LeCroy
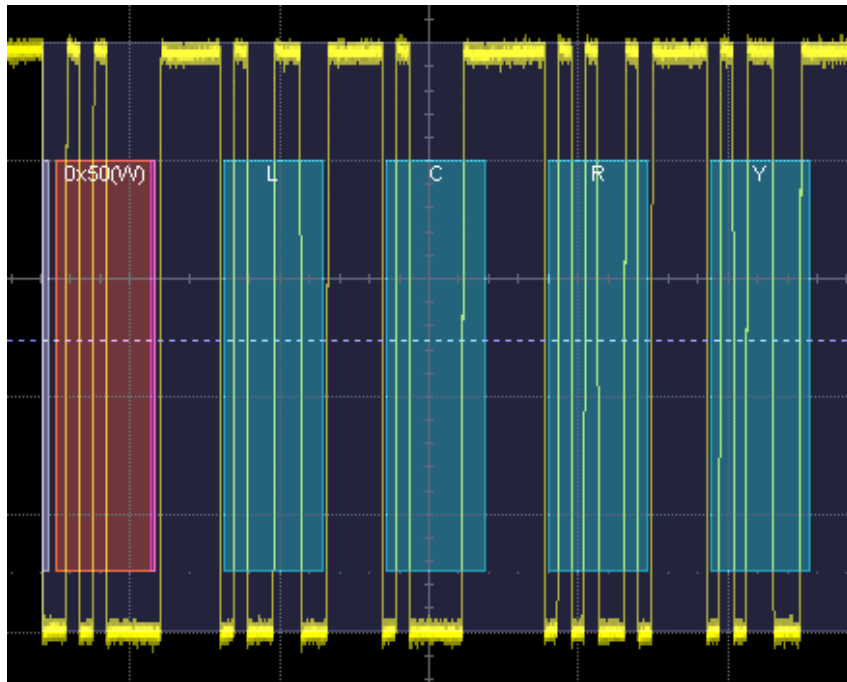
SERIAL DATA TRIGGER AND DECODE OPTIONS

Operator's Manual

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INTRODUCTION

Overview

A variety of Serial Data standards, such as Inter-IC (I^2C), Serial Peripheral Interface (SPI), UART (Universal Asynchronous Receive Transmit), RS-232, and LIN (Local Interconnect Network) are used to communicate from microprocessors to peripherals or between embedded controllers.

I^2C is a standardized protocol created by Philips with a documented technical specification. SPI was popularized by Motorola but is not standardized, per se – there are a variety of variants with the differences characterized by how data is clocked, whether data is MSB or LSB format, and whether it is multi-slave or single-slave. UART is a generic "backbone" for many proprietary serial data protocols too numerous to mention, each with different physical layers. RS-232 is a special case of UART, with a more defined protocol and specific physical layer. LIN is a low cost master/slave system designed for low cost implementation in vehicles, typically in what is commonly referred to as "body electronics". FlexRay is a time-triggered automotive communications bus designed for higher speeds and fault tolerance. A summary of the differences is in the table below:

Standard	Definition	# Lines	Data Rate	Synchronous or Asynchronous?
I^2C	Inter IC	2	Up to 3.4 Mb/s	Synchronous
SPI	Serial Peripheral Interface	3	Up to ~50 Mb/s	Synchronous
UART	Universal Asynchronous Receiver/ Transmitter	1	Up to 1 Mb/s (typical)	Asynchronous
RS-232		1	Up to 57.6 kb/s (typical)	Asynchronous
LIN	Local Interconnect Network	1	Up to 19.2 kb/s	Asynchronous
FlexRay		1 (differential	2.5, 5 or 10 Mb/s	Asynchronous

The TD and D Serial Data options are unique oscilloscope tools from LeCroy that will greatly increase your ability to debug and analyze embedded controllers that use serial bus communications. The D products are Serial Decode only, and the TD products include Serial Trigger and Decode. The serial triggers are integrated into the oscilloscope – no external hardware is used – and are selected through the normal oscilloscope trigger menus. Serial data signals are input to the oscilloscope through normal passive or active probes, such as LeCroy's ZS Series of high impedance active probes. Decoding is accessed from the Analysis pull-down menu in the File Menu. The decoding is overlaid on top of the appropriate channel, and is intuitively presented and color-coded for quick understanding. All packages contain Search capability for specific messages, and a Table to display protocol data in summary form underneath the oscilloscope grid.

