FIVE WIRE

User Manual

Five Wire User Manual

Rev. 2.2

Five Wire User Manual

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General Safety Summary

The Five Wire has been designed to provide years of safe, reliable operation. Key safety features include:

- Operation from UL listed isolated power supply

- Low power operation (7.5V @ 1A fused internally)

- Metal enclosure

For your safety, please:

- Only operate the Five Wire using the supplied power adapter. Use of other power adapters could create a safety hazard or cause damage to the Five Wire. Damage from using an improper power adapter is considered abuse and is not covered by the factory warranty or extended service contracts. (Replacement power adapters are available at www.FiveWirelogic.com).

- Do not use the Five Wire in high voltage circuits. The Five Wire is designed for digital test and debug. All I/O (input/output) signals should be limited to a 0 – 5V range. Live Logic inputs using the provided 10X probes have an extended input range, 0 - 16V.

- Only use the Five Wire for its intended purpose – digital circuit design and debug. If you have any questions about safe operation or intended use, please contact Five Wire.

Preface

Purpose of the Document

The Five Wire User Manual provides comprehensive information regarding the configuration, operation, and performance limits of the Five Wire. Please refer to this User Manual for detailed operation instructions.

The Five Wire Application user interface has been specifically designed to be easily understood, allowing operation without referencing documentation. Together, the application user interface, Tool Guides, and User Manual provide reference materials to help users get the most out of their Five Wire product.

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Organization of this Manual

The User Manual is organized by sections:

Section 1 provides a high level overview of the Five Wire and its operation.

Section 2 describes installation and setup of the Five Wire for first use.

Section 3 provides instructions on the use of each of the Five Wire tools.

Section 1 General Information

Introduction

Five Wire is a next-generation integrated instrument. Leveraging state-of-the-art technologies, highly integrated architecture, and the computing performance of modern PCs, the Five Wire provides a versatile, high performance digital test instrument for embedded and digital engineers.

Features

Five Wire provides five integrated tools: **Live Logic** ™ Logic Source Pattern Generator, Waveform Source Arbitrary Waveform Generator, Logic Analyzer, and Protocol Test. Each of the Five Wire tools was designed to provide the features required for modern microcontroller and digital design.

Live Logic provides the feel and ease of use of a two-channel oscilloscope but is specifically designed for digital engineers. Two 10X oscilloscope probes are provided for easy probing of your logic signals and clocks. The acquisition display is continuously updated, displaying your signals auto-scaled for easy viewing. Browsing from clocks to strobes to controls is a snap.

Live Logic also includes a digital voltmeter (DVM) on each input channel. The DVM allows you to use the same Live Logic probes to verify logic supplies or levels, or to measure the duty cycle of logic signals, such as pulse-width modulated (PWM) control outputs. An activity Indicator lights whenever the input signal is toggling.

The **Logic Source** tool is a full-featured pattern generator. It provides 9 output channels with programmable high and low drive levels. The pattern memory contains 1020 vectors with programmable duration from 30ns to 40ms settable in 10ns time increments. Looping and conditional branching allow continuous and triggered vector bursts to be generated.

The **Waveform Source** provides two instrument capabilities. It can generate a programmable arbitrary voltage waveform with an output range of 0 to 5V and sine wave frequencies from 0.002Hz to 50KHz. Standard waveform types can be created or the user can develop custom waveforms using standard CSV format. Looping and conditional branching allow complex waveforms to be generated and support the triggered waveform outputs.

The Waveform Source can also be used as a programmable power supply. It can source up to 100mA of current, and its output amplifier has been specially designed to drive capacitive loads. Combining the arbitrary waveform nature of the

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Waveform Source with the power supply capability allows evaluation of power supply dynamic behaviors such as power supply turn-on and turn-off cycles. The discharge/charge behaviors of batteries can be simulated to test brown-out routines.

The **Protocol** tool actually comprises several tools in one. It dynamically configures itself depending on which dedicated protocol probe is attached. Three different protocols are supported by the Five Wire: Trigger, SPI, and I2C. The Trigger Protocol provides 3 trigger signal inputs and 3 trigger signal outputs. Each tool within the Five Wire can produce and accept a triggering event. For example, events can be used to trigger acquisition tools or to trigger a pattern source output waveform, coordinating the signals to another Five Wire tool or the user circuit. For a full discussion of Five Wire Events refer to section 3.

The SPI Protocol probe provides both master and slave capabilities for shift chains from 1 to 4 bytes in length. In master mode, predefined output vectors are sent to the slave via SDO and the return data on SDI is captured for display. Up to 128 sequential vectors can be sent. Signals included are Master SCK, SDO, SDI, and Select out. In slave mode, the data sent from the master is captured for display and user defined vectors are returned to the master on SDO. Signals included are Slave SCK, SDO, SDI, and Select in.

The I2C Protocol probe provides both master and slave transactions. It includes a capture queue and a predefined pattern send queue. Signals included are SCK and SDA. Both are open-collector drive and bi-directional.

The **Logic Analyzer** is a full-featured 9 channel, 100MHz logic analyzer. It provides 3 level sequential triggering including time qualified triggering. Time qualified triggering can be used to catch signals that are too short (glitch) or signals that are too long (hang). Captured data is displayed in timing diagram format and includes user defined labels, display order, and time measurements.

All of these tools are integrated into a single System with shared trigger events that allow the tools to interact. For example, a protocol trigger or logic source pattern can send an event to the Waveform Source causing a simulated analog input waveform to be generated. The Five Wire was designed to solve the kinds of problems facing today's embedded designers.

Standard Accessories

The Five Wire includes these standard accessories:

- Two 10X 100MHz scope probes
- Logic Source probe
- Logic Analyzer probe
- I2C Protocol probe
- One Five Wire Wall Outlet Power Adapter (7.5V power supply)
- One USB A-B cable

Optional Accessories

Also available from Five Wire are these optional accessories:

- SPI Protocol probe
- Trigger I/O Protocol probe
- Replacement 7.5V power supply

Section 2 Preparation for Use

Introduction

The Five Wire is a PC hosted instrument. The PC runs the Five Wire software application and communicates with the Five Wire instrument via a USB cable. The Five Wire instrument also requires external power provided by the supplied 7.5V power supply.

Software Installation

The Five Wire application is available on the Five Wire website for download. Follow the installation instructions.

Standard Directory

The Five Wire application provides the ability to save the current configuration and to save data files associated with each tool. The application includes a standard Five Wire directory in Documents that is created at installation.

Configuration

After the Five Wire software application has been installed, the Five Wire may be connected to the PC via one of its available USB ports. The Five Wire instrument USB connector can be found on its left side panel.

Connect the Five Wire 7.5V power supply wall plug to an appropriate 100-240V receptacle and insert the supply's low-voltage barrel connector into the Five Wire power socket. The Five Wire is now ready for operation.

Five Wire Instrument Connectors and Indicators

Left Side Panel

USB connector: Provides communication between the Five Wire instrument and the Five Wire application.

Power Supply connector: Provides Instrument power. Must be connected using the provided Five Wire 7.5V power supply.

Front Panel

Power button and LED: When the Power LED is illuminated, the Five Wire instrument is ready for operation and can drive its output signals and capture input

waveforms. If the Power LED is not illuminated, the Five Wire instrument is not powered.

The Five Wire powers up automatically when the application is opened. When the Five Wire Power LED is illuminated, pressing the Power button for approximately 5 seconds will turn the instrument power off and close all tool windows.

Link LED: Illuminates when data is being transferred between the Five Wire application and the Five Wire instrument.

System button: Asserts the System Event when pressed. See the **System** description in Section 3 of this manual.

Zoom and Scroll knobs: Change the waveform scale and display position of the active acquisition tool window. See **Live Logic** and **Logic Analyzer** tool descriptions in Section 3 of this manual for tool-specific operation.

Live Logic Run LED: Illuminated when the tool is acquiring a new waveform.

Live Logic Trigger LED is illuminated if the last Live Logic acquisition captured the selected trigger event.

Live Logic Capture button: Starts an acquisition or terminates an ongoing acquisition.

CH1 and CH2 LEDs: Provides an immediate indication of signal activity. When the Live Logic probe is connected to a logic signal which is transitioning, the LED will momentarily flash. If the signal transitions are continuous the LED will be illuminated continuously. The LEDs provide a quick and easy way to check for signal activity.

CH1 and CH2 BNCs: These connectors accommodate the 10X oscilloscope probes provided as standard accessories with the Five Wire. The Five Wire **Live Logic** is designed to use 10X scope probes. If probes other than those supplied with the Five Wire are used, make sure they provide a 10X attenuation. Using 1X probes will produce incorrect operation and results.

Waveform Source Run button: Starts a waveform execution or terminates an ongoing waveform execution.

Waveform Source Run LED: Indicates that the waveform is being executed. When execution is stopped, the last waveform output value that was executed remains on the output.

Red and black binding posts. These provide the Waveform Source outputs. The black binding post provides a signal ground reference and is directly tied to the Five Wire enclosure. The red binding post provides the Waveform Source active drive

signal.

Protocol Send button and LED: Button operation and LED illumination is dependent on the currently active protocol. See Section 3 of this manual for protocol specific operation.

Protocol connector: Provides connection to the Trigger, SPI, or I2C protocol probes. Note that a Protocol probe must be installed for the protocol tool to become active.

Logic Source Run button and LED: The Run button starts or terminates pattern execution. The LED is illuminated when a pattern is being executed. When execution stops, the last pattern vector executed remains on the output.

Logic Source connector: Provides connection to the Logic Source probe. Note that the probe must be installed before patterns can be executed.

Logic Analyzer Run button and LED: The Run button starts or terminates a waveform acquisition. The LED is illuminated during the acquisition and will be extinguished when the acquisition terminates.

Logic Analyzer connector: Provides connection to the Logic Analyzer probe. Note that the probe must be installed before an acquisition can be started.

Five Wire Application Start-up

To start the Five Wire application, double-click the Five Wire application icon on your desktop or select the application using the PC start menu selecting the Five Wire application.

When operating the Five Wire instrument, the instrument should be connected to the PC via a USB cable, and the Five Wire Power Supply should be properly connected before starting the Five Wire application.

