MindWare Heart Rate Variability (HRV) Analysis

User Reference Guide

Version 3.0.14

Internet Support

E-mail: sales@mindwaretech.com

Web Address: www.mindwaretech.com

Phone

Ph: (614) 626-4888

Fax: (614) 626-4915

MindWare Technologies LTD.

1020-F Taylor Station Rd. • Gahanna, Oh 43230

Safety

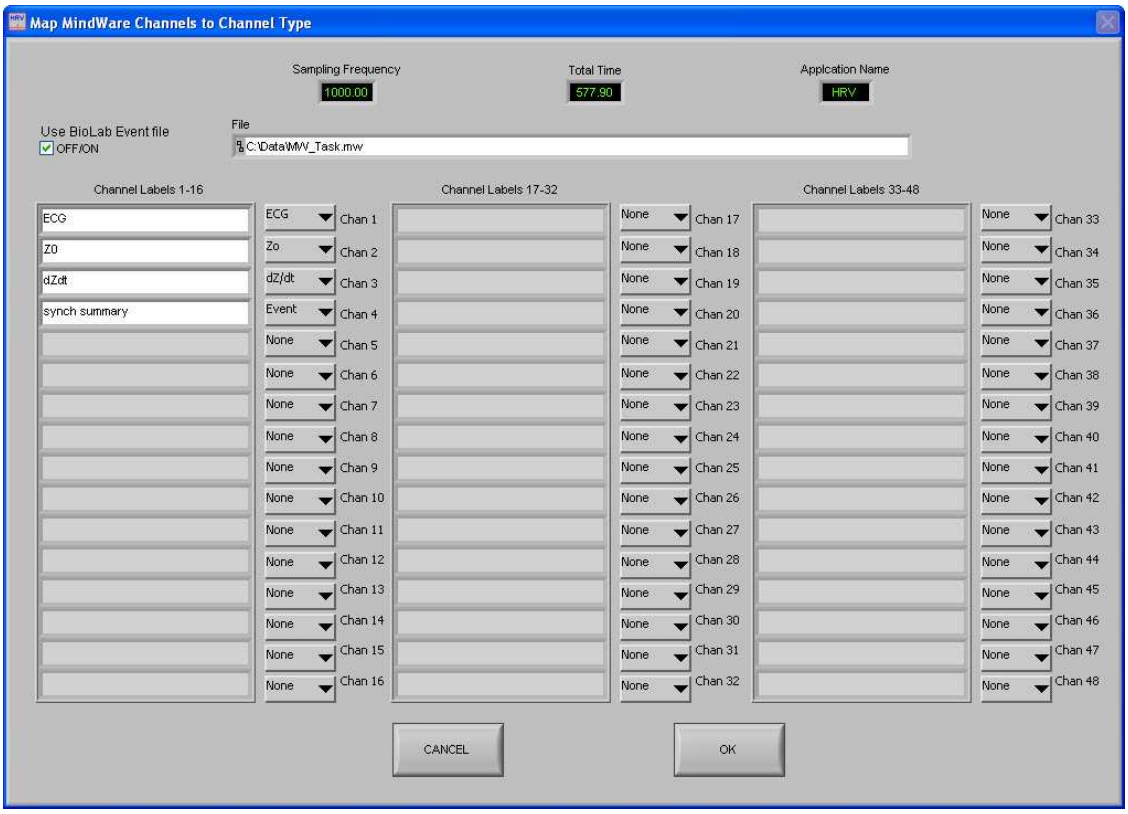
Warning Regarding Medical and Clinical Use of MindWare Technologies LTD Products.

MindWare Technologies LTD products are not designed with components and testing for a level of reliability suitable for use in treatment and diagnosis of humans or as critical components in any life support systems whose failure to perform can reasonably be expected to cause significant injury to a human. Applications of MindWare Technologies LTD products involving medical or clinical treatment can create a potential for death or bodily injury caused by product failure, or by errors on the part of the user or application designer. Any use or application of MindWare Technologies LTD products for or involving medical or clinical treatment must be performed by properly trained and qualified medical personnel, and all traditional medical safeguards, equipment, and procedures that are appropriate in the particular situation to prevent serious injury or death should always continue to be used when MindWare Technologies LTD products are being used. MindWare Technologies LTD products are NOT intended to be a substitute for any form of established process, procedure, or equipment used to monitor or safeguard human health and safety in medical or clinical treatment.

Table of Contents

Section 1: Channel Mapping

Upon opening the HRV analysis application, the user will be prompted to select a file for analysis. Once this file is selected, press OK to proceed to the channel mapping screen.



The Map MindWare Channels to Channel Type screen allows the user to identify the physiological data type for each channel in the data file using a pull down list. The list is derived from the header of the input file.

Although each data type in the file can be defined, not all channels must be assigned a specific data type. For HRV analysis, dZ/dt or Z0 or Respiration, ECG, and Event Channels (if applicable) need to be selected. Any channel defined other than these types will be ignored in HRV analysis.

File: This indicator displays the path and name of the file under analysis.

Channel Labels: This indicator displays the names of the channels as read from the file header of the input file.

Channel Types: These controls allow the user to assign a channel name from File Header Channel Names to a specific data type. For basic HRV analysis, only the ECG channels are required. The Event channel must be defined for any of the event-based analysis modes. Either Zo, dZ/dt, or Resp channel must be mapped for respiration calculations.

Total Time(s): This indicator displays the total time as read from the input file (in seconds.)

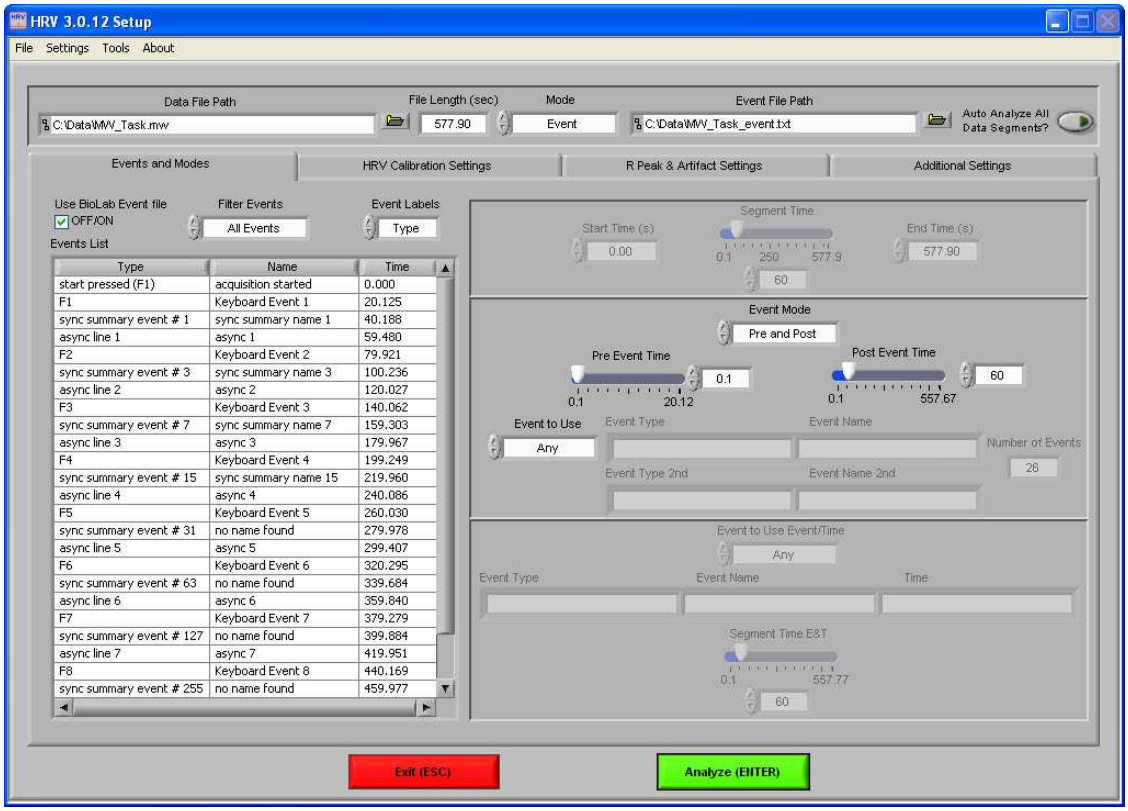
Sampling Frequency (Hz): This indicator displays the Sampling Frequency as read from the input file.

Application Name: This indicator displays the analysis application that is currently running.

Use BioLab Event File: This control allows the user to specify whether to use the event file created by BioLab in the event-based analysis rather than the Event channel.

Once the desired channels have been mapped, press OK to continue to the Setup screen.

Section 2: Setup



The Setup screen contains many options pertaining to the way in which the analysis is performed.

Data File Path: This control shows the current file selected for analysis. Also, by clicking the browse button a new file may be selected for analysis.

File Length(s): This indicator shows the total file length in seconds.

Mode: This control allows the user to select one of four analysis modes: Time, Event, Event and Time, and Real Time. The value of this control determines which controls are enabled on the Events and Modes tab.

Event File Path: If a BioLab event file is being used for analysis, the path of that event file is shown in this indicator.

Auto Analyze All Data Segments: When this control is activated, the application will automatically analyze each segment of the dataset and output it to the specified location.

All changes to settings in the Setup screen are saved to a configuration file automatically whenever analysis is initiated or the application is exited.

The following options are available from the menu bar:

File:

Open: This option allows a new file to be opened for analysis.

Re-Map Channels: This option opens the Map MindWare Channels to Channel Type screen for modifications to be made to the channel map.

Scaling and Filtering Settings: This option brings up a window detailing the scaling and filtering information as it was applied to the channels during acquisition.

Show Summary Screen: This option enables/disables the summary screen popup before analysis is started.

Exit: This option exits the analysis application.

Settings:

Open Configuration: Allows a previously saved configuration file to be opened.

Save Configuration As: This option saves all current settings in the Setup screen to a configuration file which can later be recalled.

Reinitialize All to Default: This option will return all settings in the setup screen to factory default.

Tools:

ASCII-MW Converter: Opens the ASCII-MW converter (see Appendix A).

