files can typically be stored directly to disk than to memory.

- Use the Append mode

  The Append mode allows you to pause the acquisition for arbitrary periods. This can be helpful when recording only a few key events that will occur randomly over a long period of time, since it will reduce unnecessary data.

- Compress Files

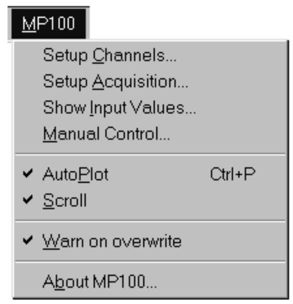
  Use the File > Save As > Compressed option to store or transfer data

Note Copy/Paste, Merge Graphs, and Transformations require Acq*Knowledge* to allocate additional memory and then load the data into memory; when these operations are executed on large data files, the application may crash.

Appendix D - Customizing Menu Functionality

Acq*Knowledge* now includes a powerful customization feature lets you choose the program features to display as menu options. If you have a specific procedure, you can limit the menu options to list only those functions you need, thereby reducing the chance for confusion or error in your lab. For instance, you might choose to remove the "Setup Triggering" and "Setup Stimulator" options from the MP150 menu, as shown below:

Default MP150 menu



Customized MP150 menu

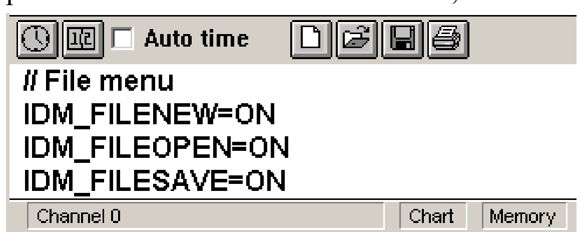
Follow the simple procedure below to customize menu display for your own needs.

1. Launch Acq*Knowledge*.
2. a) Choose Display > Preferences.
   a) Click "Create default menu configuration file."
   b) Click "Yes" when prompted about editing the file.

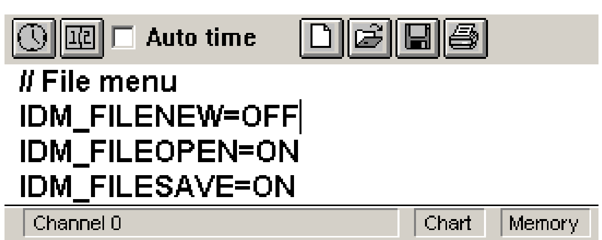
   ➢ Alternately, you can pull down the "Files of type" menu, select "All files" and then select the "menu.dsc" file from the default location and click Open.

The "menu.dsc" file will open in the Journal window, as shown below.

➢ For a complete list of the options included in the "menu.dsc" file, see the end of this section.



3. Find the menu and item you want to change (scroll through list as necessary) and type "OFF" to disable the menu display. For example, you might change the File > New option to OFF, as shown below.
   ➢ Note that ON/OFF is case-sensitive and you must type in ALL CAPS.
   ➢ Deleting a file listing instead of typing OFF will not remove the feature; it will default to ON unless you type OFF.



> To reactivate a menu item that you have turned OFF, just repeat the above procedure and type "ON" for the menu item you desire.

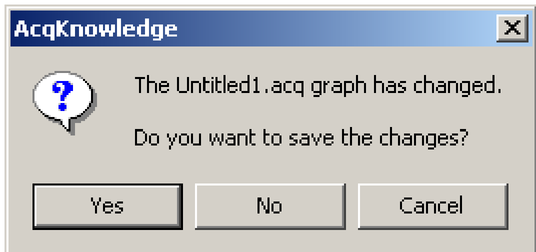
4. Activate the Journal Save As dialog.

File > Save Journal as…

5. Save the file in the exact same location by typing “menu.dsc” in the “File name” entry box and clicking Save. Leave “Save as type” set to Text (*.TXT).

6. You should be prompted that the file already exists. Click Yes to replace the existing file.

7. Quit the Acq*Knowledge* program. You do not have to save any graph or journal changes—the “menu.dsc” file has already been saved. Click No if prompted.



8. Restart Acq*Knowledge*.
9. Check your menu listing.

Note: Application menu customization has a corresponding effect on contextual menu display. If a contextual menu item does not have a corresponding application menu item, the menu customization file identifier will begin with “IDM_CM.”