The Five Wire application may also be run without connection to the Five Wire in **View Mode**. When in **View Mode** tool windows can be opened, waveforms can be loaded, and patterns can be edited and saved. Note that some functions are not available unless the Five Wire instrument is available and connected.
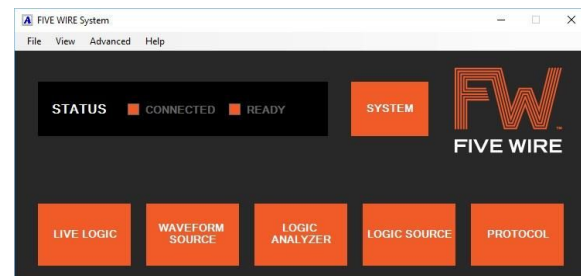
Section 3 Operation

Introduction

This section provides instructions for the operation of each tool. For further information about tool saved file formats see Section 5 of this manual. For further information about tool scripting support see Section 6 of this manual.

System Tool

The Five Wire System tool window is opened when the Five Wire application is started. The System tool manages functions that are shared by all Five Wire tools. Its primary purpose is to provide system status information and to launch the other Five Wire instrument tool control windows.

System Window Controls

System Connected LED: Illuminated (orange) if the USB connection to the Five Wire instrument is operational. The indicator is gray when not illuminated.

System Ready LED: Illuminated (orange) when the Five Wire is powered and the Five Wire Power Supply is properly connected and providing power to the instrument.

Tool Launch buttons: Each button (**Live Logic**, **Waveform Source**, etc.) launches its respective tool control window or moves the tool control window to the top of the PC display. Tools may also be launched from the View menu.

Other User Controls

File, Open/Save As...: Saves the current tool configuration or opens a previously saved configuration. Tool configuration includes the current settings for each tool that is open including source patterns and captured waveforms.

File, Run Script: Opens and runs Five Wire script files. **Scripts** can be used to configure tools for a specific activity. For more information on Five Wire script files, see the Five Wire Script Reference Manual. (MBScript reference. In the application system window click Help->Open Script Reference)

System Operation

Instrument Power

When the Five Wire application is started, the Five Wire instrument will power up. The front panel Power LED will illuminate and the System window Ready indicator will become orange. When the Five Wire application is closed the Five Wire instrument will power down.

The instrument can also be powered down by pressing and holding the instrument Power button for approximately five seconds. When the instrument powers down all tool control windows will be closed and the application will close.

System Status Indicators

The **System** Window provides two status indicators in the system group box. The Connected indicator is green when the USB connection to the Five Wire instrument is operational. The USB connection is configured automatically when the instrument is connected to a PC using the supplied USB cable.

The Ready indicator is green when the Five Wire instrument is powered and the Five Wire Power Supply is properly configured.

Save and Restore System Configuration

The configuration of the currently open tool set can be saved and then later restored by selecting File, Save As... from the **System** Window menus. A set of Five Wire configurations files will be stored in the selected directory. Multiple (different) configurations can be saved by *selecting a different folder* to store the file set. **Do *not* change the file names**. These predefined file names are always used when restoring a configuration.

Saved system configurations include the settings of tools that are open at the time of the system save. It includes the state of all control settings but not the current running state.

The **System** window generates a savedSystem.csv file in the selected directory when the system is saved. Each tool that is open also generates one or more of its own configuration files in the same directory. If the saved configuration is moved or copied to a new directory, all files in the original directory must also be copied to the new directory.

A previous configuration is restored by selecting File, Open in the **System** Window menus. Click open to restore the system from the default directory, or navigate to

the desired restore directory and click Open. Each saved tool is opened and configured. Tools that were not part of the system save are not affected during restore.

User Scripts

The Five Wire supports a scripting language that provides the ability to run automated tests. Users can write their own scripts using a simple text editor such as Notepad. See the Five Wire Script Reference Manual for a complete description of scripting.

User defined scripts are executed by selecting File, Run Script in the system tool window. Navigate to the directory and file name of the script you wish to run and click OK. The user script is then executed. If problems are found in the script during execution, an error message will be displayed and script execution will be terminated.

Live Logic Tool

The Live Logic tool is designed to allow digital designers to quickly view logic and voltage signals without requiring complex setups. Live Logic provides two channels of 400MS/s digital capture for active logic signals with a live oscilloscope-like display. Easy circuit probing is provided using the supplied 10MΩ, 10x scope probes. The CH1/2 LED indicators instantly show if the probed signal is actively toggling. Display auto-scaling allows hands-free operation so signals of interest can be quickly probed. An integrated DVM measures and displays the average voltage at each probe tip for verification of power supply voltages, hi or low logic signals, or the average value of a PWM signal.
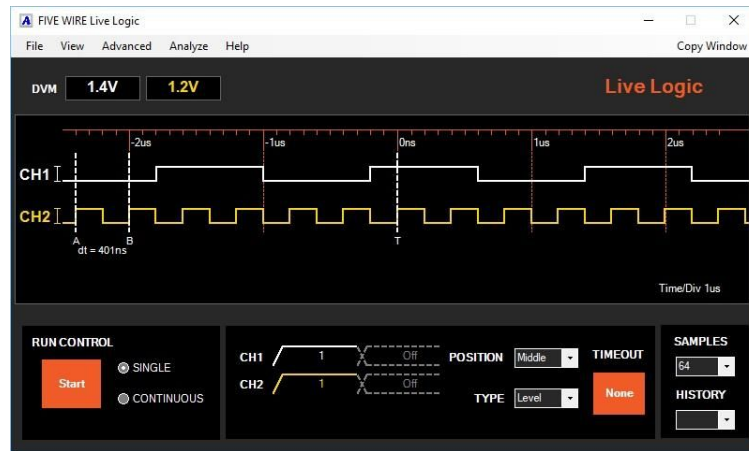
Live Logic Window Controls

VCH1, VCH2: Displays the average voltage measured on channels 1 and 2 of the probed signal(s).

Waveform Display: Displays captured digital waveform. The timescale indicates the times at which edges occur. The Samples value indicates the number of edges that must be captured during acquisition to avoid a timeout. The selected logic family is displayed below the Samples. The span indicates the period of time currently being displayed.

Run Control Button: Start or stop acquisition of a new waveform.

Run Control Selections: Selects the acquisition mode. In continuous mode, acquisitions are taken repeatedly. Each acquired waveform is scaled to fit in the waveform window for easy viewing. In Single mode, a single acquisition is taken each time the Capture Button is pressed.

Trigger Value: Click the waveform to select a trigger condition. When a trigger is detected and there are a sufficient number of edges, the captured trigger value will be placed at the selected location on the screen.

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Trigger Position: Sets the location of the trigger within the acquired waveform. Trigger position selects the number of samples before and after the trigger based on the Samples selection.

Trigger Type: Level trigger will stop the acquisition when the selected trigger is satisfied. Duration and Pulse triggers place additional timing requirements on the acquired signal to satisfy the trigger condition. External triggers are supplied by other Five Wire tools. See Advanced→Trigger In menu.

Trigger Timeout: Sets the maximum time that an acquisition will run. Acquisition terminates when sufficient edges have been captured or the duration of the acquisition exceeds the timeout value.

Samples: The number of samples that are captured in each acquisition. When in Continuous acquisition mode, the number of samples can also be changed by the front panel Zoom knob or the mouse scroll wheel.

History: The last 10 acquired waveforms are stored in the history memory and can be displayed using the history control. Select 0 for the latest waveform and 9 is the oldest waveform. History is only available when not acquiring waveforms.

Other User Controls

Zoom Waveform: Captured waveforms can be scaled by zooming in or out. Zoom can be adjusted using the:

- Front panel Zoom knob
- Selections in the View menu
- Selections in the waveform display window right-click menu
- Mouse scroll wheel (if Wheel Zooms is selected in the waveform right-click menu)
- Drag zoom
- Double-click zoom
- Accelerator keys 'i' and 'o'

When both A and B marks have been set (See Set Mark A/B below) you can zoom to the extent of the marks by selecting Zoom Marks in the waveform display drop-down menu or by pressing the 'm' accelerator key. This places the two marks near the left and right sides of the display window.

You can zoom in on a region of the display by dragging the mouse across the time area of interest in the waveform display (drag zoom). To drag the mouse, press and

hold the left mouse button at the starting time to be zoomed. Continuing to hold the left mouse button, move the cursor to the ending time to be zoomed. Release the left mouse button to complete the zoom area. Area zoom only uses the horizontal (time) selection: vertical mouse movement during the drag is ignored. Area zoom may be repeated multiple times to view the details of a narrow pulse when a large time span is currently displayed.

You can also zoom by double-clicking on the display. The location of the double-click is centered and the scale magnified. Continuing to double-click on a feature of interest zooms closer to that feature.

Scroll Waveform: Captured waveforms can be shifted left/right to view waveform data that is currently out of view. Scroll position can be adjusted using the:

- Front panel Scroll knob
- sMouse scroll wheel (Select Wheel Scrolls in the waveform right-click menu or 's' key)
- Accelerator keys 'j' or 'k'

Scroll is only available when the acquisition is stopped.

Center This: Accessed in the waveform display right-click menu, Center This scrolls the display to place the location of the mouse at the time of the right-click in the center of the waveform display.

Goto: Accessed in the waveform display right-click menu, Goto Trigger, prior edge, and next edge scrolls the waveform display to place the selected item at the center of the display. Goto Mark presents a drop down list of currently placed marks and comments. Selecting a mark or comment from the list will center that mark or comment in the display.

Open: Opens a previously stored waveform file for viewing

Save As...: Saves the currently displayed acquisition to a waveform file. The waveform can then be opened later for viewing.

Set Mark: Set Mark places a display mark at the position of the cursor. To place or remove a mark on the waveform:

- Right-click on the waveform at the desired location and select "Set Mark" and choose the type of mark
- Position the cursor at the desired location and click one of the set mark accelerator keys: a mark, b mark, ref, time, or quick
- Press the undo mark accelerator key to remove the last mark that was

placed

Marks will snap to a waveform edge if it is within 8 display pixels of the selected point and within the waveform. To avoid snap to edge place the cursor outside of any waveform or away from a waveform edge.

When A and B marks are placed, the time difference or frequency (1/time difference) between the marks is displayed. Use '/' accelerator key to toggle between frequency and time.

When a Time mark is placed it displays the relative time at that location. If a Reference Mark is also placed, the Time marks display the time relative to the reference time. If no reference mark has been placed then Time marks are relative to the start of acquisition.

Notation marks allow you to enter the text label associated with the mark. To set a notation mark, click in the text box that is opened when Notation is selected. Type the label text and then press Enter to set the mark.

Set Comment: Comments are like Notation marks (see Set Mark description) except that they do not include a mark line and do not snap to edges.

Save View: Adds the current view to the list of annotations with a user defined name.

Show View: Restores a named view.