The various TD options are available for WaveRunner Xi and WaveSurfer Xs oscilloscopes.

The various D options are available with WaveRunner 6000, WavePro 7000 and WaveMaster 8000 oscilloscopes.

The I^2C-BUS Specification published by Philips Semiconductors fully describes the I^2C standard. As of the date of printing of this manual, Version 2.1, January 2000 is the most recent version (though this does not include the recent FM+ update).

There is no formal SPI standard. Descriptions of SPI and it's variants are usually included in the technical documentation for the microprocessor that offers support for SPI.

UARTs evolved from mechanical rotating teletypewriter devices, and formats were formalized with the advent of the first electronic computers. There is no formal UART standard.

RS-232 has a defined physical layer defined in the Electronic Industries Association (EIA) EIA-RS-232-C and the Telecommunications Industry Association (TIA) TIA-232-F. This standard defines the RS-232 physical layer and does not specify use of a UART protocol layer; however, UART is commonly implemented.

The LIN specification is published by the LIN Consortium. As of the date of the printing of this manual, Version 2.1, November 24, 2006 is the most recent version. Preceding versions are 1.3 and 2.0. SAE published a variation of LIN 2.0 called J2602. This specification shares many attributes of LIN 2.1.

The FlexRay specification is published by the FlexRay Consortium. As of the date of the printing of this manual the FlexRay protocol specification is currently at V2.1 Rev A, accompanying this specification is the V2.1 Rev A Errata V1 document. Separate specifications exist for the physical layer and data link layer.

This manual will assume that you have a basic understanding of the various serial data standard physical layer and protocol layer specifications, and knowledge of how these standards are used in embedded controllers. It also assumes that you have a basic understanding of oscilloscope operation, specifically the LeCroy oscilloscope that the serial trigger and decode option will be used with. Wherever practical or necessary, details on specific oscilloscope features have been included in this manual.

Note: LeCroy has a policy of frequently updating software. It is possible that screen images in this manual may not exactly match what you see on your oscilloscope display. However, functionality will be nearly identical.

The TD Series Software

The TD option adds the following capability to the LeCroy oscilloscope software user interface dialogs:

1. Serial Trigger Selection

    If this is the first serial trigger option you have installed on your scope, an additional icon will appear in your trigger dialog box. It allows a serial trigger condition to be set from within the oscilloscope using an easy-to-understand interface.

2. Serial Decode

    If this is the first serial decode option you have installed on your scope, an additional set of Serial Decode and Decode Setup dialog boxes will be provided for setup of protocol format (as necessary) and decoding. These can be accessed from the Analysis menu.

3. Decode Protocol Selections

    As serial decode options are added to your oscilloscope, additional protocol selections are available in a pop-up dialog box within the Serial Decode dialog boxes.

    SIOP and SSPI are part of the SPIbus TD package.

    RS232 is part of the UART-RS232bus TD package
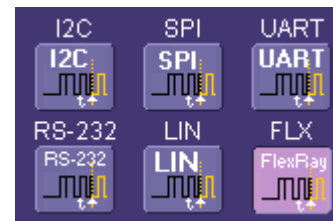
The D Series Software

The D option adds the following capability to the LeCroy oscilloscope software user interface dialogs:

1. Serial Decode

If this is the first serial decode option you have installed on your scope, an additional set of Serial Decode and Decode Setup dialog boxes will be provided for setup of protocol format (as necessary) and decoding.

2. Decode Protocol Selections

As serial decode options are added to your oscilloscope, additional protocol selections are available in a pop-up dialog box within the Serial Decode dialog boxes.
SIOP and SSPI are part of the SPIbus TD package.
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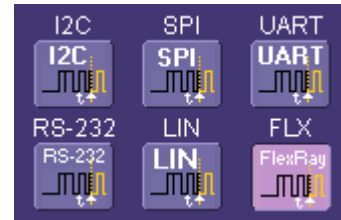
TECHNICAL OVERVIEW OF "D" AND "TD" OPTIONS

Overview

LeCroy's offering of serial trigger and decode options utilize advanced trigger circuitry and advanced software algorithms to provide powerful capability for serial data triggering and decoding.