Appendix E—Locking/Unlocking the MP150 for Network Operations

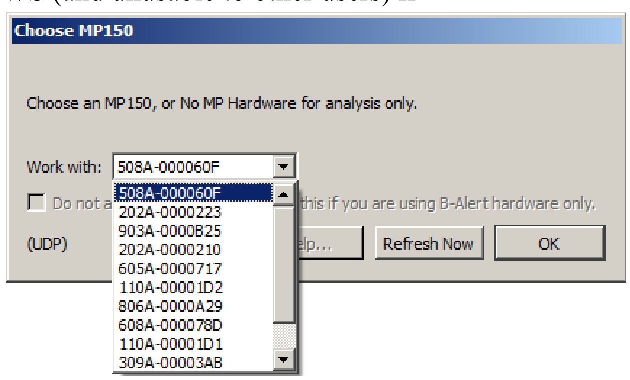
The MP150 is primarily designed to work in Local Area Networks (LAN). In a LAN, each MP150 unit may be accessed from any workstation (PC or Mac) running an Ethernet version of Acq*Knowledge* software. Theoretically, two or more workstations (WS) could be connected to one MP150 at the same time, but the MP150 cannot perform independent acquisitions simultaneously, so in such cases one or all connected WS would receive corrupted/invalid data and/or crash.

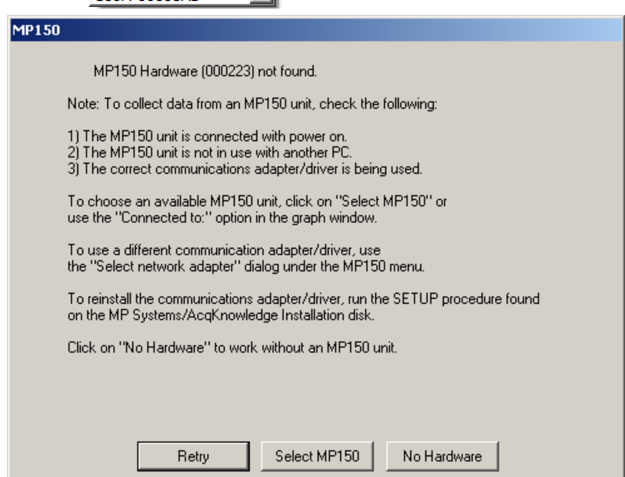
To prevent this, Acq*Knowledge* uses new "lock/unlock" technology that establishes communication between an MP150 and one —and only one— dedicated WS in the Network.

Acq*Knowledge* locks an MP150 as soon as it connects to it, which tells the MP150 to only respond to commands from that particular computer and the communication method (serial or ethernet). The lock has a timeout which is reset every time the MP150 unit receives a command from the computer that locked it. To locate MP150s in the local network, Acq*Knowledge* sends a broadcast packet to the local area network that asks all the MP150s in the network to respond. All the MP150s—whether locked or unlocked—will respond to this prompt. This means that the "Select MP150" menu may allow a user to select an MP150 that is locked. In such cases, Acq*Knowledge* will fail to connect (to a locked MP150 unit), as expected. To resolve this issue, unlock or power cycle the MP150 unit.

Locked An MP150 becomes "locked" in operation to a WS (and unusable to other users) if

a) An MP150 unit is selected from "Select MP150." The dialog lists all MP150 units that are powered ON and sitting on the same local area network. Unfortunately, this dialog cannot provide the locked/unlocked status of each MP150 in the LAN. You may refer to the BUSY and ACTIVITY lights on the MP150 to determine the status—if you cannot connect to an MP150 but its lights indicate data traffic or acquisition, the MP150 you are trying to connect to is connected to another WS.





b) When Acq*Knowledge* is launched. Acq*Knowledge* will "remember" and try to connect the last MP150 used by a WS; if the last used MP150 is not available, the user must pick an available MP150 unit from the "Select MP150" dialog.

c) With the advent of any new communications or the start of any type of acquisition to the MP150 unit. When a WS communicates with an "unlocked" MP150 unit, Acq*Knowledge* sends a "lock" command.

When an MP150 is locked, its serial number is listed in the Select MP150 dialog but any attempt to select a locked MP150 will generate a Hardware Not Found prompt (shown above).

Unlocked

An MP150 automatically "unlocks" and becomes available to other users

a) When the user exits Acq*Knowledge*.

b) The user selectes another MP150 in the Select MP150 dialog.

c) The user selects the "No Hardware" option in the Select MP150 dialog.

Other, less common conditions that may unlock the MP150 include

d) The MP150 is powered OFF and then ON.

e) The MP150 does not receive commands/data from the WS or Acq*Knowledge* for about 5 minutes. This time-out can occur when

- An Acq*Knowledge* dialog (About, Calculation setup, etc.) is open for a long time.
- Acq*Knowledge* or the WS crashes for any reason.
- You turn the connected WS off without exiting Acq*Knowledge*.