About:

Show Help: This option opens a small window containing descriptions of the controls available on the screen. Hover over the desired control to view its description.

About MindWare: Opens a small window with information about MindWare Technologies and the analysis application

Events and Modes

The first tab on the screen, titled Events and Modes, allows the user to select one of the many modes available to use to index through the dataset.

The left side of the screen shows all events in the file either from Event channel or the BioLab event file with the event name, type, and time. There are three controls for specifying the way in which the events are viewed:

Use BioLab Event File: When checked, the events displayed are from the BioLab event file. Otherwise, they are detected in the channel mapped as Event.

Filter Events: The events shown in the list and used for analysis can be filtered by type to use summary events, keyboard events, individual events, or all events.

Event Labels: This control specifies how the event will be labeled when it is shown in the analysis window.

Time Mode: In time mode, the following parameters are available:

Start Time: Used to set the time at which the first analysis segment will start.

Segment Time: Specifies the length of each segment, starting at the start time and splitting the remainder of the file into equal length segments.

End Time: Used to set time at which the last analysis segment will end.

Event Mode: The list to the left of the event controls displays all of the events detected in either the BioLab Event File or the channel mapped to “Event”. This can be changed by either marking or unmarking the box named “Use BioLab Event File” above the event list. This list can be filtered by type, including Keyboard, Individual, Summary, or All Events. Also, the type of label which will be displayed on the event during analysis can be set by using the “Event Labels” control.

There are 4 viewing modes available in event mode:

Pre Event: The Pre-Event Time slider specifies the number length of the data before the specified event that is included in the segment.

Post Event: The Post-Event Time slider specifies the length of the data after the specified event that is included in the segment.

Pre and Post: This is a combination of the previous 2 modes in which both the length of the data before and after a specified event can be set.

Event to Event: In this mode, the length of the segment is defined by the time in between the current event and the next event in the list.

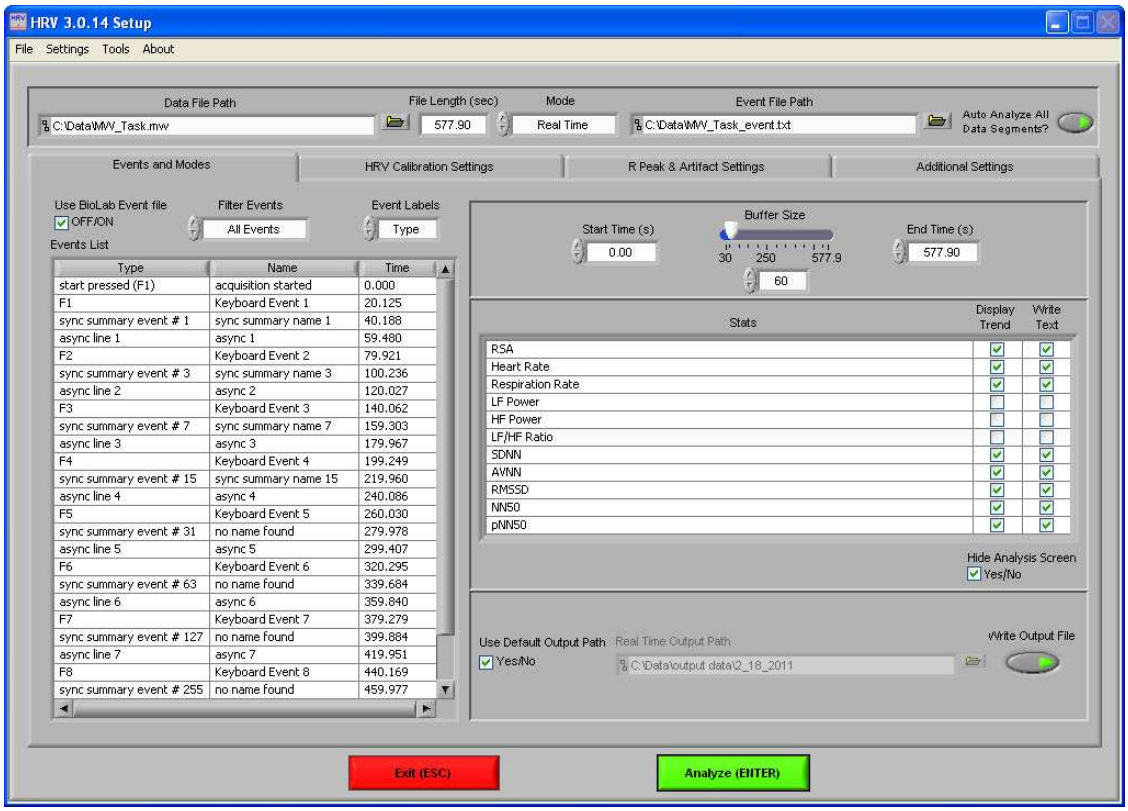
For each of these event modes, there is the option of either using any event in the list or specifying a certain event to view. A specific event can be chosen from the event list by first selecting "User Defined" in the Event to Use box, and then selecting the desired event from the list and dragging it to the box labeled "Event Type". In Event to Event mode, two specific events to go between can be selected. The number of events box shows the total number of events of the specified type which will be shown during analysis.

Event and Time: Event and Time mode combines the previous two modes to allow the selection of a specific event to use as a starting point and then to proceed through analysis in time mode from that point. The following parameters are available:

Event to Use Event/Time: This has a similar functionality as in Event mode, where "Any" will simply use whichever event is next in the list and proceed from that point and "User Defined" will proceed in time mode from the location of the specified event. The event can be specified by selecting the desired event in the event list and dragging it to the box below.

Segment Time E&T: Specifies the length of each segment, starting at the location of the specified event and splitting the remainder of the file into equal length segments

Real Time Mode: Real Time mode analyzes second by second with the specified buffer size to compute the HRV statistics in real time for the selected file. When in Real Time analysis mode, video playback is disabled.



The following parameters are available:

Start Time: Used to set the time at which the first analysis segment will start.

Buffer Size: Specifies the length of the buffer to be used when calculating real time stats.

End Time: Used to set time at which the last analysis segment will end.

Stats: This table lists the stats that are available for calculation in real time. Selecting **Display Trend** will result in the calculations being shown on the Real Time Analysis screen as they are calculated. Selecting **Write Text** will write the specified statistic in the real time output file.

Hide Analysis Screen: When selected, the standard Analysis screen will be hidden and only the Real Time Analysis screen will be shown. Displaying the standard Analysis screen slows the calculation rate considerably.

Use Default Output Path: The default output location is a folder named "output data" in the folder which contains the file being analyzed. Within the "output data" folder, files are organized in folders by the date on which they were analyzed. If any of these folders don't exist, they are automatically created when the first output file is written to that directory. A different location to save these files can also be specified in the file box.

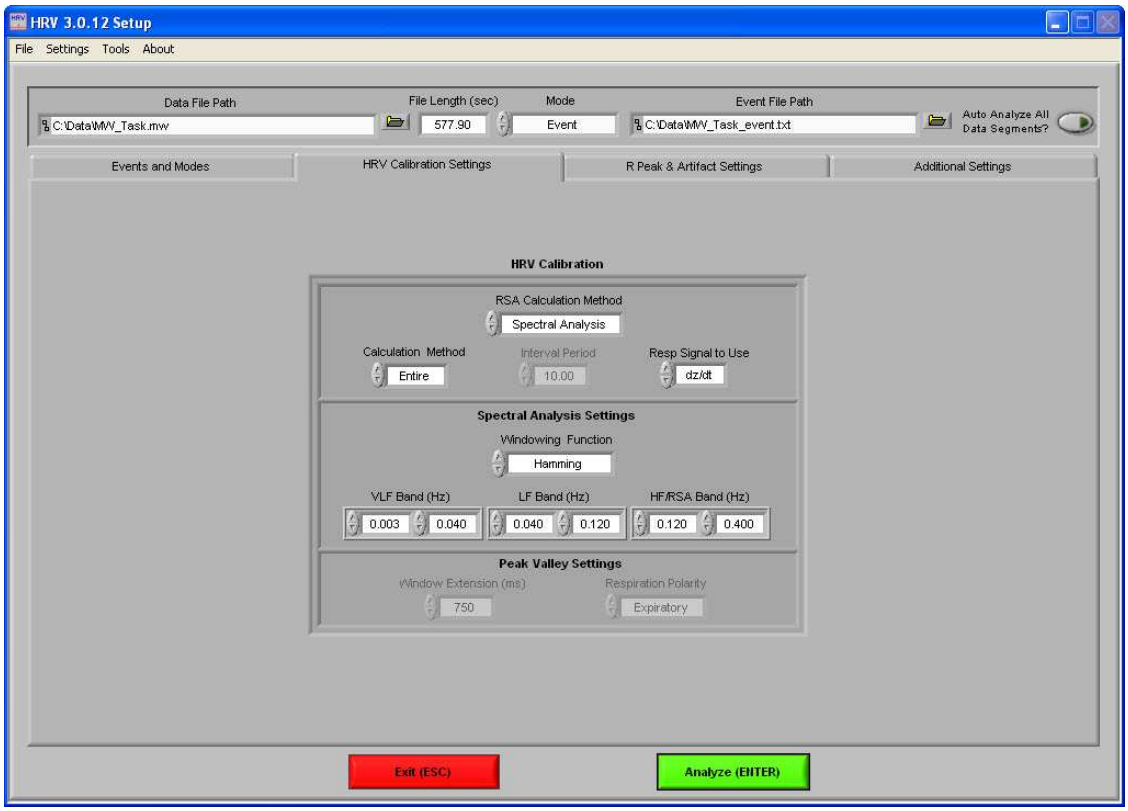
Real Time Output Path: Specifies location where output file will be saved.

Write Output File: Enables/disables writing the output file

*Note: It is recommended that a clean and edited series be used for real time analysis. Be sure to map the correct edit file (when applicable) on the **Additional Settings** tab prior to proceeding in real time mode.*

HRV Calibration Settings

The second tab on the screen, titled HRV Calibration Settings, allows the user to define a respiration source, set the filter bands and windowing method, and define a calculation method.



