# APPLICATION NOTE

02.14.2019

Application Note 200   Creating Arbitrary Waveforms for the MP160 or MP150 Stimulator

The following Application Note describes how to use Acq*Knowledge* software to create Arbitrary waveforms for the STM100C Stimulator Module. It's recommended that this Application Note be used in conjunction with Application Note 162, which describes the stimulation features of the MP160/150 System.

The Acq*Knowledge* Stimulator dialog is accessed under the MP160/150 > Set Up Data Acquisition menu. There are four different types of stimuli available, three of which are preprogrammed into the software.

- The three preprogrammed signals provide Square ⊓⊔, Sine ⋀⋀, and Ramp ⋀ waveforms that can be adapted to suit a particular experimental protocol.
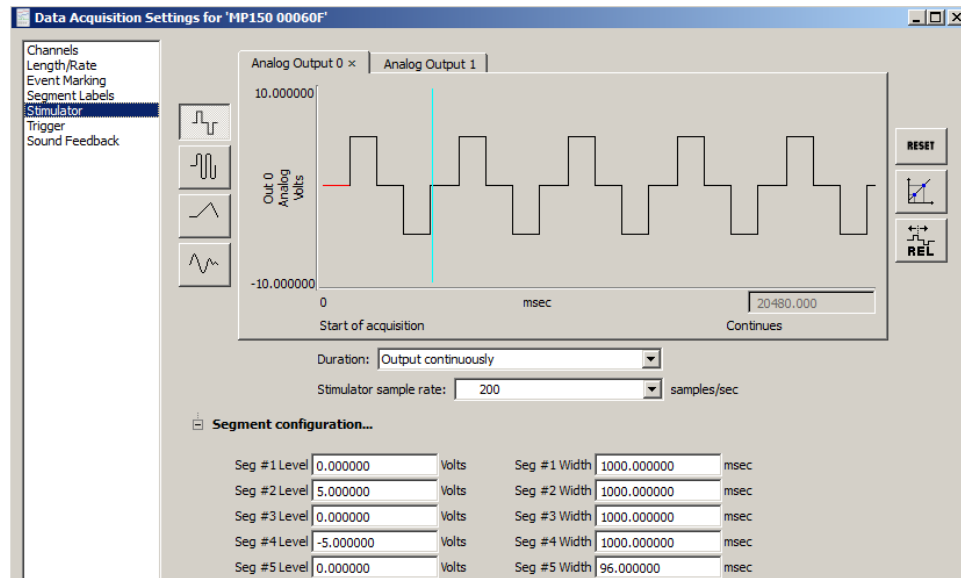
Square Wave Example

- The fourth and most flexible is the Arbitrary ⋀⋁ waveform.
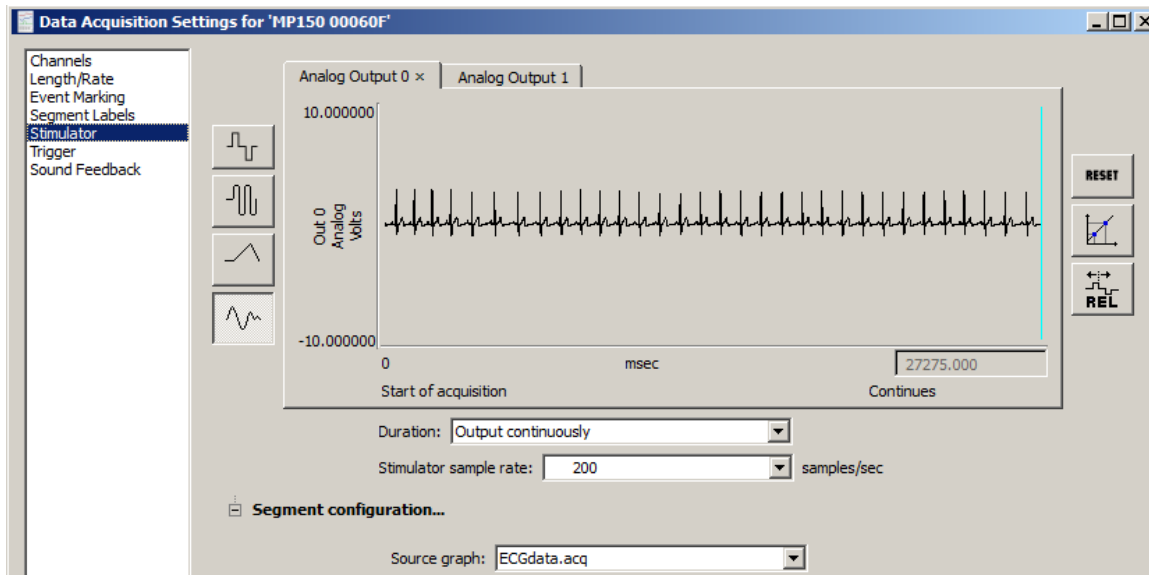
Arbitrary Wave Example