Serial Trigger

TD options contain advanced serial data triggering. This serial data triggering is implemented directly within the hardware of the oscilloscope acquisition system, and contains advanced algorithms to protocol decode, recognize, and trigger on user-defined serial data patterns. This allows a recognized serial data pattern to be used to trigger the oscilloscope at a pre-determined time, and other signals coincident with the desired serial data pattern can be captured simultaneously.

Serial Decode

Both the D and TD options contain powerful protocol decoding and annotation software algorithms. This algorithm is used in all LeCroy serial decoders sold with oscilloscopes, and differs slightly for serial data signals that have a clock embedded in data or a clock separate from data.

The software algorithm examines the embedded clock (UART, RS-232, LIN, FlexRay) or separate clock line (I^2C, SPI, SSPI, SIOP) for each message based on a default (or user set) vertical level. The algorithm is intelligent in that it applies a hysteresis to the rising and falling edge of the serial data signal to minimize the chance that perturbations or ringing on the edge will affect the decoding. The default level is usually set to 50% and is determined from a measurement of peak amplitude of the signals acquired by the oscilloscope. It can also be set to an (absolute) voltage level, if desired. For serial data signals with embedded clocks (i.e. UART, RS-232, LIN or FlexRay), the algorithm then performs an analysis of the serial data message to determine the nominal bit width. The clock rate/bit width is measured directly from the clock line for other serial data formats (i.e. I^2C, SPI, SSPI, SIOP). Once the clock signal is acquired and the decoding is completed for a serial data message with separate clock and data lines, the oscilloscope channel can be turned OFF to reduce screen clutter.

After determining bit width, a different algorithm performs a decoding of the serial data message into binary format after separation of the underlying data into logical groups (Header/ID, Data Length Codes, Data, CRC, Start Bits, Stop Bits, etc.). Finally, another algorithm provides the appropriate color coding of the message, and displays the protocol message data on the screen, as desired, overlaid on the source trace. Various compaction schemes are utilized to show the data during a long acquisition (many hundreds or thousands of serial data messages) or a short acquisition (one serial data message acquisition). In the case of the longest acquisition, only the most important information is highlighted. In the case of the shortest acquisition, all information is displayed (Header/ID, Data Length Codes, Data, CRC, Start Bits, Stop Bits, etc.) with additional highlighting of the complete message frame.

Note that although the decoding algorithm is based on a clock extraction software algorithm using a vertical level, the results returned are the same as those from a traditional protocol analyzer using sampling point-based decode. In addition, the clock extraction technique allows partial decoding of messages in the event of physical layer noise, in many cases, whereas a protocol analyzer usually cannot. This is a significant advantage for the LeCroy software algorithm.

If the sampling rate (SR) is insufficient to resolve the signal adequately, based on the bit rate (BR) setup or clock frequency, then the protocol decoding will be turned OFF in order to protect the operator from incorrect data. The minimum SR:BR ratio required is 4:1. It is suggested that you use a slightly higher SR:BR ratio if possible, and use significantly higher SR:BR ratios if you want to also view perturbations or other anomalies on your serial data analog signal.

Table Display

The tabular display of serial decoded data is a powerful feature to allow you to see all of your protocol messages, even if the compaction of serial data messages on the oscilloscope grid means that annotation is impractical. The table uses as its source the decoded data, extracted as described above. Therefore, if View Decode is not checked ON, then the table will not display.

ACCESSING THE TD TOOLSETS

Overview

TD trigger and decoding tools are easily accessible in a variety of ways. The TD options add an additional Serial selection to the Trigger Type in the Trigger dialog, and a new set of dialogs for Decode setup. These dialogs are shared by all the low speed serial protocols that LeCroy offers, so all serial trigger and serial decoding selections will be grouped in a common selection with nearly identical selection and setup. These dialogs are conveniently accessed with just one or two touches of the screen.

Trigger

Methods to access the Serial Trigger dialogs are listed below:

1. Touch the Trigger descriptor button. Then select the Serial trigger type in the dialog box.

2. Touch Trigger in the menu bar, and select Trigger Setup. Then select the Serial trigger button and choose the appropriate serial trigger.
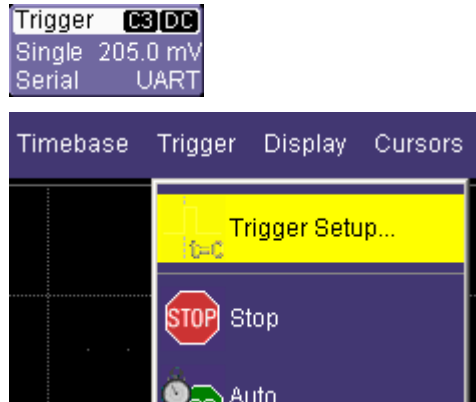
Each serial protocol is quite different. Therefore, each serial trigger is quite different. Details on setting up serial triggers are covered in corresponding sections of this manual.