Delete Mark or Comment: Presents a drop down list of marks and comments that are currently set. Selecting a mark or comment from the list deletes that mark or comment. The last mark that was placed can be deleted using the 'u' accelerator key.

Set Quick Mark: This mark is like a time mark except that only one Quick Mark can be placed at a time. Once a Quick Mark is placed, left-clicking the waveform moves the Quick Mark to the click location allowing different time points to be quickly measured.

Delete All Marks and Comments: Deletes all of the currently set marks and comments.

Analyze: This menu provides access to the measure and decode functions.

Measure: Clicking this item will open a drop down selection which sets a measurement on each channel. Measurements include frequency, period, pulse-width, and duty cycle.

Select Decoder: Clicking this item will open a drop down selection which allows

one of the decoders to be enabled. Current decoder functions include SPI, I2C, RS232, and LIN. When a decoder is selected, a configuration dialog is presented which is specific to the selected decoder. The configuration dialog allows you to assign input channels to the decoder specific signals such as the I2C SCK and SDA signals. Different decoder definition files (.dcd file extension) can be assigned to the analysis. Clicking the OK button completes the configuration.

Configure Decoder: Clicking this item will reopen the configuration dialog allowing the configuration parameters to be modified.

Enable Decode: Enables execution of the decoder after each acquisition. Each transaction is marked with a box mark and decoding text is generated which describes the content of the transaction.

Refresh Decode: Erases the current decoder marks and reruns the decoder on the current data.

Clear Decode Marks: Removes all decoder marks for the currently selected decoder.

The decoder functions work on serial data streams. Decoding the information requires that the analyzer align the start of decode with the acquired data set. In some cases the data set begins with a partial transaction that includes only a portion of the protocol. In these cases the decoder will attempt to form synchronization but may be unable to synchronize if insufficient information is available. In these cases the user should place a *Begin Analysis* mark at a location between transactions to force correct alignment. Right click in the waveform display and select *Set Mark -> Begin Analysis*.

If transactions are close to each other in the display their decode text may overlap. Zoom in to spread the transactions further apart to eliminate the overlap.

Logic Family: The logic family being probed can be selected in the Advanced, Logic Family menu. The logic family setting is used to determine the logic state of a signal, 1 or 0.

Trigger In: Selects which Five Wire tool will be the source of the Live Logic trigger (when Event is selected in the trigger Watch For box).

Trigger Out: Selects when the Live Logic tool generates an output event.

Clear History: Removes all stored acquisitions from the history memory.

Keyboard Shortcuts

Both Live Logic and Logic Analyzer provide keyboard shortcuts that make viewing waveforms fast and efficient. Each accelerator key has a corresponding context menu control. Below is a list of keys and their function.

Key	Function
i	Zoom in
o	Zoom out
j	Scroll left
k	Scroll right
n	Goto next edge
p	Goto prior edge
N	Goto next edge, jump past local activity
P	Goto prior edge, jump past local activity
a	Set mark A at the cursor location
b	Set mark B at the cursor location
m	Zoom to A and B marks
z	Set mouse wheel mode to zoom
s	Set mouse wheel mode to scroll
q	Set quick mark at the cursor location
r	Set the reference time mark at the cursor location
t	Set the time mark at the cursor location
u	Remove the last mark set
/	Toggle A-B mark measurement between time and frequency
1	Cycle through CH1 measurements
2	Cycle through CH2 measurements

Live Logic Operation

Live Logic Acquisition

Live Logic captures transitions of the signals being probed. It samples the logic value of CH1 and CH2 every 2.5ns to see if the value has changed. When a change is detected, it is stored for later display. This allows large time spans to be captured without losing the time resolution.

The user can select the number of samples (transitions) to be stored. Storing 32 samples is sufficient to determine a clock is running or to measure its period using marks. Observing more complex waveforms may require more samples to be stored. The tradeoff is the time required to retrieve the waveform data and the extra effort to browse a larger number of samples.

Live Logic includes a timeout feature that will terminate the acquisition if the requested number of samples are not captured before the selected time expires. This allows a continuous display of waveforms even when no transitions are found, for example when no signal is being probed or the probed signal is not changing. Different timeout values can be selected, including None to disable the timeout feature.

When an acquisition is started, Live Logic stores transitions that occur before the selected trigger event. To accomplish this, trigger evaluation is disabled until the number of captured samples satisfies the selected trigger position criteria. The Start trigger position enables triggers immediately at the beginning of the acquisition. The Middle trigger position enables triggering after half of the requested samples have been acquired. The End trigger position enables triggers after the requested number of samples have been captured.

Once the trigger evaluation is enabled, acquisition continues until the trigger condition is satisfied. Once the trigger condition is satisfied, acquisition continues storing additional samples equal to the remainder of the requested samples minus the requested trigger position samples. Triggers are evaluated each time a sample is taken. If no samples are taken (no input transitions occur) then the trigger will not be evaluated.

Acquisition Termination

Live Logic acquisition will terminate when one of the following conditions occur:

1. The user presses the Capture/Stop button

2. The acquisition time exceeds the timeout value

3. Live Logic is triggered and sufficient post-trigger data values have been captured.

Continuous Mode Acquisition

When the Live Logic tool is launched, it starts in Continuous mode. In this mode, acquisitions are taken and displayed repeatedly. Each acquisition terminates when one of two conditions occur: the selected number of samples (transitions) have been captured, or the duration of the acquisition has exceeded the selected timeout setting. Pressing the Capture button (software or front panel) can also start and stop the acquisition. The number of samples and timeout values can be adjusted by the user to suit the type of signal being observed.

When looking at simple signals such as square waves or simple pulses, the number of samples can be set to lower values to increase the display update rate while providing sufficient detail to see the characteristics of the captured waveform. For complex waveforms such as SPI transactions, the number of samples can be increased to capture entire transactions or a series of transactions.

The default timeout value is set to 100ms. This setting supports acquisition of signals with high repetition rates that produce thousands or millions of edges each second. The timeout value should be increased when observing low repetition rate signals. These include low frequency signals or high speed signals that occur infrequently such as a SPI transaction that occurs once each second.

When switching to continuous mode from any other mode, the timeout value will be set to 100ms if the prior setting was none.

Single Acquisition Mode

Single mode captures a new waveform each time the Capture button is pressed. This mode is useful for manually selecting the time that acquisition is to begin. By extending the timeout value, an acquisition can be started and then the user can initiate the signal of interest in their circuit manually. This mode is also useful for signals with very low repetition rates such as long-period, wake-up polling signals.

Very long periods of time can be captured. Because the Five Wire always maintains

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full time resolution, you can observe narrow pulses (tens of nanoseconds) that occur seconds apart, and measure both the time between the pulses and the width of the pulse with full resolution.

When single acquisition mode is selected from any other mode, the timeout value will be set to none.

Waveform Source Tool

Waveform Source provides an arbitrary analog waveform output. Up to 1020 sequential voltages can be generated with 10 bits of amplitude resolution. Waveform Source can generate waveforms with durations between 5μs and 5000 seconds with up to 0.2 μs resolution.

The Waveform Source tool control window includes waveform generation features that simplify its operation. Parametrized standard waveforms can be generated algorithmically, eliminating the need to directly edit waveform pattern files. To generate a waveform, select the tab for the waveform type of interest, edit the waveform parameters and the V1 and V2 voltage levels, and press Generate. A representative display of the waveform to be generated is shown in the waveform display window to verify your selections. User defined waveforms can also be written that allow truly arbitrary wave shapes.
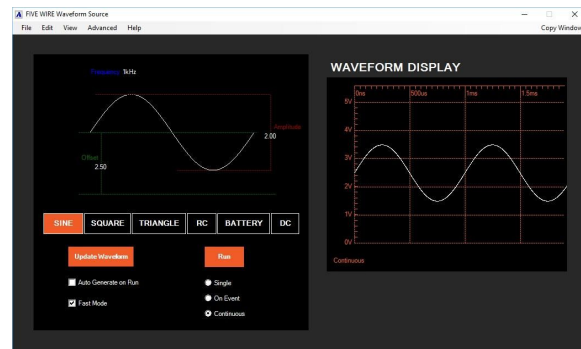
Waveform Source Window Controls

Generate Waveform box: The tabbed generate waveform box allows a number of standard waveform patterns to be generated algorithmically. Each tab supports a waveform type. Each waveform type includes parameters to specify the waveform characteristics.

Generate Waveform button: Before a waveform can be executed it must first be algorithmically generated. Generating the waveform produces the waveform pattern which can be executed and saved for later use.

When the Generate Waveform button is pressed, the currently selected waveform tab and its parameters determine which waveform pattern will be created. After a waveform is generated it is displayed in the waveform display window.

One level of undo is provided when a waveform is loaded or generated. To undo, select Undo in the Edit menu.

Auto Generate on Run: When checked, the waveform will be generated and loaded before it is executed. This is useful if different waveforms are repeatedly produced assuring each one is generated before it is executed. However, generating and loading waveforms takes time. If the same waveform is run repeatedly this feature

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should not be checked.

Fast Mode: When checked, the minimum point duration is 1.25μs (limited by analog bandwidth) and the resolution is 0.25μs. When unchecked, the minimum point duration is 10μs and the resolution is 5μs. Fast mode provides better resolution and higher frequency output waveforms. Normal mode provides longer waveform durations.

Sine: The Sine waveform produces a sine wave output. The Frequency box determines the frequency of the waveform. The Offset box determines the center level of the waveform above ground. The Amplitude box determines the P-P voltage of the sine wave.

The 'k' or 'kHz suffix can be used in the frequency box, i.e. 3e3 or 3k or 3kHz. The 'm' suffix may be used in the amplitude box, i.e. 0.3 or 300m or 300mV.

Triangle: The triangle waveform produces an output that linearly changes from V1 to V2 and back to V1. The Seconds box determines the period of the waveform. The % Duty Cycle determines the percentage of time that the waveform is rising, 0 to 100 percent of the period.

Time can be entered in scientific notation or by using the suffix 'u' for μs (microseconds), or 'm' for ms (milliseconds). For example 100 microseconds can be entered as 100u, 0.1m, 100e-6, or 1e-4.

Square: The square waveform produces a square pulse output. Inputs are provided to set pulse high time and total pulse duration. Checking the invert box inverts the waveform shape.

RC: The RC waveform produces a logarithmic shape with a settable time constant. The total duration of the generated waveform is 5 time constants. If the invert box is checked, the waveform is inverted.

Battery: The battery waveform produces discharge curves for common battery types. Discharge times from seconds to hours can be generated. Multiple cells placed in series can be selected up to the maximum Waveform Source output voltage of 5V.