The Arbitrary waveform allows for output of a variety of user-definable signals. The waveform is loaded into the Setup stimulator dialog and outputted when the MP160/150 starts recording data. The active channel in any opened graph can be used as the "source" wave for any arbitrary waveform. The above example shows the output of an ECG waveform.

Waveforms of interest can be saved into one or more data files for later use. The Setup stimulator dialog allows for the preload of a number of different Arbitrary waveforms, and the desired waveform can be easily selected from the "Source graph" drop-down menu. Any graph open in Acq*Knowledge* will appear in this menu.

The following section demonstrates how to develop a series of simple Arbitrary waveforms. The Waveform Math, Math Functions and Expression transformations provide a wide variety of useful tools for creating Arbitrary waveforms.

Before beginning, the type of waveform required should be considered, including the timing and nature of the signal. The waveform is a sequential signal which is read into memory and then outputted through either Analog Output A0 or A1 of the UIM100C (MP150), HLT100C or AMI100D (MP160) module.

The length of an arbitrary waveform is only limited by the available computer memory (RAM) if recording in Memory/Disk acquisition mode and 4096 samples if recording in MP160/150 acquisition mode. Once the acquisition cycle is started, the waveform cannot be modified during the recording.

- When using another source graph to create an Arbitrary waveform (when, for example, piping in a previously-recorded ECG waveform as shown in the example above,) the Stimulator sample rate should be set to the same sample rate the source graph was acquired at in order for the data output to accurately reflect that of the source graph. (For example, if the source graph signal was recorded at 1000 samples per second, set the Stimulator sample rate to 1000 samples/sec.)

Creating a Train of Pulses

Start by recording one channel of data with nothing connected to the input, so that you will have a signal that is exactly 0 volts. Once you have 5-seconds of data, you can stop recording. The following screen shot shows a 5-second recording of flat data.
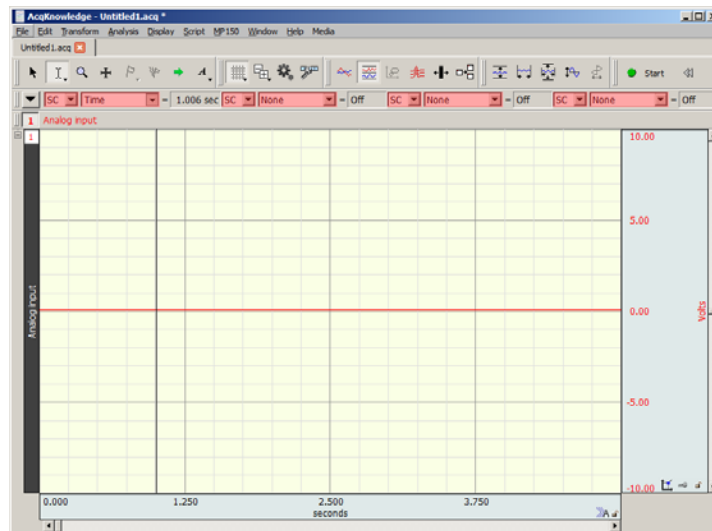

The Waveform Math function can be used to create a series of square waves to develop a pulse train. Follow these steps to create a simple 500 msec square wave at 1-volt:

1. Select the **Time** and **Delta T** measurements. These will help to determine the timing of the pulse train and the pulse width for each of the stimuli.