RSA Calculation Method: This control specifies which calculation method will be used to derive RSA. There are two methods available:

> **Spectral Analysis:** Uses the FFT and specified frequency bands of the resampled IBI series to derive RSA.
>
> **Peak Valley:** Uses phases of respiration in conjunction with the IBI series to determine RSA (requires respiration signal to use).

Calculation Method: This control defines the mode for which the mean heart rate and IBI will be determined. There are two selections available: Entire and Interval. In Entire mode, mean heart rate and mean IBI will be the mean across the total window period defined in the Events and Modes tab. In Interval mode, the window period will be the same as in the Entire mode however these measures are divided into fixed time bins as set by the Interval Period and will represent the mean heart rate and mean IBI values in these intervals.

Interval Period: This control specifies the length of each interval in seconds. (Only applies when interval mode is selected)

Respiration Signal to Use: This control selects the source to use to derive respiration measures. The options available are Resp, dZ/dt, Zo or none.

Window Function: This control allows the user to select the type of windowing used before doing the power spectrum calculation to reduce spectral leakage.

VLF Band (Hz): This control sets the VLF frequency cutoffs for filtering the heart period and respiration time series.

LF Band (Hz): This control sets the LF frequency cutoffs for filtering the heart period and respiration time series.

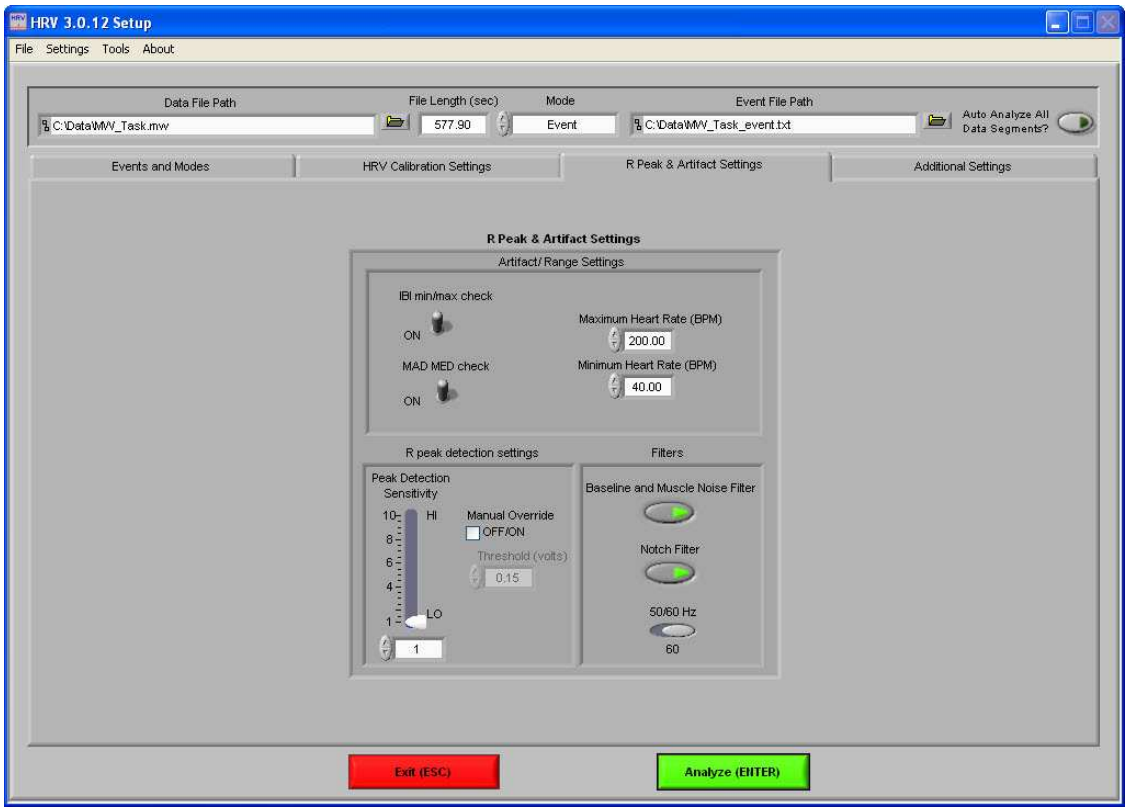
HF/RSA Band (Hz): This control sets the HF/RSA frequency cutoffs for filtering the heart period and respiration time series. The high frequency cutoff is also applied to respiration.

Window Extension (ms): When using Peak Valley RSA calculation method this control specifies how many milliseconds to extend each respiratory cycle when determining valid max and min IBI's.

Respiration Polarity: This control specifies the polarity of the respiration source. The polarity is inspiratory if the value of the respiration signal increases during inspiration. If the value of the respiration signal increases during expiration, then the polarity is expiratory.

R Peak and Artifact Settings

The third tab on the screen, titled R Peak and Artifact Settings, allows the user to set the sensitivity for the peak or enable manual override, enable or disable the MAD/MED or IBI min/max heart beat detection methods, set the expected heart rate range, and turn on the noise filters.



MAD/MED Check: This control enables or disables the application of MAD/MED criteria to the heart beat detection.

IBI Min/Max Check: This control enables or disables the application of IBI Min/Max criteria to the heart beat detection. The algorithm will test the IBI series to be in range of the settings selected in the Minimum Heart Rate and Maximum Heart Rate controls.

Minimum Heart Rate (BPM): This control allows for the selection of the minimum expected heart rate in the data series. This value will be the maximum IBI threshold.

Maximum Heart Rate (BPM): This control allows for the selection of the maximum expected heart rate in the data series. This value will be the minimum IBI threshold.

Baseline and Muscle Noise Filter: This control enables or disables the muscle noise filter. This filter applies a band pass filter (.25 to 40 Hz) to the data.

50/60 Hz Notch Filter: This control enables or disables the 50/60 Hz notch filter.

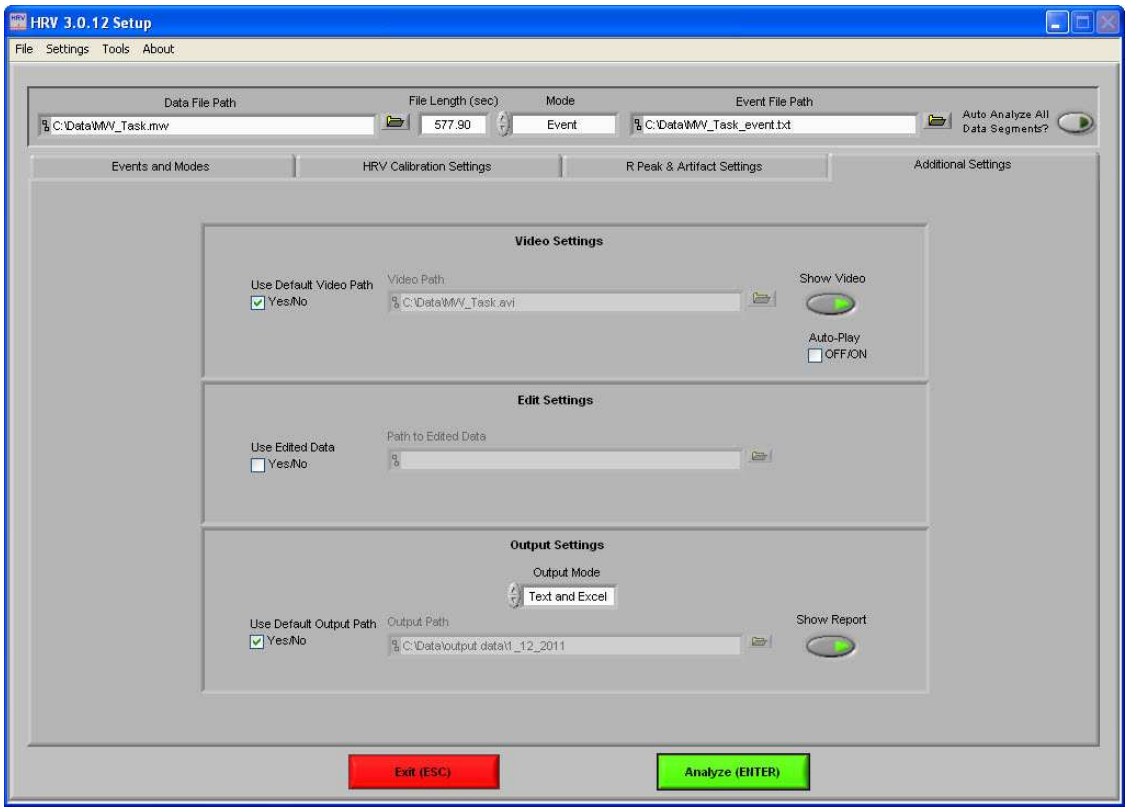
Peak Detection Sensitivity: This control is used to set the sensitivity of the dynamic peak picking algorithm from 1 (Minimum Sensitivity) to 10 (Maximum Sensitivity.)

Manual Override: This control is used to disable the dynamic peak detector and switches to the absolute threshold mode.

50/60 Hz: This control is used to select the frequency of the notch filter.

Additional Settings

The last tab on the screen, titled Additional Settings, allows the user to select settings for incorporating video in analysis, the use of edited data, and the type of output file created.



Video Settings: The following parameters are available regarding video playback during analysis:

> **Use Default Video Path:** This selects whether the default video associated with the file will be used, or a video can be specified in its place.
>
> **Show Video:** Sets whether the video will be shown during analysis or not.
>
> **Auto-Play:** When this is turned on, the specified video will automatically begin playback when a new segment is selected. Otherwise, the video will not begin playback until it is started by the user.

Edit Settings: If there is edit data associated with the current file, it can be selected here and will be used for analysis. Otherwise, only the data within the file will be used.