DC: The DC supply produces a constant output voltage selected by the Output Voltage entry.

Run button: Start or stop pattern execution and output. If a pattern has been generated or read from a file, it will be loaded prior to execution.

Continuous mode: In Continuous run mode, the waveform pattern loops back to the start of the pattern when the end of the pattern is reached. This produces a periodic waveform output.

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On Event mode: In On Event run mode, the waveform pattern is held at the start of the pattern until the selected event is asserted. When the event is received, the waveform pattern output will be generated. When the complete waveform has been output, the Waveform Source returns to the beginning of the waveform pattern and waits for the next event input.

Events are received when the selected input event transitions from unasserted to asserted. The event cannot be received again until it becomes unasserted.

Single mode: In Single run mode, the waveform pattern will be output once each time the run button is pressed.

V2: Sets the highest voltage that generated ramp, pulse, and RC waveforms will produce.

V1: Sets the lowest voltage that generated ramp, pulse, and RC waveforms will produce.

Waveform Display: Displays an analog simulation of a waveform pattern when it is generated or loaded from a file.

Waveform Display Scroll Bar: Scrolls the waveform display forward or backward in time.

Other User Controls

Zoom the waveform display: The Waveform Display can zoom in/out showing a smaller/larger time span. To zoom the display, roll the mouse wheel (if Wheel Zooms is selected), select Zoom In or Zoom Out in the view menu, or right-click in the waveform display window and select Zoom In or Zoom Out.

The mouse wheel can be configured to zoom or scroll the waveform display. To change the configuration, right-click in the waveform display and select Wheel Scrolls or Wheel Zooms.

Scroll the waveform display: You can also scroll with the mouse wheel (if Wheel Scrolls is selected; see Zoom the waveform display above).

Select Input Event Source: In the Advanced menu select Event In and choose one of the available input event sources from the side menu.

Load a Waveform File: In the File menu, select Open. Navigate to the folder that contains the previously stored pattern, select the file, and click Open. The waveform pattern is updated with the file contents. The new waveform pattern is displayed in the waveform display window. A single level of undo is provided for load pattern by selecting Edit, Undo.

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Save a Pattern File: In the file menu select Save As... Select a folder and file name to store the pattern and click Save. Pattern files are saved in a human readable CSV format.

Maintain Output on Stop: When waveform generation is stopped the output voltage is returned to 0V. Checking the Advanced, Maintain Output on Stop the output will continue to be the last value produced. Note that the DC supply function always returns to 0V regardless of this setting.

Waveform Source Operation

Waveform Execution

The Waveform Source can produce arbitrary analog waveform shapes. It does this by sequentially executing waveform pattern lines stored in its memory. Each pattern line contains both a 10-bit value that defines the voltage to be output when the line executes and a time duration value that determines how long the voltage will be output. Duration values can range from 1μs to 16 seconds with a resolution maximum of 0.2μs. The output waveform is just a series of timed voltage outputs.

To provide more complex waveforms, a command parameter is included in each waveform pattern line. Commands can alter the sequence of pattern lines executed, form counted pattern loops, or wait for events before executing the next line. These commands are used in the waveform generator to produce Continuous, On Event, or Single pattern types.

The algorithmic waveform generator greatly simplifies using the Waveform Source for common waveforms. It includes built in algorithms for common waveform shapes (Sine, Triangle, Pulse, RC, Battery, DC). Once generated, the waveform patterns can be executed or saved to a file.

Run Modes

The Waveform Source provides three run modes for generated waveforms. Continuous mode produces a periodic waveform output. When the waveform pattern reaches the last output level, it will continue from the start of the waveform pattern. Pressing the Run button starts/stops the waveform output.

In On Event mode, the waveform waits at the first output level of the waveform pattern until the selected input event is received. When the event transitions from unasserted to asserted, the waveform pattern is output. When the waveform pattern reaches the last output level it will continue from the start of the waveform pattern. Once again it will wait for an input event before the waveform pattern is output

again. Events are received when the selected input event transitions from unasserted to asserted. The event cannot be received again until it becomes unasserted.

Input events are selected from a list in the Advanced, Event In menu. The event can come from another Five Wire tool or from an external signal using the Trigger I/O Protocol probe.

The Single run mode outputs the waveform pattern once each time the run button is pressed. This allows the user to coordinate the signal manually with their circuits.

Custom Waveforms

The Waveform Source provides waveform generation for common waveform types. This greatly simplifies the use of the Waveform Source for most users. However, much more complex arbitrary waveforms can be generated. Custom waveforms can be defined using a spreadsheet. The spreadsheet is then saved in CSV format. The CSV waveform pattern file can be loaded into the Waveform Source to produce your custom waveform.

Waveform Source Output Events

The Waveform Source generates an output event each time the waveform pattern is output. In Continuous mode the events will repeat at the period of the waveform. In On Event mode, an event will be output each time an event is received. In Single mode, an event will be output each time the run button is pressed.

Logic Source Tool

The Logic Source is a pattern generator with 9 output channels. It provides 1020 pattern memory vectors. Each vector contains a 9-bit output value, a time duration value, and a command value. The vector duration determines the length of time each vector will drive the output pins. The vector duration can be programmed from 30ns to 40ms with 10ns resolution. Vectors are output sequentially starting with line 0. If the vector includes a command the execution sequence can be altered to form for/next loops, infinite loops, and conditional branches based on event inputs.
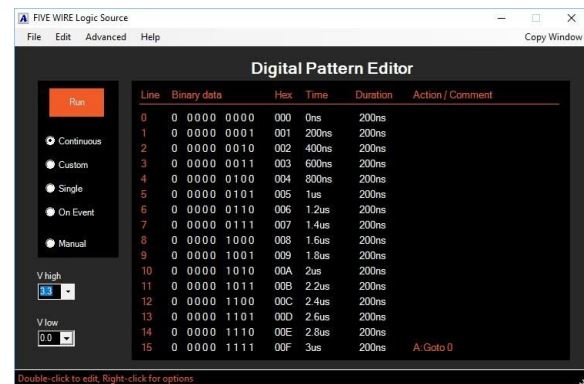
The Logic Source tool provides configuration, run control, and a pattern editor. Logic Source patterns can be saved and recalled later. Pattern files use a human readable CSV format which allows patterns to be generated in a spreadsheet or by user written programs.

Logic Source Window Controls

Run button: Start or stop pattern execution and output. If the pattern has been edited it will be loaded prior to execution.

Continuous: In Continuous run mode, an "A:Goto 0" sequence instruction is placed on one of the pattern lines (default is line 15). When the "A:Goto 0" line is executed, execution will jump back to line 0 forming an infinite loop. The "A:Goto 0" command may be moved to any line, allowing different pattern repeat lengths.

On Event: On Event run mode includes two commands. It includes an "A:Goto 0" command and a "B:Wait for Event then Goto 1". The B:Wait command causes the line 0 vector to be repeatedly executed until the selected input event is asserted. When the input event is asserted, execution will proceed to line 1 and continue sequentially until the line with the "A:Goto 0" is executed. When that line completes, execution will proceed to line 0. The B:Wait command again will repeatedly execute line 0 until another event is received.

Events are received when the selected event transitions from unasserted to asserted. The event cannot be received again until it becomes unasserted.

In On Event mode, the "A:Goto 0" command may be moved to another line, but the

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B:Wait command cannot be moved.

Single: Single run mode includes a "Stop" command that can be moved to any line. When the run button is pressed, pattern execution begins at line 0 and proceeds sequentially until the Stop line is executed. When the Stop line completes, execution is terminated.

Custom: In the modes described above, specific commands were set for the user to implement common use cases. In custom mode there are no predefined commands. Any valid command may be placed on any line.

Manual: Manual mode allows direct control of the logic outputs by the user.

V high: Determines the voltage of the probe output when the pattern bit is set to a 1. V high must always be greater than V low.

V low: Determines the voltage of the probe output when the pattern bit is set to a 0. V low must always be less than V high.

Digital Pattern Editor: Displays the current pattern and supports editing vector values, durations, actions (commands), and comments. Data is shown in both binary form and hexadecimal form. The running time of execution since line 0 and the time duration of each vector are displayed. Any assigned commands or user entered comments are also displayed. See Other User Controls, Pattern Editing below for a discussion of pattern editing.

Pattern Editor Scroll Bar: Scrolls the vector lines up/down to provide access to all of the 1020 vectors. The mouse wheel can also be used to scroll the pattern editor window.

Other User Controls

Pattern Editing (*in the Data Window*): Output pattern vectors are shown in two formats: binary and hexadecimal. An edit in one of the formats will immediately be reflected in the other.

Editing the binary format data is accomplished by Double-clicking on a binary digit. This inverts the bit so that a 1 becomes a 0 and a 0 becomes a 1.

Double-clicking on a hex value initiates Hex Edit Mode, and the value that was double-clicked turns from blue to red. In Hex Edit Mode, hexadecimal characters typed on the keyboard overwrite the red highlighted vector value. When the Enter key is pressed, the red highlighted vector moves to the next line enabling that line to be edited. When no more lines need to be edited, press the ESC key to exit Hex Edit Mode. The red highlighted line becomes blue.

Changing a Line's Duration: To change the duration of a line, double-click on the duration value. A text box appears with the current duration in scientific notation (units are seconds). Click in the text box to edit the value. Press the Enter button on your keyboard to complete the change.

You can use scientific notation or use the suffix 'n' for ns (nanoseconds), 'u' for μs (microseconds), or 'm' for ms (milliseconds) when entering a new duration value. For example you can enter 200n, 0.2u, 200e-9, or 2e-7 to set the duration to 200 nanoseconds.

An alternate way to change the duration of a vector is to right-click on the line you want to change and select Change duration from the drop-down menu. A similar text box is displayed.

Changing the Duration of All Lines: In the Advanced menu, select Set all duration. A blank text box will open. Type in a duration as described above. Press the Enter key on the keyboard to complete the change. All vectors are set to the selected duration.

Change the Goto or Stop Line: Right-click on any line in the pattern edit window and select Set Loop/Stop Line. Click in the text box and enter a valid line number. Press Enter on the keyboard to complete the action. Note that this selection is not available when the Run mode is set to Custom.

Add a Comment on a Line: Double-click on a line in the Action / Comment column. A text box will open. Click in the text box and type in your comment from the keyboard. Press the Enter key to complete the comment. An alternate way to edit a comment is to right-click on the line you want to change and select Add/edit Comment from the drop-down menu. Note: comments are only shown on lines which do not contain a command.