2. **Pulse Width.** Place the I beam cursor at the 1-second point in the recording and highlight .5-seconds by dragging the cursor to the right with the mouse held down. Note the Delta T measurement. Delta T = 0.501 sec

3. From the Transform menu select the Waveform Math function.

4. **Pulse Amplitude**. Add a constant to your source channel. Source CH1 + K = CH1.

5. Add a constant of 1. Constant = 1. Click OK.
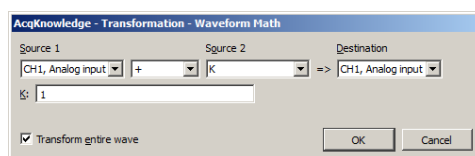
Intricate pulse trains can be created by repeating the steps and varying the Pulse Width and Pulse Amplitude per Steps 4 and 5 above. The following screen shot shows a variety of different pulse train scenarios:
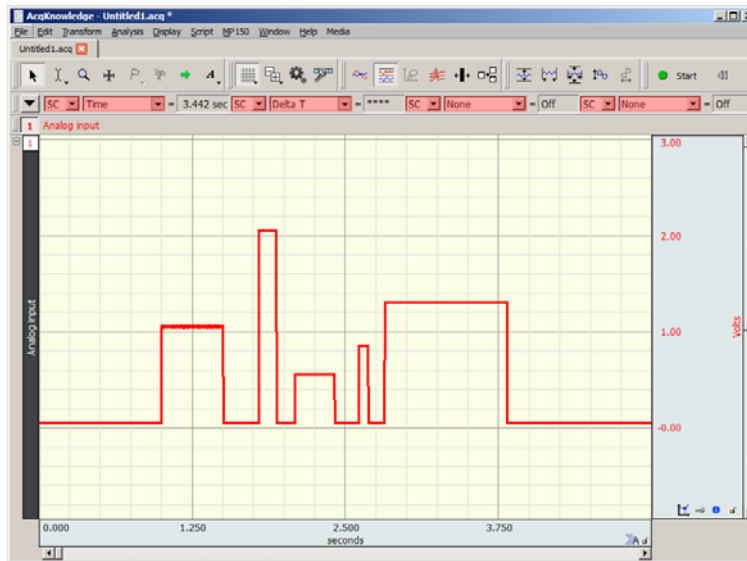

To speed up this process, use the Cut, Copy and Paste tools to make multiple copies of the same waveform.