Output Settings: The following parameters are available to specify the type and location of the output files:

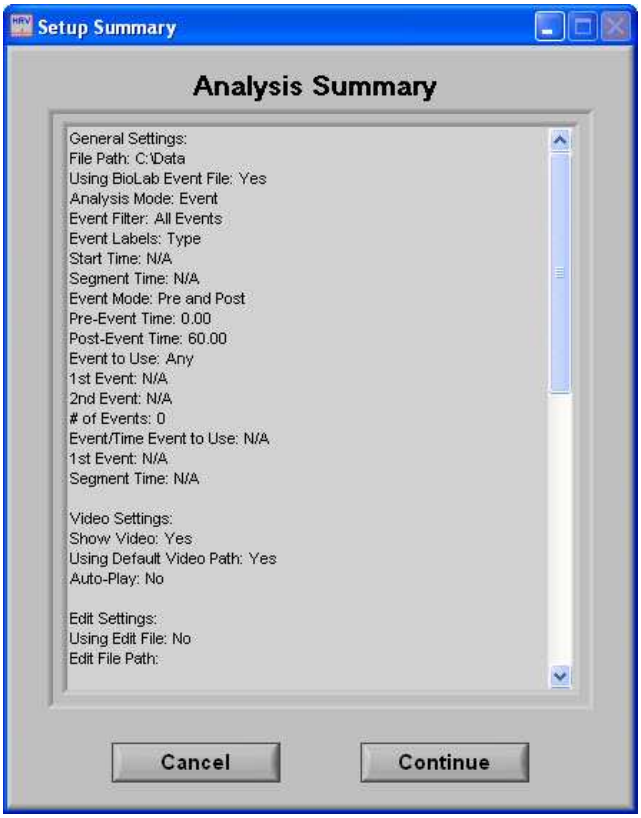
Output Mode: Either a text file (.txt), an excel spreadsheet (.xls) or both can be output at the end of analysis.

Use Default Output Path: The default output location is a folder named "output data" in the folder which contains the file being analyzed. Within the "output data" folder, files are organized in folders by the date on which they were analyzed. If any of these folders don't exist, they are automatically created when the first output file is written to that directory. A different location to save these files can also be specified in the file box.

Show Report: When turned on, the excel spreadsheet will be opened and written to as the user writes segments to the report. When turned off, the spreadsheet will be written following analysis and saved to the specified directory but never opened.

Section 3: Analysis

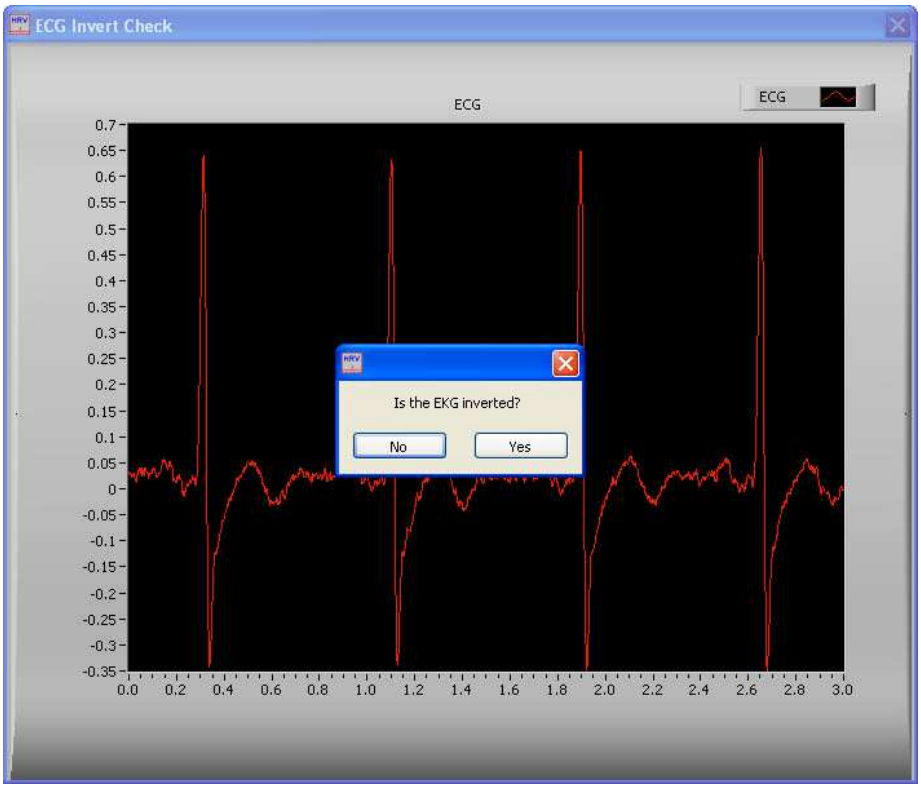
When the Analyze button is pressed, if the summary screen has been enabled then the Analysis Summary screen is displayed, showing the various settings from the Setup screen.



Cancel: This control will return the user to the Setup screen to adjust analysis settings before continuing.

Continue: This control will begin analysis using these settings.

At this point, the user will be shown a segment of data from the channel mapped as ECG. The user can then invert the ECG signal if required. It is important to have the phase of the R-Wave positive for the peak detection to work effectively.



One of the next screens made visible is the Controls screen, which initially sits just above the HRV Analysis window.

The Controls screen is the interface for sequencing through each data segment as well as viewing the program status indicators, editing data, and writing the output file. From here, the user can select the next data segment to analyze, write the statistical information to the output file, or quit to return back to the Setup screen.

Current Segment: The Current Segment control allows the user to switch from one data segment to another. Clicking the up/down arrows or clicking the mouse in the selection window can change this value. If the selection window is clicked, all data segments that are available will be displayed depending on the mode criteria in the Setup Screen. Selecting one of these segments will change to that data segment. Pressing the "Page-Up" and "Page-Down" keys allows the user to cycle through the Segments.

File Name: This indicator displays the name of the data file being analyzed.

Write: The Write control is used to write the analysis results for the current segment into the output format specified during setup. This button must be pressed after each segment or the results will not be saved. If data for this segment already exists in the file, it will be overwritten.

*Note: The **Write** button is disabled when in Real Time mode.*

Done: This control is used to terminate the current session and return the user to the Setup screen.

Edit R's: The Edit control switches the window to the graphical ECG editor. The user can insert, delete or move a marker allowing for the correction of any movement artifact or to manually adjust the values as derived by the peak detector. The user is also able to remove data portions.

Edit Resp: The Edit Resp control switches the window to the graphical Respiration editor. The user can then insert, delete, or move peaks and troughs as detected in the respiration signal.

*Note: The **Edit Resp** button is only available when using Peak Valley RSA calculation method.*

R Peak and Artifact: The R Peak and Artifact control allows the user to modify the values in the R-Peak and Artifact Settings without having to exit this analysis sequence.

Video Settings: The Video Settings control allows the user to modify the video settings from the Setup screen without having to exit this analysis sequence.

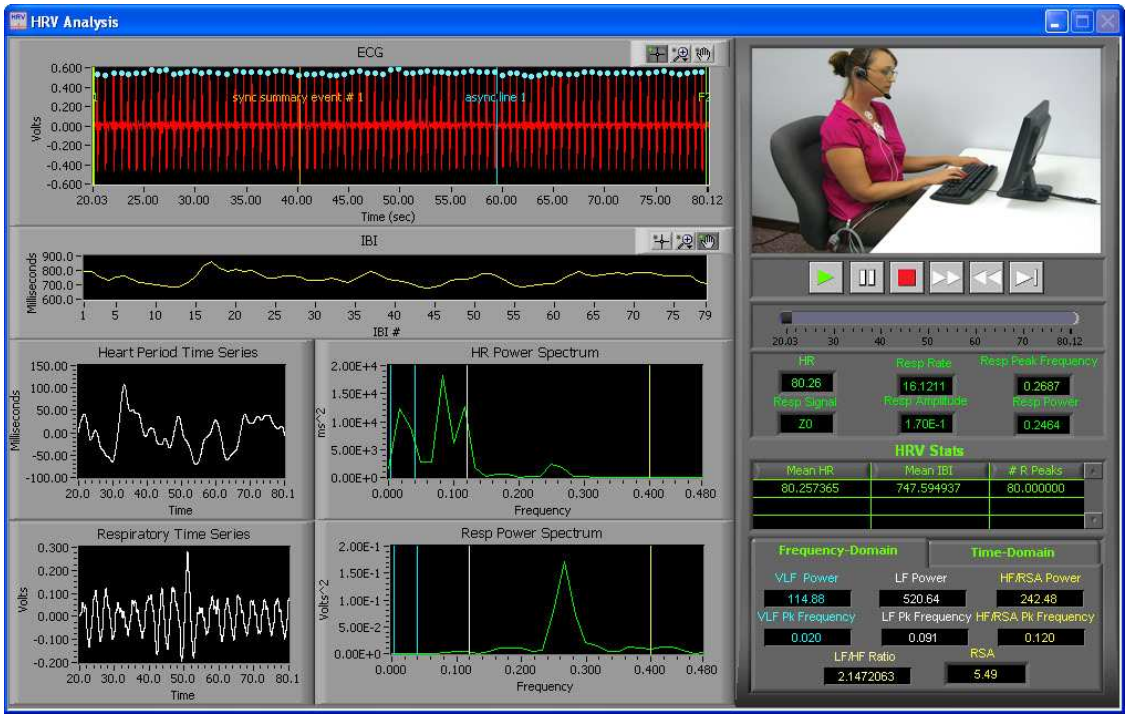
Writing: The Writing indicator will be illuminated when the current segment results are being written to the output spreadsheet.

Reading: The Reading indicator will be illuminated when the current data file is being read.

Edit: The Edit indicator will be illuminated when edited data is being used. This will be on when the user exits the editor or is using a previously edited session.

HRV Analysis – Spectral RSA Calculation

The HRV Analysis screen displays the analysis window for the selected data segment. This screen is shown when the Spectral RSA calculation method has been selected.



There are six plots visible on this screen:

ECG: The values plotted on the ECG window are a beat to beat analog waveform. Also shown on this plot are the event markers and the position cursor. The event markers are labeled with either the event name or type (as specified in the Setup screen) and are color coded by type (Keyboard = Green, Summary = Orange, Individual = Blue). The position cursor can be dragged anywhere within the current dataset, at which point the video will be updated to reflect this new position.

IBI: The values plotted in this window are the IBI Time Series of ECG.

Heart Period Time Series: The values plotted in this window are the IBI series sampled in milliseconds.

HR Power Spectrum: The values plotted in this window are the spectral output of the Heart Period Time Series.