Serial Decode and Decode Setup

These dialogs provide the ability to set the oscilloscope up for protocol decoding of serial data messages, with display of the protocol data overlaid on the signal. They also allow quick and easy access to oscilloscope zooming, searching, table display, and table export.
The serial decode and decode setup dialogs are accessed in the following ways:

1. Touch Analysis in the menu bar, and select Serial Decode. This will open and display the Serial Decode Summary dialog, and provide access to Decode Setup.

2. Touch the Channel or Memory Descriptor Box to open the respective dialog box, and touch the Decode button in the bottom toolbar.

3. Touch a Channel, Memory, or Math trace to open a pop-up dialog that displays a shortcut to the Decode Setup dialog box
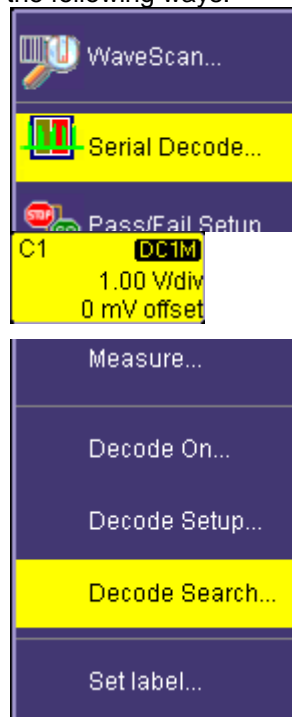
There is a great deal of commonality in decode setup among the various serial data standards. Therefore, the common areas are discussed below. Specifics about triggering and decoding each protocol are discussed in later chapters.

Serial Decode (Summary) Dialog Box

The Serial Decode dialog box is a summary page of which decoders are ON, and how they are set up. In addition, there are shortcuts to Decod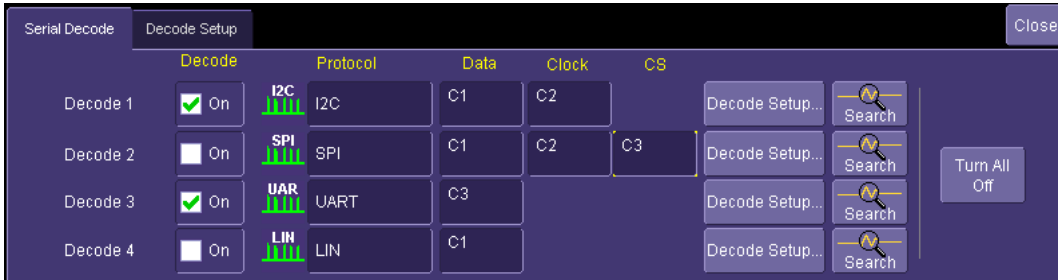e Setup and Search. A sample dialog box is shown below (Note: This dialog box reflects an oscilloscope that has I^{2}C, SPI, UART and LIN options).

There are four independent decoders. A user can operate up to four at a single time, though the limitation may be on the number of channels that can be accommodated at one time. Practically speaking, if a user was decoding signals with a clock and data line (and perhaps also a chip select or other third line), then two simultaneous decodes is the maximum number using the LeCroy oscilloscope analog channels. Addition of the MS-250 or MS-500 Mixed Signal Oscilloscope options allows usage of digital lines for trigger and decoding, which preserves analog channels for other uses. Contact LeCroy for more information about this option.

The detail of the Serial Decode dialog box is described below:

Decoder # - There are four independent decoders, each can be set up a different way for a different protocol.

Decode ON Checkbox – If checked, it means the decoder is turned ON and will decode, if the protocol is correctly setup in the Decode Setup dialog box.

Protocol – This pop-up dialog allows selection of a specific serial protocol. In some cases where the protocol is not completely standardized, or where there are higher-level definitions of the protocol, multiple selections may be provided. For example, SPI has variants with no chip select. Examples are Simplified SPI (SSPI), Simple Synchronous Serial I/O Port (SIOP), and RS-232. Each of these has a selection in this pop-up dialog.