- For example, to create a randomly occurring train of pulses, highlight the entire train and select Edit > Copy. Place the cursor at the end of the 5-second recording period and select Edit > Paste. This will paste the original sequence to the end of the recording.
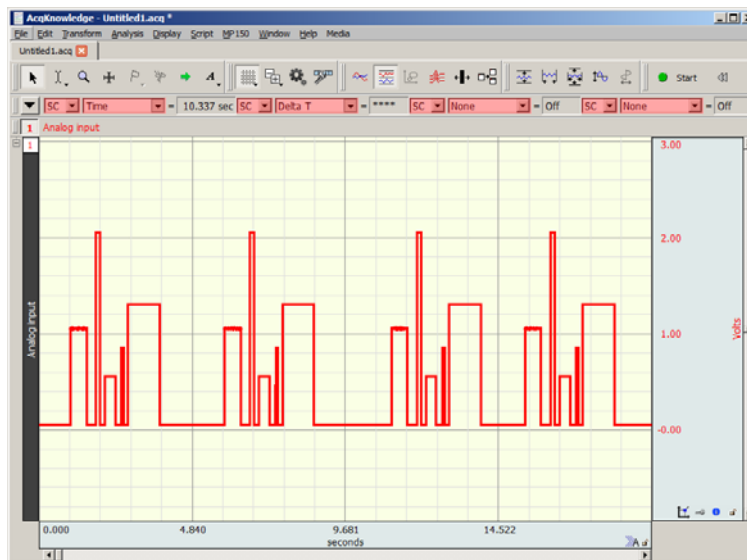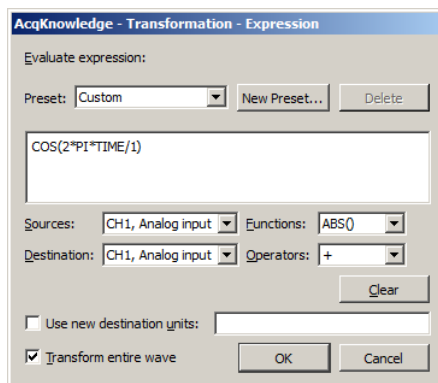
Creating a Sine Wave
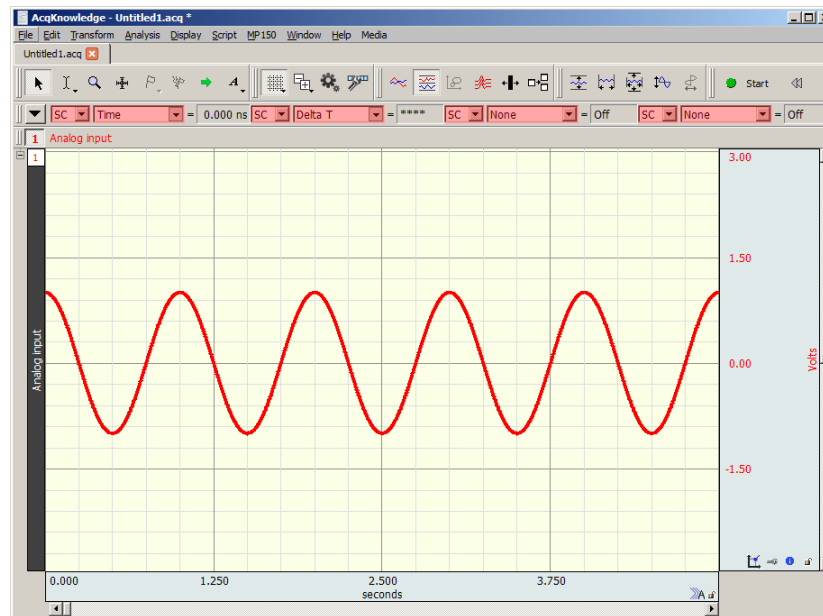
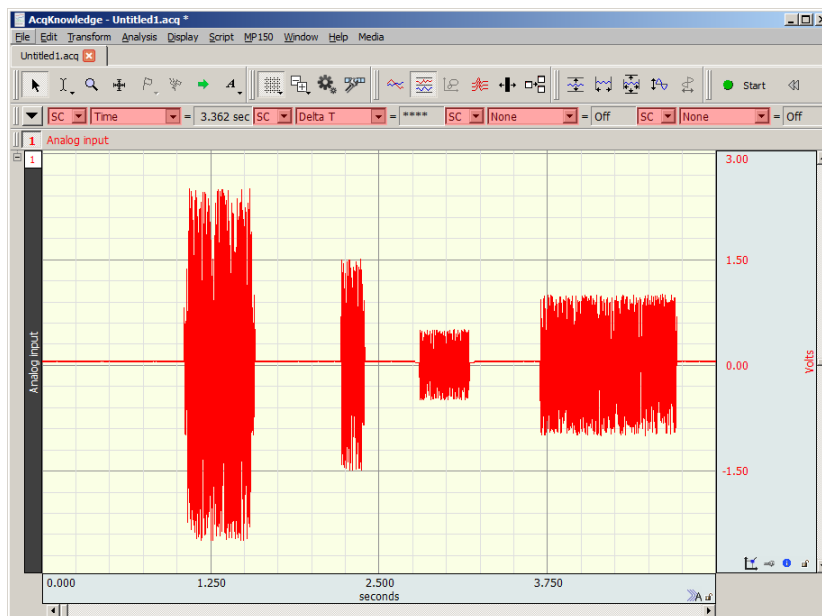The following steps will show you how to use the Expression transformation to develop a variety of sine waves.