Edit a Block of Pattern Vectors: In the Edit menu select Edit Block. The Program Edit dialog will be displayed. Select the type of edit and the remaining parameters. Help text is provided in the dialog for each block edit type (what it does and how the parameters affect the algorithm. Click OK when done and the data will be changed. A single level of undo is provided for block edits by selecting Edit, Undo multi-line edit.

Select Input Event Source: In the Advanced menu select Event In and then one of the available input event sources.

Set Logic Family: In the Advanced menu select Logic Family and then one of the predefined logic families. This will change the V high and V low settings described above.

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Load a Pattern File: In the File menu select Open. Navigate to the folder that contains the previously stored pattern, select the file, and click Open. The pattern edit window is overwritten with data loaded from the file. When pattern files are loaded the mode is automatically switched to custom. A single level of undo is provided for load pattern by selecting Edit, Undo multi-line edit.

Save a Pattern File: In the file menu select Save As... and then select a folder and file name to store the pattern and click Save. Pattern files are saved in a human readable CSV format. If you have edited the pattern, you will be prompted to save or discard your edits when the Logic Source window is closed.

Logic Source Operation

Run Modes

There are 3 run modes that provide predefined looping constructs. Continuous mode provides an infinite loop. Its loop length can be set from 1 to 1020 vectors.

On Event mode provides triggered bursts. The loop executes once each time the specified event is received. This allows the digital pattern execution to be coordinated with another MicroBench tool or the activity of the user's circuit.

Single mode supports a user initiated burst that starts when the Run button is pressed (or clicked).

These three modes are provided to simplify generation of common pattern types. In these modes, the Logic Source software manages the setting of commands for you.

The Custom mode allows you to be in complete control of the types and placement of commands. This allows more complicated sequences to be generated but requires knowledge of the Logic Source commands and jump controllers.

Custom Run Mode

Custom run mode provides access to most commands via the Logic Source tool window. However, to get complete access to the Logic Source commands you must write CSV pattern files.

It is helpful to first understand the address jump controllers. The Logic Source includes 3 jump controllers designated A, B, and C. The jump controllers contain a jump evaluation type, a target address, and a loop counter. For example, in Continuous mode, jump controller A is set to type Always, and its target address is set to 0. The Jump A command is placed initially on line 15. When line 15 is executed, jump controller A is activated and generates a new next address of 0

causing vector execution to jump to address 0. The pattern edit window drop-down menu allows you to move the Jump A command placement but not the target line to which the jump occurs. When Custom mode is selected this restriction is eliminated.

For example, when you launch the Logic Source tool, its default mode is Continuous and the "A:Goto 0" command is set on line 15. The Logic Source window configures the jump controller A type to Always and its target address to line 0. It then sets a Jump A command on line 15.

Selecting Custom run mode allows you to change the Jump A parameters. For example, in the Advanced Menu select Configure Jump A. A Dialog box allows you to edit the jump controller A type, Jump to line, and loop count. Changing the "Jump to line" to 8 and clicking OK changes the command on Line 15 to be "A:Goto 8". This provides an infinite loop structure with a preamble.

The jump controller functions are:

- **Always**: Always jump
- **If (Event)**: If event is true Jump else execute the next sequential vector
- **If (No Event)**: If event is false jump else execute the next sequential vector
- **Wait for Event**: Hold execution on this vector waiting until the event becomes true and then execute the next sequential vector
- **Loop**: Jump N times and then execute the next sequential vector
- **Inner Loop**: Same as loop except the loop counter is reloaded after it is exhausted and then the next sequential vector is executed

The Jump A, Jump B, or Jump C command can be set on as many lines as you want. However, there are only 3 jump controllers. This limits the complexity of structures that can be realized. Note that the Stop command does not use a jump controller.

To set a command on a line in custom mode, right-click on the line and select Add/Edit Command, and then the command you wish to place. Remember to configure the referenced jump controller when the command is placed (in the Advanced menu). To remove a command, select None.

Generating Logic Source Output Events

To generate a Logic Source output event on a vector line, right-click on that line and select Generate Event. This will cause the Logic Source event to be asserted for the duration of that vector.

One interesting use of events for both sources, Logic Source and Waveform Source,

is to use one tool as a clock for the other. For example, the Logic Source can be configured in Continuous mode to complete its loop once each second. If an Event Out is set on one of the loop vectors, then an output event will be generated every second. The Waveform Source can be configured to generate a ramp that goes from 0 to 5V over a 20ms period every time it receives an Event In from the Logic Source. The two tools working together would then produce a 20ms ramp once each second.

The roles can be reversed with the Waveform Source providing the periodic event and the Logic Source bursting a set of vectors on each event.

Logic Analyzer Tool

The Logic Analyzer tool provides 9 channels of 100MS/s digital capture. A time span up to 36 minutes can be captured while maintaining 8ns resolution for each captured edge. Three-level triggering including value and time-qualified triggers can capture errors caused by missing signal activity. A simple, single-window user interface makes this powerful tool easy to use.
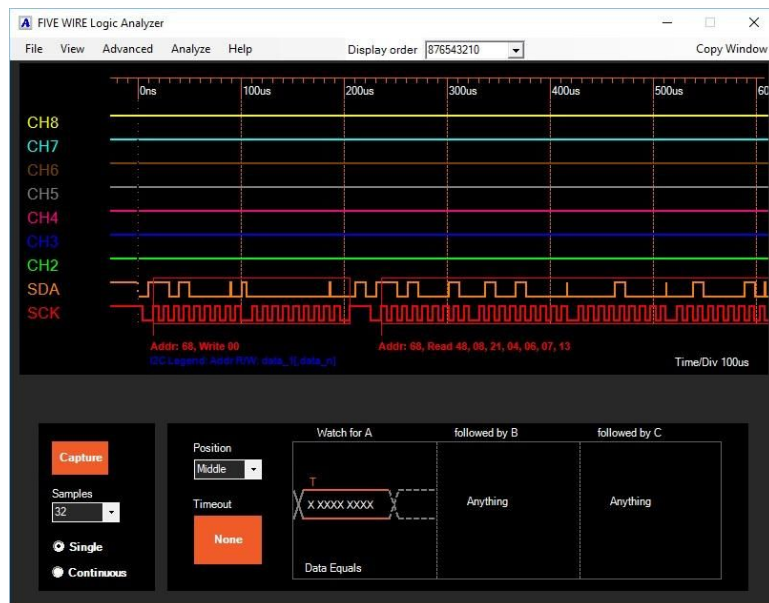
Logic Analyzer Window Controls

Waveform Display: Displays captured digital waveform. The timescale indicates the time at which edges occur. The Samples value indicates the number of edges that must be captured during acquisition to avoid a timeout. The selected logic family is displayed below the Samples.

Display Order: The display order determines which channels are displayed and in what order. To reorder or hide channels, click the display order box and enter the channel numbers in the desired order. For example enter 0123 to view the bottom nibble with channel 0 at the top of the display. Pressing the Enter key on the keyboard updates the waveform display with the new display order.

Watch For A, B, C: Selects a trigger condition. When a trigger is detected and there are a sufficient number of edges, the captured trigger value will be placed at the center of the screen.

To select a trigger type, right-click on the trigger window (*not* the value) or right-click the Watch for A/B/C text above the window and select the desired trigger type.

Set the Trigger Value: To change the trigger value, click in the value box in the center of the waveform. The value is in binary format. An 'X' or 'x' value character indicates that the bit is don't care and will not be included in the trigger evaluation.

A '1' or '0' value character indicates that the bit position should evaluate true when a 1 or 0 value is detected. Space characters may also be included to improve readability. Space characters are ignored.

The characters in the value entry are evaluated from least significant bit (right) to most significant bit (left). The first value character X, x, 1, 0 is assigned to channel 0, the following value character to channel 1, etc. If fewer than 9 value characters are found, the remaining channels will be set to don't care (X). If more than 9 value characters are found the first 9 are used and the rest are ignored.

Set Trigger Time Parameters: Some trigger types include minimum or maximum times as part of the trigger evaluation. To set time parameters click on the parameter and edit the value.

Time values may be entered in scientific notation (units are seconds) or using the suffix 'n' for ns (nanoseconds)or 'u' for μs (microseconds). For example, 200 nanoseconds can be entered as 200n, 0.2u, 200e-9, 2e-7, etc.

Capture Button: Start or stop acquisition of a new waveform.

Run Control Selections: Select the acquisition mode. In continuous mode, acquisitions are taken repeatedly. In Single mode, a single acquisition is taken each time the Capture Button is pressed.

Acquisition Timeout: Sets the maximum time that an acquisition will run before it is terminated by the timeout condition. An acquisition terminates when the requested number of samples have been captured or the duration of the acquisition exceeds the timeout value. To disable the timeout feature set the timeout to "None", by right clicking the button until None is displayed or left-click and select None.

Other User Controls

Zoom Waveform: Captured waveforms can be scaled by zooming in or out. Zoom can be adjusted using the:

- Front panel Zoom knob
- Selections in the View menu
- Selections in the waveform display window right-click menu
- Mouse scroll wheel (if Wheel Zooms is selected in the waveform right-click menu)
- Drag zoom
- Double-click zoom

- Accelerator keys 'i' and 'o'

When both A and B marks have been set (See Set Mark A/B below) you can zoom to the extent of the marks by selecting Zoom Marks in the waveform display drop-down menu or by pressing the 'm' accelerator key. This places the two marks near the left and right sides of the display window.

You can zoom in on a region of the display by dragging the mouse across the time area of interest in the waveform display (drag zoom). To drag the mouse, press and hold the left mouse button at the starting time to be zoomed. Continuing to hold the left mouse button, move the cursor to the ending time to be zoomed. Release the left mouse button to complete the zoom area. Area zoom only uses the horizontal (time) selection: vertical mouse movement during the drag is ignored. Area zoom may be repeated multiple times to view the details of a narrow pulse when a large time span is currently displayed.

You can also zoom by double-clicking on the display. The location of the double-click is centered and the scale magnified. Continuing to double-click on a feature of interest zooms closer to that feature.

Scroll Waveform: Captured waveforms can be shifted left/right to view waveform data that is currently out of view. Scroll position can be adjusted using the:

- Front panel Scroll knob
- Mouse scroll wheel (Select Wheel Scrolls in the waveform right-click menu or 's' key)
- Accelerator keys 'j' or 'k'

Center This: Accessed in the waveform display right-click menu, Center This scrolls the display to place the location of the mouse at the time of the right-click in the center of the waveform display.