Respiration Time Series: The values plotted in this window are the signal mapped to Respiration sampled in milliseconds.

Resp Power Spectrum: The values plotted here are the spectral output of the Resp Time Series.

There are three colored bands shown on the HR Power Spectrum and Resp Power Spectrum plots. Each represents a specific frequency range in the power spectrum. (VLF Band = Blue, LF Band = White, HF/RSA Band = Yellow).

In the upper right hand corner of the screen, the video selected during setup is displayed. Below it are the various video playback controls:

 **Play:** This control initiates playback of the video at normal speed from the specified location.

 **Pause:** This control pauses playback of the video at the current location.

 **Stop:** This control stops playback of the video and returns to the start of the segment.

 **Fast Forward:** This control speeds playback of the video up to 2x normal speed.

 **Rewind:** This control rewinds the video at 2x normal speed.

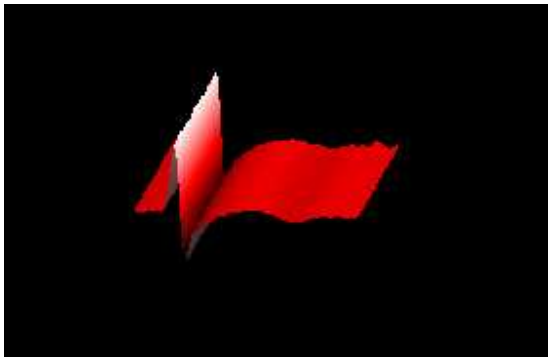
 **Slow:** This control slows playback of the video to half normal speed.

Position Slider: This control reflects the current position in both the physiological data and the video playback. It can be dragged to a certain location, at which point the video and the position cursor in the ECG plot will be updated to reflect the new position.

By right-clicking the video and selecting Undock from the run-time menu, the video will be removed from the analysis window and re-opened in its own resizable, floating window.

To return the video to the analysis window, right-click the floating video window and select Dock from the run-time menu.

In the event that either the video is undocked or there was no video selected to be shown during setup, the video display is replaced by the ECG Ensemble Elements plot.



ECG Ensemble Elements: The 3D plot displays the ensemble average of all of the ECG waveforms found in this data segment. The plot can be rotated to show different views by selecting or holding the plot with the left mouse button and moving to a different viewpoint.

Below the video/ensemble plot and the video controls, in the lower right hand corner of the HRV Analysis screen are the calculated stats about the current data segment:

HR: This value represents the mean heart rate for this segment.

Resp Rate: This value represents the respiration rate measured in breaths per minute as derived from the Resp Power Spectrum.

Resp Peak Frequency: This value represents the peak frequency in the respiration power spectrum.

Resp Signal: This value shows the source used to derive respiration.

Resp Amplitude: This value represents the mean respiration amplitude for this segment.

Resp Power: This value represents the spectral power in the respiration power spectrum.

HRV Stats: This table will contain one row when calculation mode is set to Entire. When calculation mode is set to Interval, there will be a row for each interval shown in the ECG plot. This table contains three fields:

Mean HR: This value represents the mean heart rate.

Mean IBI: This value represents the mean inter-beat interval in milliseconds.

#R Peaks: This value represents the number of R peaks that were detected within the window.

Frequency-Domain: This submenu contains frequency domain values pertaining to the calculation of RSA. The following calculated values are shown:

VLF Power: This value represents the amplitude in the heart rate power spectrum at the frequency identified as VLF Peak Frequency.

LF Power: This value represents the amplitude in the heart rate power spectrum at the frequency identified as LF Peak Frequency.

HF/RSA Power: This value represents the amplitude in the heart rate power spectrum at the frequency identified as HF/RSA Peak Frequency.

VLF Peak Frequency: This value represents the peak frequency in the heart rate power spectrum as measured in the VLF Frequency Band.

LF Peak Frequency: This value represents the peak frequency in the heart rate power spectrum as measured in the LF Frequency Band.

HF/RSA Peak Frequency: This value represents the peak frequency in the heart rate power spectrum as measured in the HF/RSA Frequency Band.

LF/HF Ratio: This value represents the ratio of Low Frequency Power divided by the High Frequency Power.

RSA: This value represents the RSA value for the current segment.

Time-Domain: This submenu contains time domain calculations derived from NN intervals in the IBI series. The following calculated values are shown:

SDNN: This value represents the standard deviation of NN intervals.

AVNN: This value represents the average of all NN intervals.

RMSSD: This value represents the root mean square of successive NN intervals.

NN50: This value represents the number of NN intervals which differ by more than 50 ms from the previous interval.

pNN50: This value represents the fraction of NN intervals which differ by more than 50 ms from the previous interval.

HRV Analysis – Peak Valley RSA Calculation

The HRV Analysis screen displays the analysis window for the selected data segment. This screen is shown when the Peak Valley RSA calculation method has been selected.

There are three plots visible on this screen:

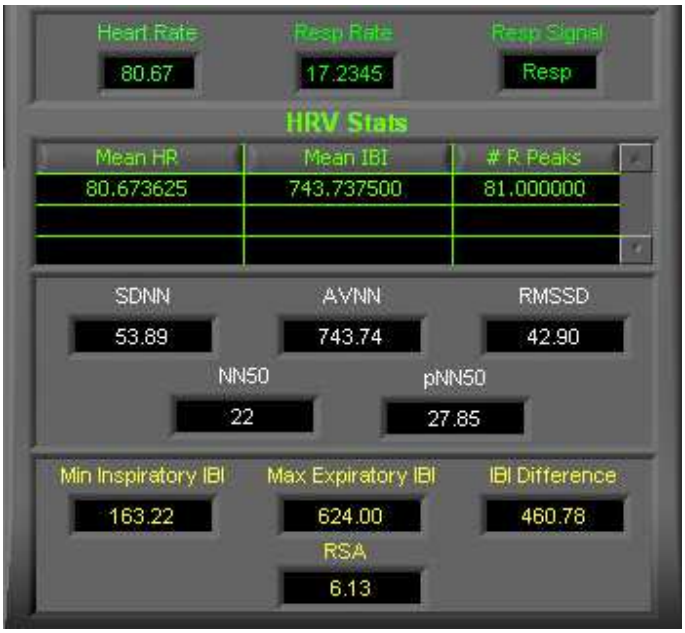
ECG: The values plotted on the ECG window are a beat to beat analog waveform. Also shown on this plot are the event markers and the position cursor. The event markers are labeled with either the event name or type (as specified in the Setup screen) and are color coded by type (Keyboard = Green, Summary = Orange, Individual = Blue). The position cursor can be dragged anywhere within the current dataset, at which point the video will be updated to reflect this new position.

IBI: The values plotted in this window are the IBI Time Series of ECG.

Respiratory Time Series: The values plotted in this window are the signal mapped to Respiration sampled in milliseconds. Detected peaks are marked with a light blue cursor, and detected troughs are marked with a green cursor.

All video and ensemble controls behave as described in the **HRV Analysis: Spectral RSA Calculation** section.

Below the video/ensemble plot and the video controls, in the lower right hand corner of the HRV Analysis screen are the calculated stats about the current data segment:



HR: This value represents the mean heart rate for this segment.

Resp Rate: This value represents the respiration rate measured in breaths per minute as derived from the peaks and toughs detected in the Respiratory Time Series.

Resp Signal: This value shows the source used to derive respiration.

HRV Stats: This table will contain one row when calculation mode is set to Entire. When calculation mode is set to Interval, there will be a row for each interval shown in the ECG plot. This table contains three fields:

Mean HR: This value represents the mean heart rate.

Mean IBI: This value represents the mean inter-beat interval in milliseconds.

#R Peaks: This value represents the number of R peaks that were detected within the window.

SDNN: This value represents the standard deviation of NN intervals.

AVNN: This value represents the average of all NN intervals.

RMSSD: This value represents the root mean square of successive NN intervals.

NN50: This value represents the number of NN intervals which differ by more than 50 ms from the previous interval.

pNN50: This value represents the fraction of NN intervals which differ by more than 50 ms from the previous interval.

Min Inspiratory IBI: This value represents the minimum IBI found during all inspiratory phases of respiration.

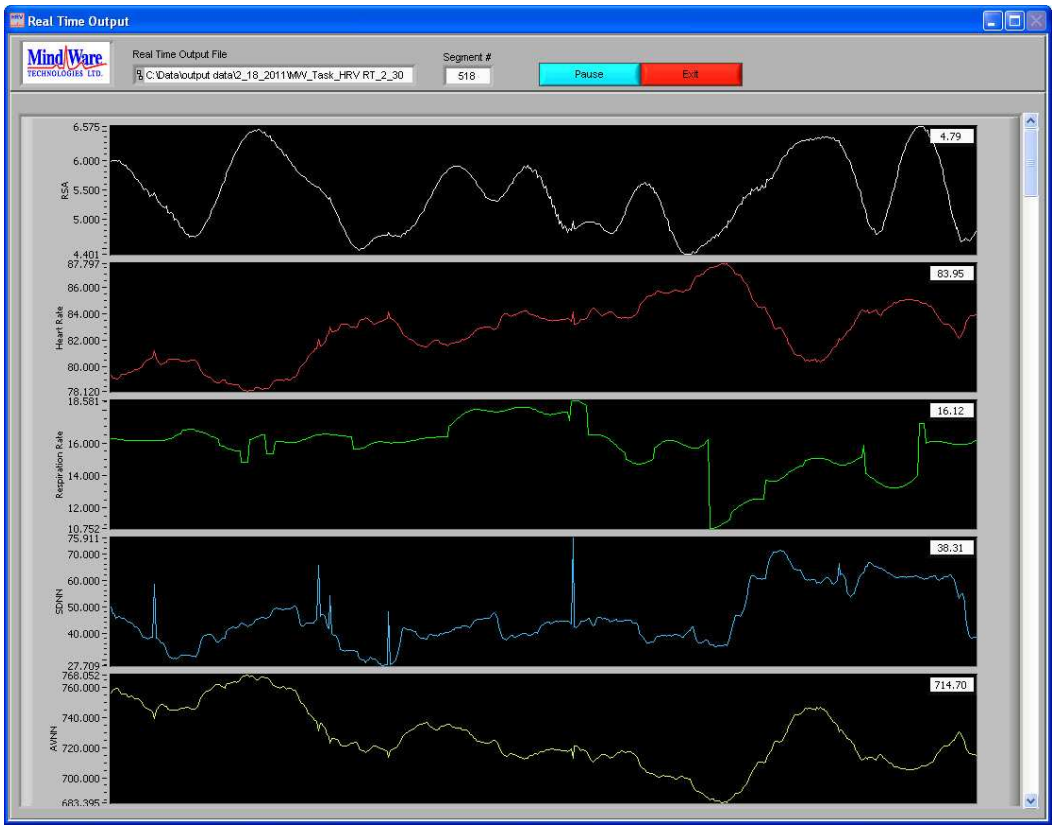
Max Expiratory IBI: This value represents the maximum IBI found during all expiratory phases of respiration.