1. Start with a flat line of 5 seconds of data.
2. From the Edit menu, choose Select all.
3. From the Transform menu, select Expression.
4. Enter or paste the following equation into the Expression window: COS(2*PI*TIME/1) and click OK.

The above steps will generate a sine wave with a 1 Hz periodicity.

- To increase or decrease the number of sine waves within the selected area, adjust the last value in the equation.
- Preloaded 2 Hz and 5 Hz sine wave expressions are available in the "Preset" menu.
- User defined expressions can be saved permanently by clicking the "New Preset" button.
- To increase and decrease the amplitude of the sine wave and also adjust the timing of the wave, use the Waveform Math features and the Edit menu tools.

Creating a Noise Signal

The following steps will allow you to create a noise signal for auditory startle response signals. Again, start by recording a baseline of 5-seconds of flat data.

1. Use the I-beam tool to highlight a selection of data at the desired point in the recording.

2. From Transform > Math Functions, select Noise.

The above will generate a random noise signal at the selected area. To reproduce and modify the amplitude of the signal, use the Waveform Math and Edit menu tools.

NOTE: To have the Noise signal appear in the original channel, go to Preferences ⚙ , choose Waveforms and deselect "Duplicate before transformations."

Creating a Physiological Output Signal
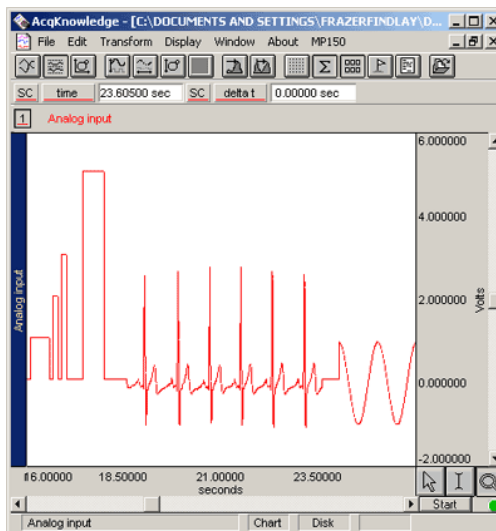
The Arbitrary waveform signal can also output sections of previously recorded data. The following example shows how to cut a section of ECG data and paste it into the middle of a train of pulses.