Data and Clock Selection – This pop-up dialog allows you select a channel or other source for decoding. Some protocols may require a third selection (for instance, SPI also requires a Chip or Slave Selection). Asynchronous protocols, such as UART, RS-232, LIN and FlexRay, only require a single source.

Decode Setup Shortcut Button – This provides quick access to the second tab (Decode Setup) where there are quick buttons for Search, and Table (Configure Table and Export Table). If you have already defined the trigger, then the trigger setup settings will copy over into the decode
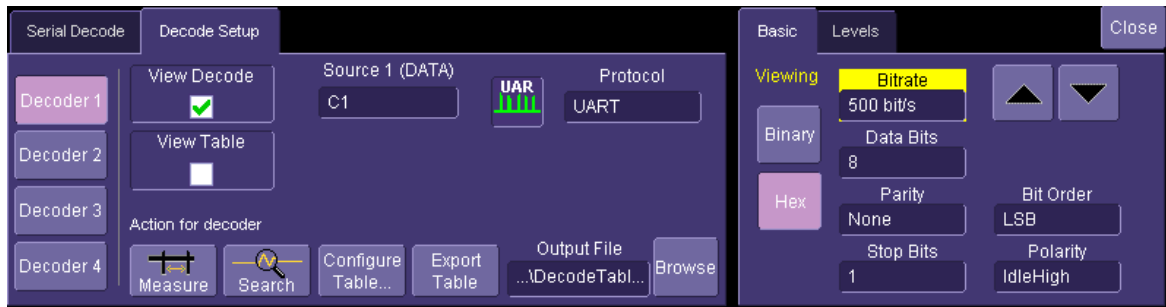
setup.

Search – Push this button to open a Zoom (Zx trace) that has, as its source, the corresponding Channel (Cx trace). In addition, the right hand dialog in the Zoom trace has Search options specific to the serial protocol that the Source is assigned to.

Decode Setup Dialog Box

The Decode Setup dialog box is where the details of a specific protocol decode are entered. It appears as follows (the UART Decode Setup dialog is shown as an example):

This is a single tab with an indicator on the left side that describes which of the four decoders the setup information pertains to. The left hand side of this dialog box is described below (the right hand side is described in the protocol specific chapters):

Decoder # Buttons – This describes which of the four decoders the currently entered information pertains to.

View Decode Checkbox – Touch this box to check or uncheck whether you want decoding turned ON. Decoding ON will provide a highlight of each message frame, with color-coded highlighting and decoding of the various portions of the protocol message. Note that for very long acquisitions with hundreds or thousands of messages, decoding of the entire acquisition will take longer.

View Table Checkbox – Checking this box turns the Table ON. Un-checking it turns the Table OFF.

Note: If the View Decode checkbox is not checked (i.e. decode is not ON), then the View Table checkbox will be grayed out. The Table cannot display unless decode is occurring.

When the Table is displayed, it appears similar to that shown to the right (the example shown is for I^2C)

Source Selection – Touch these selections to open a pop-up dialog box which allows for selection of sources for Clock, Data, and (for some protocols) a third line (e.g. Chip Select for SPI).

Touch inside the Source field areas and choose a source
to use for Clock, Data, and (for some protocols) a third
line (e.g. Chip Select for SPI). The Source selection is
dynamically linked to the Protocol selection, so the
appearance and number of sources to choose will
change depending on your selected Protocol.
This source can be either a Channel (C1 – C4), a
Memory Trace (M1 – M4), or a Math Function (F1 – F4).
A Channel would be used for a new, real-time
acquisition.
A Memory would be used if you had saved data from a
previous acquisition and were recalling it to do further
analysis. Reference the oscilloscope's on-line Help for
information about how to Store and Recall Waveforms.
A Math Function would be used to view decoded data on
Sequence mode acquisitions. Sequence Mode is a
unique capability whereby you can utilize oscilloscope
memory to capture events widely spaced in time, and
view them sequentially. Reference the chapter on
Isolating and Analyzing Serial Bus Activity for more
information on setting the oscilloscope up in this mode.
Protocol Selection – Touch this selection to open a
pop-up dialog box which allows for selection of protocol
decoders. Depending on the decoder selected, the
correct inputs (i.e. Clock, Data, and a third line, if
required) will be shown to the left.
Action for Decoder Toolbar – Various buttons on this
toolbar provide context sensitive shortcuts for decoding.