Goto: Accessed in the waveform display right-click menu, Goto Trigger, prior edge, and next edge scrolls the waveform display to place the selected item at the center of the display. Goto Mark presents a drop down list of currently placed marks and comments. Selecting a mark or comment from the list will center that mark or comment in the display.

Change Channel Labels: To change a timing diagram channel label, double-click the label you wish to change. An edit window opens indicating which physical channel you are changing. Enter a new label into the text box and click OK.

Open: Opens a previously stored waveform file for viewing.

Save As...: Saves the currently displayed acquisition to a waveform file. The

waveform can then be opened later for viewing.

Set Mark: Set Mark places a display mark at the position of the cursor. To place or remove a mark on the waveform:

- Right-click on the waveform at the desired location and select "Set Mark" and choose the type of mark

- Position the cursor at the desired location and click one of the set mark accelerator keys: a mark, b mark, ref, time, or quick

- Press the undo mark accelerator key to remove the last mark that was placed

Marks will snap to a waveform edge if it is within 8 display pixels of the selected point and within the waveform. To avoid snap to edge place the cursor outside of any waveform or away from a waveform edge.

When A and B marks are placed, the time difference or frequency (1/time difference) between the marks is displayed. Use '/' accelerator key to toggle between frequency and time.

When a Time mark is placed it displays the relative time at that location. If a Reference Mark is also placed, the Time marks display the time relative to that reference time. If no reference mark has been placed then Time marks are relative to the start of acquisition.

Notation marks allow you to enter the text label associated with the mark. To set a notation mark, click in the text box that is opened when Notation is selected. Type the label text and then press Enter to set the mark.

Notation labels must be unique. If a Notation mark is placed with the same label as an existing Notation mark, the original mark is deleted before the new mark is placed, effectively moving that Notation mark to a new location.

Set Quick Mark: This mark is like a time mark except that only one Quick Mark can be placed at a time. Once a Quick Mark is placed, left-clicking the waveform moves the Quick Mark to the click location allowing different time points to be quickly measured.

Set Comment: Comments are like Notation marks (see Set Mark description) except that they do not include a mark line, do not snap to edges, and their text label does not have to be unique.

Save View: Adds the current view to the list of annotations with a user defined name.

Show View: Restores a named view.

Delete Mark or Comment: Presents a drop down list of marks and comments that are currently set. Selecting a mark or comment from the list deletes that mark or comment. The last mark that was placed can be deleted using the 'u' accelerator key.

Delete All Marks and Comments: Deletes all of the currently set marks and comments.

Analyze: This menu provides access to the analyze/decode functions. Multiple decoders can be added to an acquisition.

Select Decoder: Clicking this item will open a drop down selection which allows one of the decoders to be applied. Current decoder functions include SPI, I2C, RS232, and VALUE. When an analyzer is selected, a configuration dialog is presented which is specific to the selected decoder. The configuration dialog allows you to assign input channels to the decoder specific signals such as the I2C SCK and SDA signals. Specific decoders definition files (dcd) can also be assigned to the decoder. Clicking the OK button completes the configuration.

Configure Decode: Clicking this item will provide a drop down that selects which decoder is to be configured. Selecting a decoder will reopen the configuration dialog for that decoder allowing the configuration parameters to be modified.

Enable Decoder: Enables/disables waveform decoding.

Refresh Decode: Deletes decode marks and re-runs the decoder on the current data.

Clear Decode Marks: Removes all decoder marks.

The decoder functions work on serial data streams. Decoding the information requires that the analyzer align the start of decode with the acquired data set. In some cases the data set begins with a partial transaction that includes only a portion of the protocol. In these cases the decoder will attempt to form synchronization but may be unable to synchronize if insufficient information is available. In these cases the user should place a *Begin Analysis* mark at a location between transactions to force correct alignment. Right click in the waveform display and select *Set Mark -> Begin Analysis*.

If transactions are close to each other in the display their decode text may overlap. Zoom in to spread the transactions further apart to eliminate the overlap.

Remove Decoder: Clicking this item will provide a drop down that selects which decoder is to be configured. Selecting a decoder will delete that decoder.

Number of Samples: The number of samples that are captured in each acquisition can be adjusted by selecting the Advanced, Number of Samples menu.

Trigger Position: Sets the trigger location within the acquisition. When Start is selected, triggering is enabled immediately. When Middle is selected, the trigger is not enabled until the number of acquired samples is greater than half the requested number of samples. When End is selected, the trigger is not enabled until the number of acquired samples is greater than the requested number of samples.

Logic Family: The logic family being probed can be selected in the Advanced, Logic Family menu. The logic family setting is used to determine the logic state of a signal, 1 or 0.

Event In: Selects which MicroBench tool will be the source of the Logic Analyzer trigger (when trigger type is external event).

Event Out: Selects when the Logic Analyzer tool generates an output event.

Keyboard Shortcuts

Both Live Logic and Logic Analyzer provide keyboard accelerators that make viewing waveforms fast and efficient. Each accelerator key has a corresponding context menu control. Below is a list of keys and their function.

Key	Function
i	Zoom in
o	Zoom out
j	Scroll left
k	Scroll right
n	Goto next edge
p	Goto prior edge
N	Goto next edge, jump past local activity
P	Goto prior edge, jump past local activity
a	Set mark A at the cursor location
b	Set mark B at the cursor location
m	Zoom to A and B marks
z	Set mouse wheel mode to zoom
s	Set mouse wheel mode to scroll
q	Set quick mark at the cursor location
r	Set the reference time mark at the cursor location
t	Set the time mark at the cursor location
u	Remove the last mark set
/	Toggle A-B mark measurement between time and frequency

Logic Analyzer Operation

Setting Triggers

The Logic Analyzer trigger can be used to look for specific logic signal levels or behavior and to stop the acquisition ensuring the event of interest is captured in memory. Triggers are evaluated each time the logic analyzer inputs change, so if there is no activity on the signal inputs, the trigger will evaluate to false.

The Trigger Position selection determines the number of samples that will be taken before triggering is enabled. This allows control of the number of samples that are captured before the trigger event. The trigger position can be set to Start, Middle, or End. The Start trigger position enables triggers immediately at the beginning of the acquisition. The Middle trigger position enables triggering after half of the requested samples have been acquired. The End trigger position enables triggers after the requested number of samples have been captured.

Once the trigger evaluation is enabled, acquisition continues until the trigger condition is satisfied. Once the trigger condition is satisfied, acquisition continues storing additional samples equal to the remainder of the requested samples minus the requested trigger position samples.

The Logic Analyzer tool provides three-level triggering. First the Watch for A trigger is evaluated. If the input signals cause the A trigger to become true, the Watch for B trigger will become the active trigger. Each following input change will be evaluated by the B trigger. If the B trigger evaluates true then the C trigger becomes the active trigger. If the C trigger evaluates true the logic analyzer becomes triggered.

When the logic analyzer is triggered, it will continue to store a fixed number of post-trigger samples before terminating the acquisition. This ensures that data before and after the trigger are available for viewing. To place the trigger value in the center of the timing display, right-click the window and select Center Trigger.

When an acquisition is started, the Watch for A text color changes from black to red. This indicates that the A trigger is the active trigger. If the A trigger is satisfied the followed by B text will become red indicating that the B trigger is active. The same is true for the followed by C text. If all triggers have been satisfied all trigger labels will be black.

Time Qualified Triggers

Time-qualified triggers evaluate the input value of the logic signals and the length of time those signals have been stable (time since the prior signal change). There are three types of time qualified triggers:

- **Stable longer than time**: Evaluates to true only if all input signals have not changed state for at least the time specified. If a trigger value is set, then it must also evaluate to true.

- **Stable shorter than time**: Evaluates to true only if at least one signal has changed within the time specified. If a trigger value is set, then it must also evaluate to true.

- **Stable for time window**: Evaluates to true only if no signal has changed for the specified minimum time and at least one signal changes before the specified maximum time. If a trigger value is set, then it must also evaluate to true.

Stable longer than time is useful in finding hang problems – when the signal activity stops for an extended time due to a software bug or hardware hang. Setting the trigger value to don't cares and the time parameter to a value longer than the expected quiescent time of your signals, you can trigger when signal activity hangs.

Stable shorter than time triggers can be used to catch signals transitioning more quickly than expected. For example, if a strobe should last 10µs but is occasionally shorter, you can set the time parameter a little less than 10µs and trigger on the shortened strobe.

A word of caution about this trigger type: All active inputs to the logic analyzer are evaluated, even if their data value trigger is set to don't care. If there are several signals that transition at the same time, the trigger will also evaluate the intermediate states of the transitioning signals. Zooming in on the transaction will reveal that the signals actually each changed at slightly different times. If this is a problem use the Stable for time window trigger.

Stable for Time Window is useful for triggering on signals with intermediate states that should be ignored. Any state with a duration less than the minimum specified time will evaluate to false eliminating intermediate states during transitions. If the signal has been stable for more than the minimum time and it transitions before the end of the window then the trigger will evaluate to true. The window time is set to the minimum acceptable stable value time, so if a trigger occurs, the stable value time was not sufficient.

Acquisition Termination

Once the Logic Analyzer acquisition is started, it will terminate when one of three conditions occurs:

1. The user presses the Capture/Stop button

2. The acquisition time exceeds the timeout value

3. The logic analyzer is triggered and sufficient post-trigger data values have been captured.

The Logic Analyzer expects to capture a specified number of samples (edges) before acquisition is complete. If a sufficient number of samples are not captured within the timeout setting, the acquisition will be terminated. If you are capturing low repetition rate signals such as wake-up polling strobes, the timeout value can be increased to avoid the timeout termination. You can also increase or decrease the number of samples required to avoid timeout.

I2C Protocol Tool

The I2C Protocol Tool provides both master and slave I2C compliant capabilities. When in master mode, the I2C tool takes control of SCK and SDA to generate user defined read and write transactions. In slave mode, the I2C tool can respond to one or all addresses capturing write data and returning user defined read data.
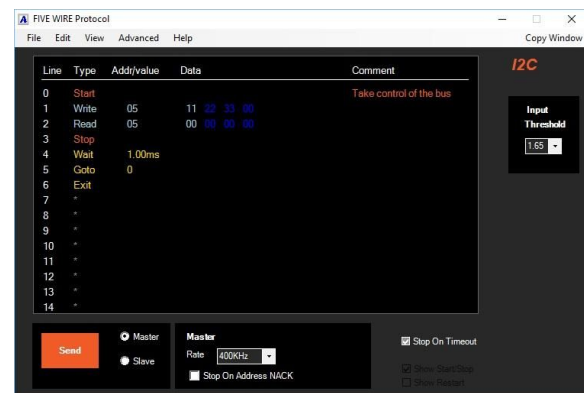
The I2C tool provides a transaction viewer and editor. When in master mode the user defines transactions that will be placed on the bus. In slave mode, captured transactions are displayed. Transactions can be saved to a human readable CSV file and reloaded at a later time.