1. Open a previously recorded file. The previously recorded signal must match the sample rate of the new recording.

2. Use the I-beam tool to select an area of data.

3. From the Edit menu, select Copy.

4. From the Acq*Knowledge* Window menu, select the original "pulse train" file.

5. Place the I-beam cursor at the point where the ECG data is to be inserted and select Paste.
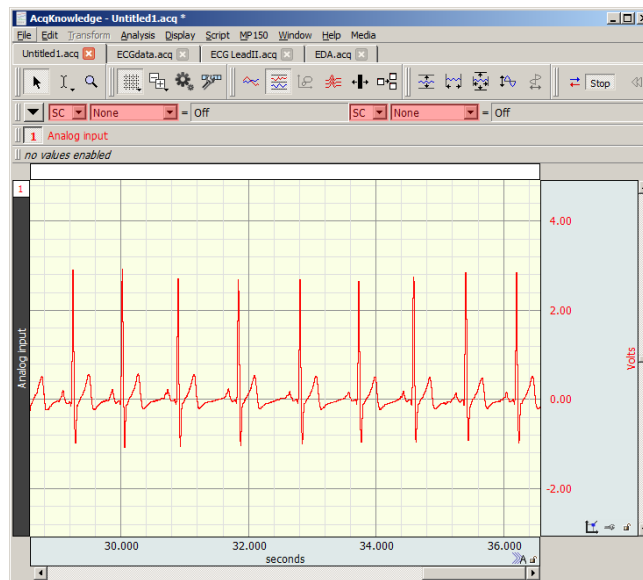
Creating a Waveform Library
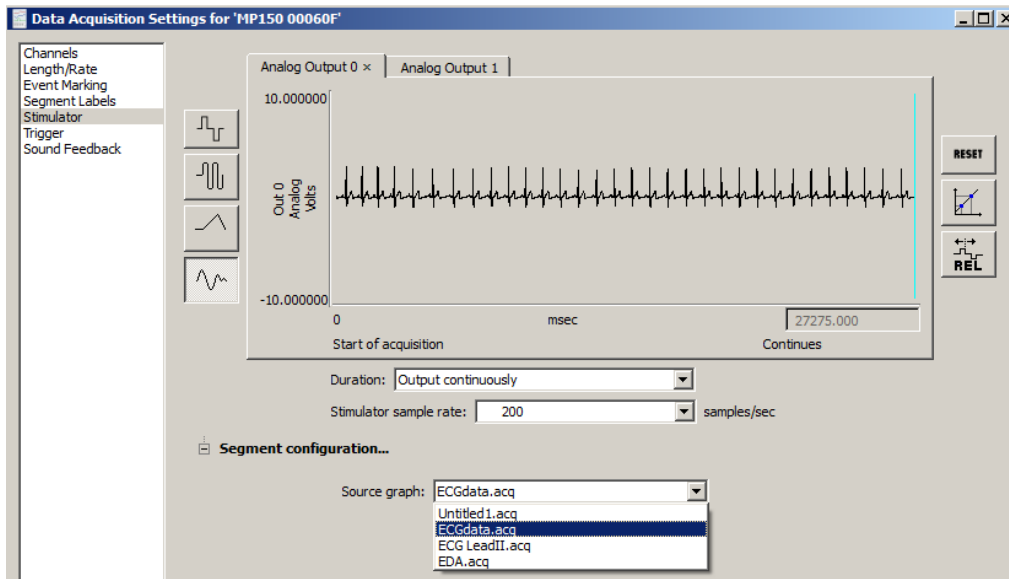
1. Open the graph containing the data to be used as the source signal for the Arbitrary waveform.

2. Select the graph channel containing the data to be used as the source signal. (The active channel will be used as the source, so it's important to select the correct channel.)

3. Toggle back to the new (destination) graph and launch the Stimulator setup (MP160/150 > Set Up Data Acquisition > Stimulator).

4. Make certain the Arbitrary button is depressed and select the graph containing the desired signal from the "Source graph" list. (Any graph currently open in Acq*Knowledge* will appear in this list.)

5. Close the Stimulator setup dialog and click "Start."

6. To validate the Arbitrary waveform output, connect a CBL100 cable from the UIM100C module's A0 or A1 Analog Outputs (MP150), or a CBL122 cable from the HLT100C/AMI100D module's A0 or A1 Analog Outputs (MP160) to one of the Analog input channels (see below). This allows you to record or monitor the Arbitrary waveform as it is being sent from the STM100C module.

Analog Output 0 connected to CH 1   *Outputted Arbitrary ECG Waveform*

7. The Arbitrary waveform will appear in real time in the selected channel of the new (destination) graph, as shown above right.

Analog Outputs Upper Limits Summary

The upper limits for short burst, long and longer waves are detailed below. At high or aggregate acquisition sample rates, the data display may become sluggish. Additional user actions may overwhelm the system.

	Short Burst Wave (≤ 4096 samples)	Long Wave (> 4096 samples but ≤ 512 K samples)	Longer Waves (≤ 512 K samples)
Stimulator Sample Rate:	100 K max (sample rate not adjustable for averaging)	100 K max	20 K max
Acquisition Modes:	Save to MP160/150 Memory Save to Averaging	Save to MP160/150 Memory Save to Memory or Disk	
Source Output Maximum per Analog Output:	4096 samples	512 K samples (256 K if dual stimulators are used via outputs A0 and A1)	
Maximum Aggregate Acquisition Sample Rate:	400		

For additional Stimulator resources, see the Acq*Knowledge* 4 Software Guide or the MP Hardware Guide's MP160/HLT100C/AMI100D or MP150/UIM100C and STM100C sections.

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