IBI Difference: This value represents the difference between the minimum IBI found during all inspiratory phases and the maximum IBI found during all expiratory phases of respiration.

RSA: This value represents the RSA value for the current segment.

HRV Analysis – Real Time Analysis

The HRV Real Time Analysis screen displays the real time HRV statistics. This screen is shown when the Peak Valley RSA calculation method has been selected.



This screen will either appear on its own, or along with the standard Analysis screen depending on the setting on the Setup screen. On this screen, a plot is shown for each of the selected HRV statistics. As these statistics are calculated second by second, their values appear in their respective charts. This screen can be expanded to display more plots at a time, or these additional plots are available by scrolling down. The following options are available:

Pause: Pressing pause will temporarily stop the calculation of the real time stats. Pressing **Resume** will continue the calculation of the statistics.

Exit: This control will end the calculation of real time stats and close this window.

Section 4: Output File

	A	B	C	D	E	F
1	Version	HRV v3.0A				
2	Date	3/19/2009				
3	Time	10:48 AM				
4	File Name	C:\Data\MW_Task.mw				
5	Analysis Mode	Event				
6	Event Filter	All Events				
7	Start Time	N/A				
8	Segment Time	N/A				
9	Event Mode	Pre and Post				
10	Pre-Event Time	0				
11	Post-Event Time	60				
12	Event to Use:	Any				
13	1st Event	N/A				
14	2nd Event	N/A				
15	# of Events	26				
16	Event/Time Event to Use	N/A				
17	1st Event	N/A				
18	Segment Time	N/A				
19						
20	Sampling Frequency	1000				
21	Volts Full Scale	10				
22	A/D Resolution	16 Bit				
23	50/60 hz notch filter	Off				
24	baseline/muscle noise filter	On				
25	VLF Frequency Band	0.0030, 0.0400				
26	LF Frequency Band	0.0500, 0.1500				
27	HF/RSA Frequency Band	0.1500, 0.5000				
28	Windowing	Hamming				
29	Respiration Signal Used	dZ/dt				
30	Calculation Method	Entire				
31	Interval Period	N/A				
32						
33	Segment Number	1	2		4	
34	Mean Heart Rate	80.256007	80.575246		78.173912	
35	RSA	4.80655	4.339758		6.120362	
36	Mean IBI	747.607595	744.64557		767.519481	
37	Event	F1	sync summary event # 1		F2	
38	Event Time	20.12	40.19		79.92	
39	# of R's Found	80	80		78	
40	Respiration Rate	16.171839	16.484246		14.917304	
41	Respiration Amplitude	0.718647	0.430838		0.229192	
42	Respiration Peak Frequency	0.269531	0.274737		0.248622	
43	Respiration Power	1.0616	0.556607		0.533249	
44	First ECG R Time	20.443	40.912		80.223	

There are three different output modes:

Text (.txt): Seven .txt files will be created:

*Filename*_**HRV_stats**_*time*.**txt:** This text file contains the calculated statistics from the specified segment of data.

*Filename*_**HRV_IBI**_*time*.**txt:** This text file contains the IBI series derived from the specified segment of data.

*Filename*_**HRV_power band**_*time*.**txt:** This text file contains the stats about each power band for the specified segment of data.

*Filename*_**HRV_heart period time series**_*time*.**txt:** This text file contains the heart period time series for the specified segment of data.

*Filename*_**HRV_heart period power**_*time*.**txt:** This text file contains the heart period power series for the specified segment of data.

*Filename*_**HRV_resp time series**_*time*.**txt:** This text file contains the respiration time series for the specified segment of data.

*Filename*_**HRV_resp power spectrum**_*time*.**txt:** This text file contains the respiration power series for the specified segment of data.

Excel (.xls): An Excel spreadsheet file will be created containing seven worksheets:

HRV Stats: This worksheet (shown above) contains all setup information as well as the calculated statistics from the specified segment of data.

IBI Series: This worksheet contains the IBI series derived from the specified segment of data.

Power Band Stats: This worksheet contains the stats about each power band for the specified segment of data.

Heart Period Time Series: This worksheet contains the heart period time series from the specified segment of data.

Heart Period Power Spectrum: This worksheet contains the heart period power series from the specified segment of data.

Respiration Time Series: This worksheet contains the respiration time series from the specified segment of data.

Respiration Power Spectrum: This worksheet contains the respiration power series from the specified segment of data.

Text and Excel: Outputs both .text files and an Excel spreadsheet file as specified above.

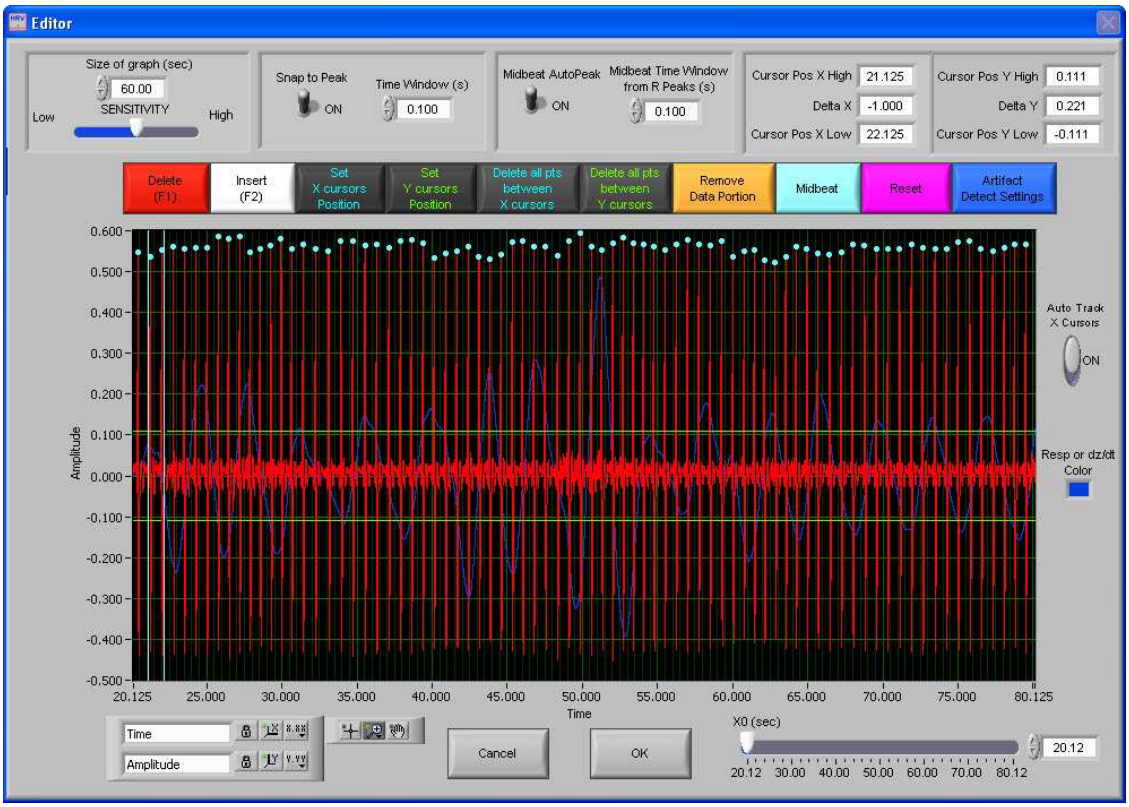
When in interval mode, an additional worksheet will be created titled **Interval Stats**, which contains the mean heart rate, mean IBI, and # of R Peaks from each of the intervals in the current data segment.

When in Real Time analysis mode, a different output file is written containing the real time HRV statistics second by second in a tab-delimited table along with a header containing important setup information. This file is named

*Filename*_**HRV RT**_*time*.**txt**

and is stored in the specified Real Time Output Path.

Section 5: R Peak Editor



The R Peak Editor is an easy to use, yet powerful tool allowing for the modification of the placement of ECG R- peaks detected programmatically from the peak detection algorithm. It is a graphical based editor and will carry any modification that is made back to the analysis screen. The editor has built in artifact detection algorithms and will dynamically update the graph as points are edited. The artifact detection algorithms can also be turned on or off from within the editor.

There are two waveforms visible from within the editor. Displayed in red is the ECG time series with the peaks marked in blue. Displayed in blue is the respiration time series.

There is also a set of green horizontal cursors and blue vertical cursors. By selecting the crosshair tool under the graph the user can move the position of these cursors and then click the Delete all Points between X Cursors or Delete all Points between Y Cursors, all peaks detected between their respective cursors will be deleted. This is especially helpful for removing large T components of ECG. This will only remove the markers on the ECG waveform.

ECG waveform graph: The ECG waveform is displayed in red. The blue markers denote the R peaks as detected from the peak detection algorithm. The yellow circular markers with cross hair markers denote potential artifact detected by the error detection algorithms. The Y values are scaled in volts and the X values are in time (seconds.) The graph tools window in the bottom left has three tools for aid in editing. The tool with the cross hairs should be used for inserting and/or deleting points. The second tool, the magnifying glass, can be used to zoom in on the graph. The third tool, the hand, is used to scroll through the entire data set. The control in the bottom left corner can be used to zoom out the graph after zooming in by clicking on the X or Y button to zoom the graph back to its original position. This graph also contains cursors used to delete multiple points simultaneously. These cursors can be dragged freely to a desired location.