Instrument Front Panel Controls

Send button: The function of the send button changes depending on the mode that has been selected:

- **Master mode**: Starts execution of the transaction list
- **Slave mode**: Starts slave execution providing response to the programmed address.

Run LED: Illuminated when transactions are enabled or occurring.

I2C Protocol Window Controls

Send button: Same functions as the front panel send button. See Send button above.

Master Slave Select: Determines which mode the I2C execution is in.

Master Controls, Rate: Sets the approximate bit rate of transmission. Note that the bit rate can be affected by slave response times

Master Controls, Stop On Address NACK: If checked, execution will terminate if the address transmission does not receive an acknowledge from an addressed slave.

Slave Controls, Address: Determines which address(es) the I2C tool will respond to. An address of 'X' will respond to all addresses. A hex address 0 - 7F will respond at that address only.

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Slave Controls, Continuous: The slave function will continue until the Stop button is pressed.

Slave Controls, Once: The slave function will stop as soon as transaction memory is filled.

Slave Controls, Stop On Event: The slave function will continue until an event is received from the selected source or the Stop button is pressed.

Slave Controls, Enter Slave Read Data: Open the Edit Read Data dialog box. Up to 8 bytes can be entered in hex. Each byte is returned in order during a read transaction.

Stop On Timeout: If checked, the master or slave function will terminate execution when a transaction element takes longer than about 100ms.

Input Threshold: Determines the voltage boundary between interpretation of the input as a logic low or logic high for the SCK and SDA signals.

Transaction Window Scroll Bar: Scrolls the vector lines up/down to provide access of up to 64 transactions. The actual number of transactions that are displayed depends upon the number of elements in each transactions and the complexity of the I2C traffic. The mouse wheel can also be used to scroll the data and pattern editor window.

Other User Controls

Master transaction editor: In master mode the Line and Type columns include context menus that are opened by right clicking within the intersection of a column and line. The Line context menu allows new lines to be inserted or existing lines to be deleted. The Type column menu allows transactions and commands to be set on that line. Transactions include Start, Read, Write, and Stop. Commands include Wait (time), Wait for event, Send event, Goto (line), and Exit.

Adding Master I2C transactions: I2C transactions must always begin with a Start. When the bus is Idle a Start condition is required to take ownership of the bus. After the Start transaction Read and Write transactions may be included. The I2C automatically places a Restart condition between each Read or Write transaction (although they are not shown in the display). Finally a Stop transaction should be added to release ownership of the bus returning to the Idle state.

Read and Write transactions require an address and data to be entered for the transaction. When a Read or Write transaction is selected, an Address Entry dialog box is presented. Enter the desired address and click OK or press the enter key. Once the address is entered, data edit mode is entered. A '00' hex byte is presented

highlighted in red. For Write transactions, entering hex digits on the keyboard will change the value of the highlighted value. Pressing the Enter key will fix the current value and a new highlighted value is presented. This process can be repeated for up to 8 bytes to be written. For read transactions the values cannot be changed. However, the number of bytes entered determines how many bytes are read during execution. Once the number of desired bytes have been entered pressing the ESC key or adding a new transaction on another line will terminate edit mode.

Write data can be edited or additional Read or Write bytes can be added later by double clicking on the byte of interest. However, to remove bytes the transaction must be re-entered.

Adding Master Commands: Commands do not directly affect the I2C bus signals. Instead, they alter the timing or sequence of transaction execution. The Wait command inserts a time delay of selectable duration from 10us to 500ms. The Wait for event command pauses execution until the selected event is received. The Goto command jumps execution to the selected line allowing indefinite loops to be formed. Send event causes an event to be output on the ProtocolB event line. Exit causes execution to terminate and has the same effect as pushing the Stop button.

Adding Master or Slave Comments: Double click in the Comment column on the line the comment is to be placed. A text entry box is opened. Click in the box and enter a comment. To edit an existing comment double click on the comment.

Select Input Event Source: In the Advanced menu, select Event In then one of the available input event sources. This menu is only enabled in Master On Event mode.

Set Logic Family: In the Advanced menu select Logic Family and then one of the predefined logic families. This will change the Input Threshold settings to be appropriate for that logic family.

Load a Transaction File: In the File menu select Open. Navigate to the folder that contains the previously stored transaction list, select the file, and click Open. The transaction window is overwritten with data loaded from the file.

Save a Transaction File: In the file menu select Save As... Select a folder and file name to store the transaction list and click Save. Transaction files are saved in a human readable CSV format.

I2C Protocol Operation

The I2C Protocol tool can act as an I2C master or an I2C slave. It generates transactions using a custom micro-coded protocol engine (uMPE). When the I2C tool is started, a program appropriate for selected function is compiled and loaded into

hardware. The uMPE executes the program which encodes the protocol behaviors and produces the required signals and responses. In master mode the users transactions are also compiled providing the I2C activity specified by the user.

The uMPE executes at 25MHz (40ns) which establishes its maximum time resolution. The duration of SCK and SDA cycles are set using uMPE timers. For standard I2C speeds SCK the SCK duration is 5 - 10us and the uMPE provides better than 1% timing accuracy. uMPE timers are also used to determine if a transaction has hung and can terminate execution for further analysis.

The uMPE includes program and data memory. Program memory contains the protocol behavior definitions for both master and slave mode operation. In master mode the program memory also includes the compiled user transactions and commands. In master mode, data memory contains bytes to be written and bytes captured during read transactions. In slave mode data memory contains a record of the captured transactions.

The actual number of transactions and data read write values that can be used with the I2C protocol is limited by the program and data memory capacity. In most applications there is more than enough memory for transactions and data. However, the I2C tool does not contain sufficient memory to emulate large I2C RAM or flash memory devices.

Master Mode

When the Master mode is selected the I2C Protocol tool acts as the I2C master. It generates Start, Restart, Read, and Write transactions that access I2C slave devices. In master mode SCK is controlled by the I2C tool. Data bytes can be written to I2C slave devices and data bytes read from a slave device are captured for later display.

To execute I2C Read and Write cycles transaction commands must be entered into the transaction window. Below is an example master program. Note that Read and Write transactions must be bracketed by Start and Stop transactions. The program also shows the use of commands that insert time delay and cause the program to loop indefinitely.

Read and write transactions require an address and data values. When these transactions are inserted the user is prompted to enter an address. Once the address is entered data bytes that are part of the transaction are entered. The transaction window enters data edit mode presenting a hex data byte highlighted in red. For Write transactions the byte value is editable by typing hex digits at the keyboard. Pressing the Enter key adds another byte. Up to 8 bytes can be added. Read transaction data is not editable. It will be overwritten by actual read data during

program execution. However, the number of bytes entered is important. A read transaction will be terminated with a NACK when the last byte is read. To exit data edit mode press the ESC key or enter a new transaction or command on a different line.

Slave Mode

In slave mode the I2C Protocol tool monitors the SCK and SDA signals for I2C transactions. The slave can be configured to respond to all transactions by setting its address to 'X' (don't care) or just one address by entering a decimal address value. When the I2C tool detects a Start condition it captures the address byte that follows and evaluates its contents to determine if it is addressed. If addressed and the R/W address field is low, bytes written by the master are captured for later display. If the R/W field is high, the I2C tool returns the bytes that were programmed by the user. Up to 8 bytes are stored or sent for each transaction.

To enter the data bytes that will be returned during a Read transaction, click the "Edit Slave Read Data" button. This opens a new window that allows up to 8 hex values to be entered. During a Read transaction these bytes are returned in the order shown. The master device will determine the actual number of bytes read.

Once the I2C tool is started, it captures all Start, Stop, and Restart conditions. When addressed it captures the transactions for its address also. When the I2C tool is stopped the captured information is displayed in the transaction window. Display of Start, Stop, and Restart conditions can be controlled using the Show Start/Stop and Show Restart selections respectively.

Timeout Conditions

The uMPE times the duration of protocol actions that can be extended in time by the slave or master to detect hang conditions. A timeout can be caused by the master setting the SCK signal high and the slave extending the SCK low to hold off the master or due to a protocol fault. Other timeout conditions occur when a transaction fails to complete in the timeout period. The I2C tool has a timeout period of approximately 100ms. Timeouts can be disabled when appropriate, to aid in troubleshooting for example.

Master Stop On Address NACK

In master mode the I2C tool executes the transactions defined in the transaction window. Each transaction begins with a Start followed by an address byte. If a slave exists at the presented address, it returns an ACK signal on the following SCK cycle.

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If no slave is addressed, the SDA line remains high and the master receives a NACK signal. The I2C tool master can be configured to stop execution on an address NACK or to continue with the next transaction using the Stop On Address NACK checkbox.

Trigger I/O Protocol Tool

The optional Trigger I/O Protocol tool provides three external trigger inputs and three external trigger outputs. The trigger probe inputs and outputs can be directly connected to the user's circuit. Trigger inputs are high impedance and have a settable threshold. Trigger outputs have settable high and low logic levels.

Trigger inputs can drive the internal events Protocol A and Protocol B. These events can be used by any of the Five Wire tools. Trigger outputs can be assigned to one of the Five Wire events.
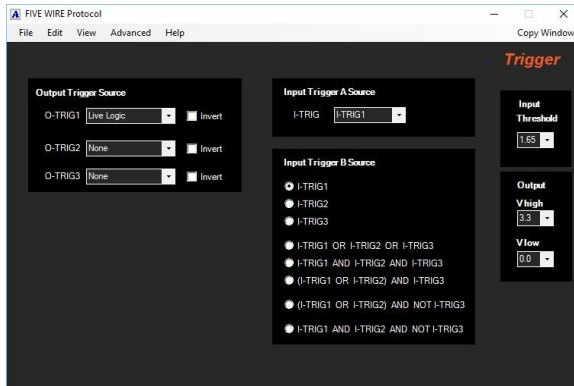
Trigger I/O Protocol Window Controls

Output Trigger Source: Assigns one of the internal events to a trigger output. If the Invert box is not checked, the output will be high when the selected event is asserted. If checked, the output will be low when the selected event is asserted.

Input Trigger A Source: Selects one of the trigger input signals to drive the Five Wire Protocol A event.

Input Trigger B Source: Selects a logical combination of the trigger input signals to drive the Five Wire Protocol B event.