If the MP150 becomes unlocked due to a time-out, two scenarios are possible:

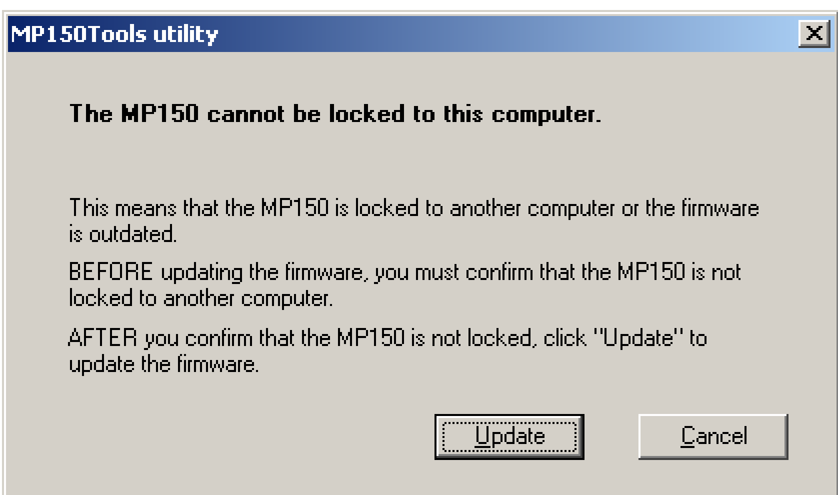
1) The MP150 is locked—If another user has locked the MP150 you had been using, you will see the No Hardware Prompt. Check the MP150 lights to determine its status.

2) The MP150 is unlocked—Your WS will "lock" the MP150 as soon as you initiate communication or acquisition; until then, the MP150 remains unlocked and available to others.

No Hardware

When a user selects the "No Hardware" option, the menu of available MP150 units is grayed out and becomes unselectable. If a user attempts to connect to a locked MP150, an error message will be generated to advise that the MP150 unit is locked to a different computer.

Cannot lock



If you receive this "cannot lock" prompt, check that no other user on the network is using the MP150, power-cycle the MP150, check the current firmware version (About MP150), and, if necessary, update the firmware using MP150Tools (see next Appendix).

Appendix F—Firmware Upgrade

MP150 firmware is upgraded automatically. Unless a firmware warning is diplayed at application launch, your MP150 already has the latest firmware revision and no further action is necessary. If a firmware warning is displayed, contact BIOPAC technical support for more information.

Firmware Rollback Switch

IMPORTANT!

Use the Firmware Rollback Switch only if the MP150 fails to operate after a Firmware Upgrade.

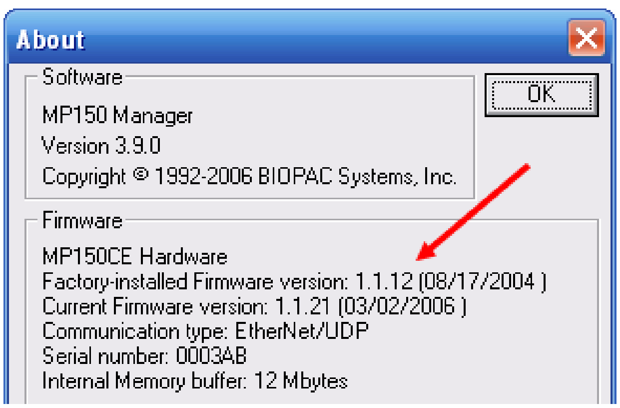
In all other cases, just turn the MP150 power OFF and then ON and check the results of the Start up/Self-Test.

The Firmware Rollback Switch is located on the bottom of the MP150 unit and is recessed to prevent accidental activation.

Activation of the Firmware Rollback Switch will cause the MP150 unit to operate under the factory-installed firmware version. If no upgrades have been performed (the MP150 has only the factory-loaded firmware), the Firmware Rollback Switch will have no effect.

Procedure:

1. Turn the MP150 unit ON.
2. Use About MP150 in the Acq*Knowledge* software to determine the factory-installed firmware version:



IMPORTANT!

Factory-installed Firmware version 1.1.2 or previous (purchased approximately November 2002 or before) may not reset to a level compatible with UDP communication. In such cases, you will need to install a DLC-compliant version of Acq*Knowledge* and update to UDP in stages; contact BIOPAC for additional support if necessary

Mac OS X: Labeled “Manufacturer’s ROM” and “Current ROM”

3. Turn the MP150 unit OFF.
4. Turn the MP150 unit upside down and use a small-tipped device (an unfolded paperclip will do) to depress and hold the switch down.
5. Continue to hold the switch down, and turn the MP150 unit ON.
   - One green and one yellow LED light will begin to blink simultaneously 5 times.

     ✓ While the lights are blinking simultaneously, you may cancel the Rollback by releasing the Firmware Rollback Switch. If Rollback is cancelled, the MP150 will try to load the latest firmware upgraded version.
   - Then the MP150 will perform a normal Startup/Self-Test with the factory-loaded firmware.
6. When the simultaneous blinking stops, release the switch.
   - The MP150 is now restored to the previous version of firmware.
   - You can check the firmware version via the MP150 > About MP150 menu item in Acq*Knowledge*.

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COPYRIGHT

Open source software for Specialized Analysis:

- PCRE

  Regular expression support is provided by the PCRE library package, which is open source software, written by Philip Hazel, and copyright by the University of Cambridge, England.
  ftp://ftp.csx.cam.ac.uk/pub/software/programming/pcre/

- The Apache Software License, Version 1.1

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