Auto-Track Cursors: When activated, the cursors will retain their position on the screen as the data is scrolled through. When off, the cursors keep their position in the data and can leave the screen if scrolled past.

Resp or dZ/dt Color: This color box shows the current color of the respiration or dZ/dt plot. Clicking this control allows the user to change the color of this plot.

X0 (seconds): The X0 control determines where to start the graph in time. The user can slide this control to move their way through the segment in the edit screen.

Size of Graph (seconds): The Size of Graph control determines how much of the waveform to display at once. This value can be changed to fit less data onto the screen at once much like a zoom window.

Snap to Peak Control and Sensitivity Control: The snap to peak switch when in the "On" position will enable the snap to peak algorithm for point insertion. When the snap to peak switch is in the "OFF" position, it disables the snap to peak algorithm and allows for manual insertion of a point at the point clicked upon within the graph indicator. The time window control sets the size of the time window centered about where the mouse is clicked (ie: If the user clicked on a point at 10 seconds, the snap to peak function will cut out 250ms to the left and 250ms to the right of this point and determine the peak value within this range.) To successfully insert a point using the snap to peak setting, the user must also click the mouse within a band defined by the sensitivity control. The lower the sensitivity control, the more precisely the user must click on the exact spot of desired insertion. The higher the sensitivity control, the less precise the user needs to be, but this can cause point insertion at a place other than the desired point and removal of too many points when deleting.

Midbeat Auto Peak Control and Time Window from R Peak Control: When the Midbeat Auto Peak Control is in the "On" position the mid beat algorithm is enabled. When the switch is in the "Off" position the midbeat control will mark a position exactly half way between the two selected points. The time window control defines the amount of time from each selected R Peak to go before finding a peak value (ie: If point 1 is at 1 second and point 2 is at 2 seconds and the time window is on 100ms, then the midbeat algorithm will find the peak value in the window from 1.1 seconds to 1.9 seconds.)

Set X Cursor Position: The Set X Cursor Position brings up a window through which the user can set the high and low position of the X cursors by changing their numerical value. The Cursor Pos X Low and Cursor Pos X High show these settings.

Set Y Cursor Position: The Set Y Cursor Position brings up a window through which the user can set the high and low position of the Y cursors by changing their numerical value. The Cursor Pos Y Low and Cursor Pos Y High show these settings.

Delete (F1): This control latches when pressed until pressed again. If the points are within the range defined by the sensitivity control and the mouse click they will be deleted.

Note: Having the sensitivity to high or too low will result in too many points being deleted or not enough depending on the signal quality (noise, etc) and the rate of signal being edited.

Insert (F2): This control latches when pressed until pressed again. If the points are within the range defined by the sensitivity control and the mouse click they will be inserted at the point of the mouse click or at the peak defined by the snap to peak window control above as long as snap to peak is on.

Delete All Points Between X Cursors: All points within the boundary defined by the vertical blue cursors will be removed.

Delete All Points Between Y Cursors: All points within the boundary defined by the horizontal green cursors will be removed.

Remove Data Portion: This control will remove all data within the boundary defined by the cursors.

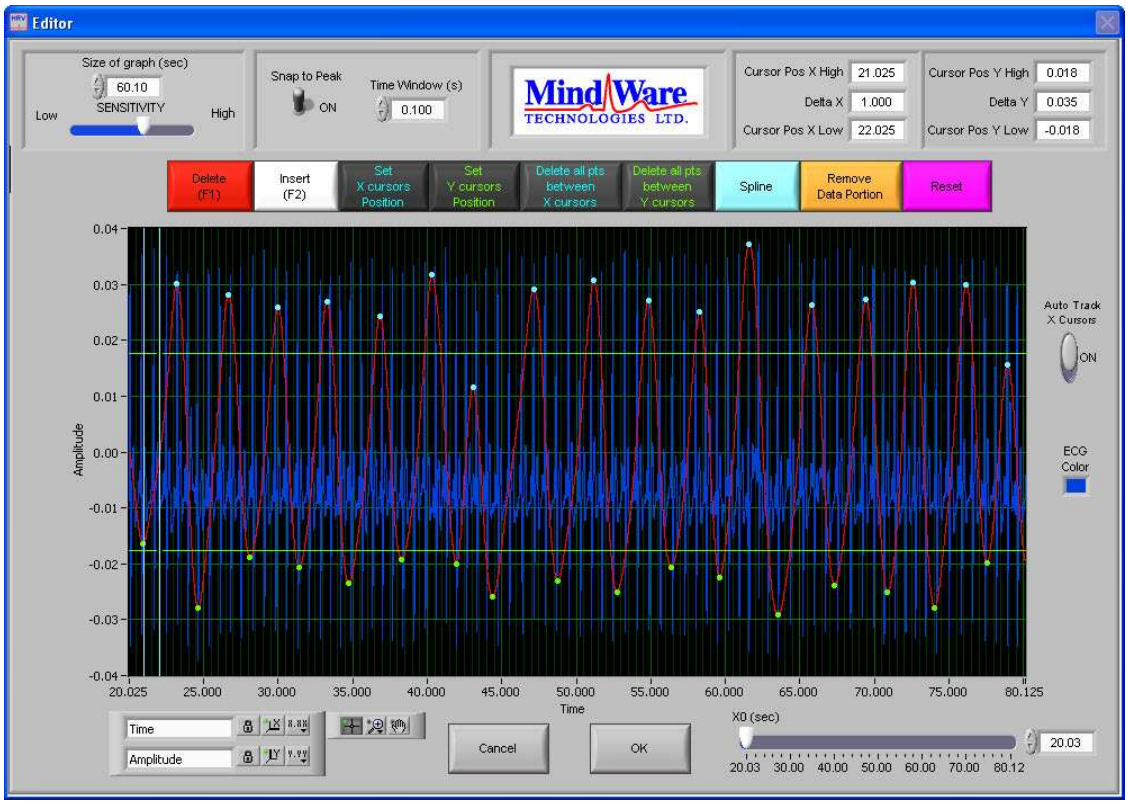
Midbeat: This control will mark a Midbeat point between two points selected with the cursor window and described above in the Midbeat controls sections.

Reset: This control resets the R peaks to the original state when the editor was first entered.

Artifact Detect Settings: Allows the user to turn on and off the artifact detection algorithms and settings.

OK and Cancel: When editing is complete and the user wants the changes to transfer back to the analysis screen, select OK. When the user selects Cancel, the data that has been edited will not be transferred and the editing will be lost.

Section 6: Resp Editor



The Resp Editor is an easy to use tool allowing for the modification of the placement of respiratory peaks and troughs. It is a graphical based editor and will carry any modification that is made back to the analysis screen. The editor has built in artifact detection algorithms and will dynamically update the graph as points are edited.

There are two waveforms visible from within the editor. Displayed in red is the respiratory time series with the peaks marked in blue. Displayed in blue is the ECG time series.

There is also a set of green horizontal cursors and blue vertical cursors. By selecting the crosshair tool under the graph the user can move the position of these cursors and then click the Delete all Points between X Cursors or Delete all Points between Y Cursors, all peaks and troughs detected between their respective cursors will be deleted. This will only remove the markers on the respiration waveform.

Respiration waveform graph: The Respiration waveform is displayed in red. The blue markers denote the respiratory peaks, while the green markers denote respiratory troughs. The yellow circular markers with cross hair markers denote potential artifact detected by the error detection algorithms. The Y values are scaled in volts and the X values are in time (seconds.) The graph tools window in the bottom left has three tools for aid in editing. The tool with the cross hairs should be used for inserting and/or deleting points. The second tool, the magnifying glass, can be used to zoom in on the graph. The third tool, the hand, is used to scroll through the entire data set. The control in the bottom left corner can be used to zoom out the graph after zooming in by clicking on the X or Y button to zoom the graph back to its original position. This graph also contains cursors used to delete multiple points simultaneously. These cursors can be dragged freely to a desired location.

Auto-Track Cursors: When activated, the cursors will retain their position on the screen as the data is scrolled through. When off, the cursors keep their position in the data and can leave the screen if scrolled past.

ECG Color: This color box shows the current color of the ECG plot. Clicking this control allows the user to change the color of this plot.

X0 (seconds): The X0 control determines where to start the graph in time. The user can slide this control to move their way through the segment in the edit screen.

Size of Graph (seconds): The Size of Graph control determines how much of the waveform to display at once. This value can be changed to fit less data onto the screen at once much like a zoom window.

Snap to Peak Control and Sensitivity Control: The snap to peak switch when in the "On" position will enable the snap to peak algorithm for point insertion. When the snap to peak switch is in the "OFF" position, it disables the snap to peak algorithm and allows for manual insertion of a point at the point clicked upon within the graph indicator. The time window control sets the size of the time window centered about where the mouse is clicked. The higher the sensitivity control, the less precise the user needs to be, but this can cause point insertion at a place other than the desired point and removal of too many points when deleting.

Set X Cursor Position: The Set X Cursor Position brings up a window through which the user can set the high and low position of the X cursors by changing their numerical value. The Cursor Pos X Low and Cursor Pos X High show these settings.

Set Y Cursor Position: The Set Y Cursor Position brings up a window through which the user can set the high and low position of the Y cursors by changing their numerical value. The Cursor Pos Y Low and Cursor Pos Y High show these settings.

Delete (F1): This control latches when pressed until pressed again. If the points are within the range defined by the sensitivity control and the mouse click they will be deleted.

Note: Having the sensitivity to high or too low will result in too many points being deleted or not enough depending on the signal quality (noise, etc) and the rate of signal being edited.

Insert (F2): This control latches when pressed until pressed again. If the points are within the range defined by the sensitivity control and the mouse click they will be inserted at the point of the mouse click or at the peak/trough defined by the snap to peak window control above as long as snap to peak is on.

Delete All Points Between X Cursors: All points within the boundary defined by the vertical blue cursors will be removed.

Delete All Points Between Y Cursors: All points within the boundary defined by the horizontal green cursors will be removed.