Input Threshold: Sets the trigger input voltage level that determines evaluation to a logic high or low. Voltages above this level evaluate to a 1. Voltages below this level evaluate to a 0.

V high/low: Sets the trigger output voltage levels driven when the selected event is asserted or unasserted.

Other User Controls

Logic Family: An alternate way to set input/output levels is to select your logic

family in the Advanced, Logic Family menu. Input threshold, V high and V low are set to the appropriate levels.

Trigger I/O Protocol Operation

Trigger Outputs

Each Five Wire tool generates output events, including the System tool. The Live Logic and Logic Analyzer tools assert their event at the start of acquisition or when their triggers are satisfied. Waveform Source asserts its event at the start or end of each waveform output. Logic Source asserts its event when the line selected by the user is executed. The System tool asserts its event when the front panel System button is pressed.

The trigger outputs can be used to coordinate external circuits with Five Wire tool activity. They can also be used independently. For example, selecting the System event to drive a trigger output provides a manually controlled logic level that can be used to test the user's circuit. If a static level is desired, the Invert box can be used to control the trigger output. If a periodic clock is needed and the Waveform Source is not in use, it can be configured to generate a periodic waveform at the needed frequency. Its event can then be selected as a source for a trigger output.
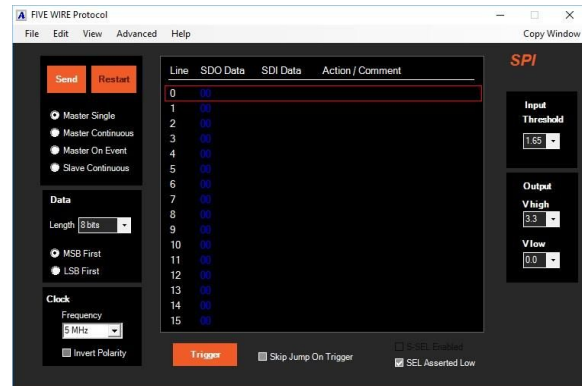
Trigger Inputs

Three trigger inputs are provided by the Trigger I/O Protocol tool. These inputs can be used to drive the 2 event outputs, Protocol A and Protocol B. These events can be selected by other tools as their input event. For example, the Waveform Source can be configured to use the Protocol A event to cause its output waveform to be generated. The user's circuit would control the output of an analog waveform.

SPI Protocol Tool

The optional SPI tool includes a 128 word output queue, which contains values to be sent via SDO, and a 128 word input queue, which stores values received from SDI. On each transaction, one word in the output queue is serialized onto the SDO output signal and one word is stored in the input queue, deserialized from the SDI input. The queue line then is incremented to prepare for the next transaction. Commands and triggering can change the sequence of execution. When execution is stopped, the captured data can be inspected for proper operation.

The SPI protocol tool provides a hexadecimal pattern editor allowing easy entry of output queue data. Captured data is displayed next to output data so transactions can be easily evaluated. Master transactions can be single-stepped or sent each time an event is asserted. The input and output queues can be saved to a CSV file and later restored.

Instrument Front Panel Controls

Send button: The function of the send button changes depending on the mode that has been selected:

- **Master Single mode**: The send button sends one SPI transaction.
- **Master On Event**: The send button Starts or stops transmission of SPI transactions, with each transaction being driven by the event input.
- **Slave Continuous mode**: The send button starts or stops the receipt of SPI transactions.

Run LED: Illuminated when transactions are enabled or occurring.

SPI Protocol Window Controls

Send button: Same functions as the front panel send button. See Send button above.

Restart button: In Master Single mode, the restart button resets the input and output queues to line 0.

Master Single: In master single run mode, a SPI transaction is sent each time the

send button is pressed. A red cursor box indicates the next line that will be processed. SDI data is updated in real-time so transactions can be immediately evaluated.

Master On Event: In master on event mode, a SPI transaction is sent each time the selected input event is asserted. Pressing the send button enables or stops the SPI transactions. When stopped, the SDI data display is updated to reflect captured data.

Events are received when the selected event transitions from unasserted to asserted. The event cannot be received again until it becomes unasserted.

Slave Continuous: In slave continuous mode, SPI transactions are driven by the user's SCK. When the Send button is pressed, the SPI Protocol tool will capture and respond to SPI transactions. Pressing the send button again will stop the tool and the SDI data display will be updated.

Data Length: Sets the shift length for SPI transactions.

MSB/LSB First: Sets the order in which SDO data is sent and SDI data is displayed.

Clock Frequency: Sets the bit clock rate for master modes.

Clock Invert Polarity: If checked, the master mode clock is asserted low, and in slave mode data is clocked in on the negative edge of SCK.

Input Threshold: Determines the voltage boundary between interpretation of the input as a logic low or logic high for the S-SEL, S-SCK, and SDI signals.

V high: Sets the voltage that will be driven onto M-SEL, M-SCK, and SDO when these signals are high.

V low: Sets the voltage that will be driven onto M-SEL, M-SCK, and SDO when these signals are low.

Trigger button: Opens the trigger dialog allowing the trigger value to be set.

Skip Jump on Trigger: When checked, the Jump command becomes conditional. In this mode, the trigger result from the Jump line determines if the jump is taken. If the trigger evaluates to false, the Jump is taken and the next executed line is the jump target. If the trigger evaluates to true, the jump falls through and the next executed line is the line that follows the Jump line.

S-SEL Enabled: Enables the slave select input in Slave Continuous mode.

SEL Asserted low: Determines the polarity of both the M-SEL output and the S-SEL input. If checked, these signals are asserted and evaluated as low true.

Transaction Window Scroll Bar: Scrolls the vector lines up/down to provide

access to all of the 128 vectors. The mouse wheel can also be used to scroll the data and pattern editor window.

Other User Controls

SDO Data Editing: SDO data vectors are shown in hexadecimal format. Double-clicking on a hex value initiates Hex Edit Mode (HEM) and the value that was double-clicked turns from blue to red. In HEM mode, hexadecimal characters typed on the keyboard overwrite the red highlighted vector value.

When the Enter key is pressed, the red highlighted vector moves to the next line enabling that line to be edited. When no more lines need to be edited, press the ESC key to exit HEM mode. The red highlighted line becomes blue.

Add a Goto 0 command: Right-click on any line in the transaction window and select Goto 0. A Goto 0 command is placed on that line. Only one Goto 0 command can be set. The Goto target is always line 0. Goto 0 allows a set of SPI transactions to be repeated indefinitely.

Add a Jump Command: Right-click on any line in the transaction window and select "Jump to." Click in the text box and enter a line number between 0 and 127. Only one Jump command can be set. The target line is selectable by the user. The Jump command can be made conditional based on the programmed trigger. This allows wait loops to be generated that send a transaction or set of transactions until an expected response is returned. When triggered the Jump is not taken and the next sequential vector is executed.

Add a Stop Command: Right-click on any line in the transaction window and select Stop. A Stop command is placed on that line. When a stop command is executed the tool stops executing transactions and displays captured SDI data.

Add a Generate Event: Right-click on any line in the transaction window and select Generate Event. An Output Event A command is placed on that line. When the line is executed, Protocol A output event will be asserted.

Add a Comment on a Line: Double-click on a line in the Action / Comment column or right-click and select Add/Edit Comment. A text box will open. Click in the text box and type in your comment from the keyboard. Press the Enter key to complete the comment. Note that comments are only shown on lines which do not contain a command.

Select Input Event Source: In the Advanced menu, select Event In then one of the available input event sources. This menu is only enabled in Master On Event mode.

Set Logic Family: In the Advanced menu select Logic Family and then one of the

predefined logic families. This will change the V high, V low, and Input Threshold settings to be appropriate for that logic family.

Load a Pattern File: In the File menu select Open. Navigate to the folder that contains the previously stored pattern, select the file, and click Open. The pattern edit window is overwritten with data loaded from the file.

Save a Pattern File: In the file menu select Save As... Select a folder and file name to store the pattern and click Save. Pattern files are saved in a human readable CSV format.

SPI Protocol Operation

Master Mode

When Master Single or Master On Event modes are selected the SPI Protocol tool acts as the SPI master. It generates M-SCK to shift data out of SDO and captures data received on SDI.

Master Single mode provides single-step operation. A transaction is initiated each time the Send button is pressed. A cursor box is drawn around the line that is to be executed. The SDO data in the cursor box is sent and the SDI Data in the cursor box is received. The display is updated with the received data and the cursor box is moved to the next executing line.

Master On event allows transactions to be sent periodically or triggered by a user signal. Each time the selected input event is asserted, a SPI transaction is initiated. SDI input data is captured but the display is not updated until the tool is stopped.

Slave Mode

In Slave Continuous mode the SPI Protocol tool acts as a slave. The Send button starts the tool and it waits for transitions on the S-SCK input. During a transaction the output queue generates the data sent on SDO, and data received on SDI is captured to the input queue. The SPI Protocol tool can then be stopped by pressing the send button, and the SDI data display will be updated with the captured values.

Sequence Commands

The SPI Protocol provides three pattern sequence commands: Goto 0, Jump, and Stop. The Goto 0 command can be placed on any line and causes execution to restart at line 0. This provides a simple infinite loop mechanism.

The Jump command specifies the target line of the jump. The jump can be forward,

backward, or can be to the same line that contains the jump command. The jump command can be configured as a jump always or a conditional jump. When conditional, the jump is taken if the trigger evaluates to false on that line. If the trigger evaluates to true, the jump falls through and the next sequential line is executed. This allows a tight loop to be formed that continuously polls for a value and then continues when the value is received. The Goto 0 and Jump commands may be combined to provide complex sequence control. However, only one Goto 0 and one Jump command can be placed in the queue.

The Stop command terminates the SPI Protocol tool execution and displays captured data.

Triggers

The SPI Protocol tool provides a single trigger that evaluates SDI data. Trigger values are encoded in binary format. An 'X' or 'x' value character indicates that the bit is don't care and should not be included in the trigger evaluation. A '1' or '0' value character indicates that the bit position should evaluate true when a 1 or 0 value is detected. Space characters may also be included to improve readability. Space characters are ignored. Each byte in the trigger is shown separately but they all contribute to trigger evaluation.

The characters in the trigger entry are evaluated from right to left. The first value character X, x, 1, 0 is assigned to bit 0, the following value character to bit 1, etc. If fewer than 8 value characters are found, the remaining bits will be set to don't care (X).

The result of trigger evaluation is driven onto protocol event output B for use by other tools. If the Skip Jump on Trigger box is checked in the trigger dialog, the Jump command becomes conditional based on the trigger result.