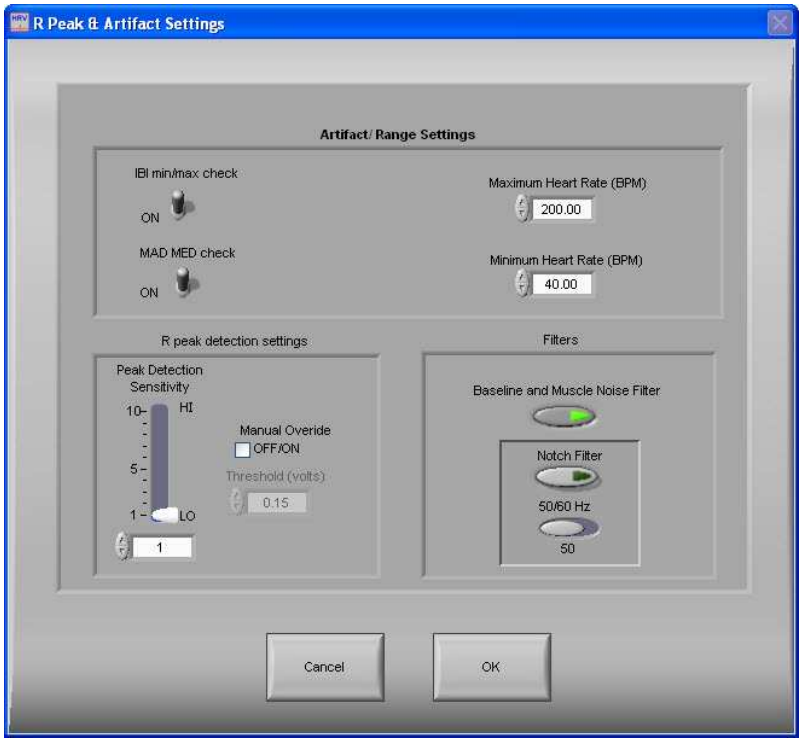
Spline: This control connects the two data points specified by the X cursors with a line, or splines the data between the two cursors.

Remove Data Portion: This control will remove all data within the boundary defined by the cursors.

Reset: This control resets the R peaks to the original state when the editor was first entered.

OK and Cancel: When editing is complete and the user wants the changes to transfer back to the analysis screen, select OK. When the user selects Cancel, the data that has been edited will not be transferred and the editing will be lost.

Section 7: R Peak and Artifact Settings



The R Peak and Artifact Settings window allows the user to change these settings without exiting the analysis session.

MAD/MED Check: This control enables or disables the application of MAD/MED criteria to the heart beat detection.

IBI Min/Max Check: This control enables or disables the application of IBI Min/Max criteria to the heart beat detection. The algorithm will test the IBI series to be in range of the settings selected in the Minimum Heart Rate and Maximum Heart Rate controls.

Minimum Heart Rate (BPM): This control allows for the selection of the minimum expected heart rate in the data series. This value will be the maximum IBI threshold.

Maximum Heart Rate (BPM): This control allows for the selection of the maximum expected heart rate in the data series. This value will be the minimum IBI threshold.

Baseline and Muscle Noise Filter: This control enables or disables the muscle noise filter. This filter applies a band pass filter (.25 to 40 Hz) to the data.

50/60 Hz Notch Filter: This control enables or disables the 50/60 Hz notch filter.

Peak Detection Sensitivity: This control is used to set the sensitivity of the dynamic peak picking algorithm from 1 (Minimum Sensitivity) to 10 (Maximum Sensitivity.)

Manual Override: This control is used to disable the dynamic peak detector and switches to the absolute threshold mode.

50/60 Hz: This control is used to select the frequency of the notch filter.

Section 8: Video Settings

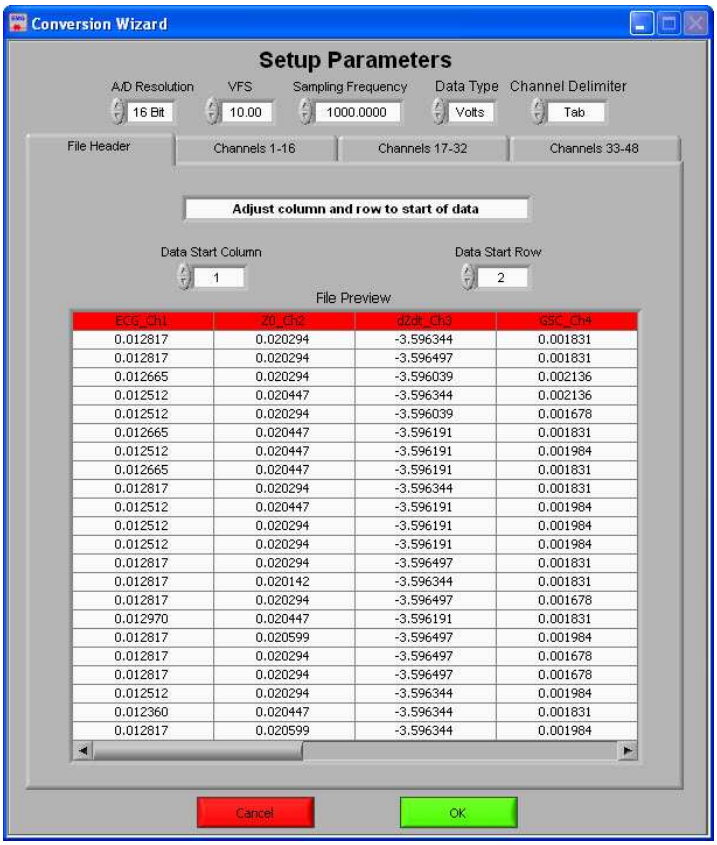
The Video Settings Window allows the user to modify these settings without exiting the current analysis setting.

Show Video: Sets whether the video will be shown during analysis or not.

Auto-Play: When this is turned on, the specified video will automatically begin playback when a new segment is selected. Otherwise, the video will not begin playback until it is started by the user.

Appendix A: ASCII-MW Converter

The ASCII-MW Converter allows the conversion of any text file containing data in some character-delimited columns to the .mw format so that it may be used in any analysis application. To begin conversion, select a text file containing data by using the browse button on the file path control and pressing Convert. To exit the converter and return to the setup screen, press Exit.



The next screen in the conversion process is the Text File Conversion Wizard. From this screen, details about the data in the text file must be entered in order to properly scale and display the data in the analysis applications. It is extremely important that these values are identical to the way the data was acquired to ensure the correct conversion.

A/D Resolution: This control is the resolution of the A/d converters in the hardware used to acquire the data in the file.

VFs: This control is the volts full scale of the hardware used to acquire the data in the file.

Sampling Frequency (Hz): This control is the sampling frequency at which the data in the file was collected.

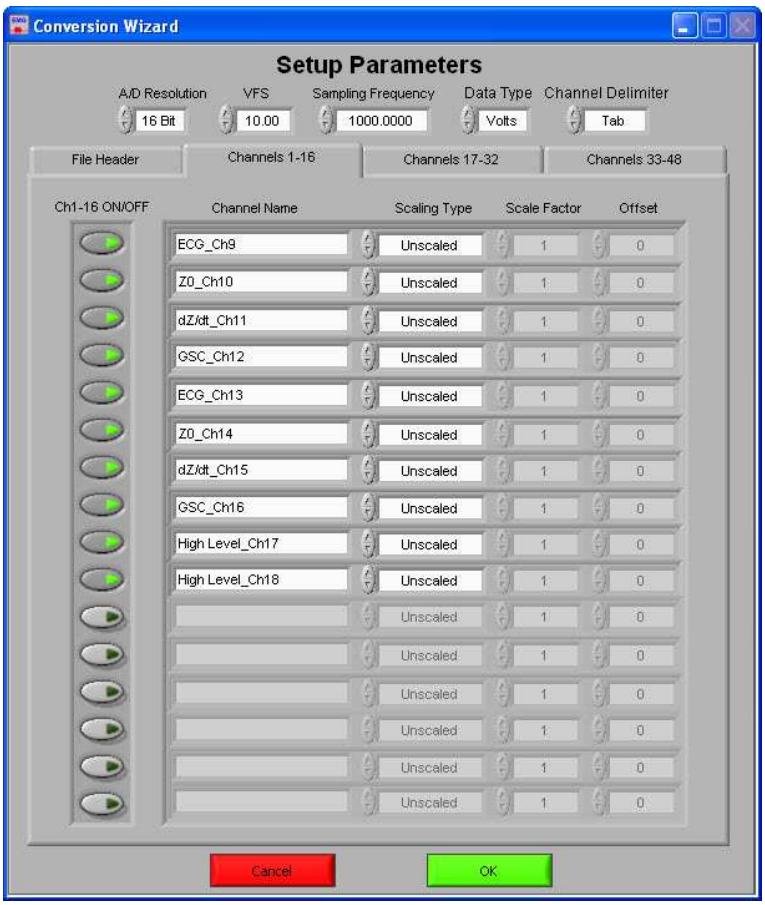
Data Type: This control specifies whether the data in the file is in volts or A/d counts.

Channel Delimiter: This control specifies the character which is used to separate data channels in the file.

Below these settings is the submenu control. The following submenus are available:

File Header: This submenu contains a preview of the beginning of the selected text file. Using the controls **Data Start Column** and **Data Start Row**, select where the data actually begins in the file past any file header information. Rows and columns which will not be included in conversion appear in red.

Channels 1-16: This submenu contains the channels found in the text file and allows for them to be selected/deselected for conversion.



The following controls are available:

Channel Names: This control allows the user to specify a name for the data channel to be saved in the .mw file header.

Scaling Type: This control specifies whether the data in the file is scaled or unscaled. If the data is scaled, the Scale Factor and Offset fields will be enabled for modification.

Scale Factor: If the data in the specified channel is scaled, this control represents the factor by which it is scaled.

Offset: This control represents the offset of the scaled data channel.

Submenus **Channels 17-32** and **Channels 33-48** behave in the same way.

Pressing OK will convert the file to the .mw format (may take several minutes depending on size of data file) and return to the Setup screen. Pressing cancel will return to the file selection window.

1020-F Taylor Station Road

Gahanna, OH 43230

(614) 626- 4888

www.mindwaretech.com