- **Search** allows quick creation of a zoom trace
  and changes the dialog box to the zoom/search
  dialog box. Acquire long records of message
  data, and use Search to look through the record
  for a particular message. Upon finding a
  message that meets the search criteria, the
  complete message will be displayed with the
  Zoom Trace. Touch the arrow buttons to
  advance to the next message, or revert to the
  previous message. Unsuccessful searches will
  be noted in a text line.

- **Configure Table** displays a pop-up dialog box
  specific to a particular protocol. The pop-up
  dialog contains checkboxes for various columns
  in the table. Check or uncheck the checkboxes to
  display or not display that particular column in
  the table.

- **Export Table** exports the complete protocol
  table data to a user-defined file. The output file
  name and directory can be selected by the user
 using the controls to the right.
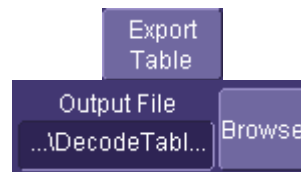
Protocol Results Table

The protocol results table provides a quick and easy way to understand all of your protocol data as decoded by the oscilloscope, even when messages are too compacted to allow annotation on the display. In addition, the table provides a quick and easy method to look at decode results, and quickly zoom to a specific message. When displayed, the protocol results table will appear under the waveform grid. It looks like the following (this example is for I^2C – each protocol table will look different):

Idx	Time	Addr Length	Address	R/W	Length	Data
8	240.494 ms	7	0x21	1	2	0xff 00 00
9	360.555 ms	7	0x21	0	1	0x08
10	360.698 ms	7	0x21	1	2	0x49 00 00
11	481.865 ms	7	0x21	0	1	0x0a
12	482.007 ms	7	0x21	1	2	0x00 00 00
13	606.294 ms	7	0x20	0	3	0x01 36 00
14	721.235 ms	7	0x20	0	1	0x00
15	721.377 ms	7	0x20	1	2	0x12 36 00
16	841.266 ms	7	0x20	0	1	0x02

The slider bar on the right can be used to navigate through the protocol table. If the slider bar is yellow, then you can use the Adjust knob on the oscilloscope front panel to move the slider bar.
If you touch a row, a decoded zoom trace will be created that will display that message trace in a zoom.
The table will only display if the View Table checkbox is checked and decoded has occurred on the trace. Only one protocol table can be viewed at a time. As described in the preceding section, the protocol table can be configured or exported. If you press the "Configure Table" button in the Decode Setup dialog box, a pop-up dialog similar to the one below will appear:
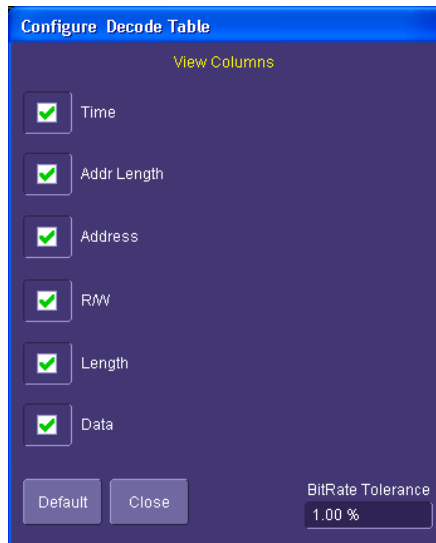
Default – Press the Default button to return to the default state of the table for that particular protocol.

Checkboxes – If you wish the item to be present as a column in the table for that particular protocol, touch the item to check the box.

BitRate Tolerance – Some protocols have a Bit Rate Tolerance setting. This can be set to any value from 0.01% to 10%. If the bit rate is outside the tolerance range set, then the calculated bit rate will appear as red text in the table
Protocols with wide variance of bit rates, such as I^2C, which often has clock stretching, do not have this feature.
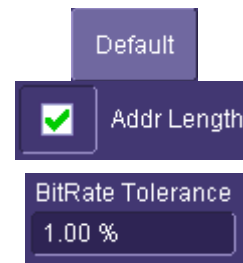
Searching for Messages

There are several ways to search for specific messages.

1. Touch the decoded waveform to open a pop-up dialog

2. Touch the Search button in the Serial Decode Summary dialog box or the Decode Setup dialog box

3. From the File Menu, go to Math, and choose Zoom Setup to turn a Zoom ON, define it's source, and search directly.
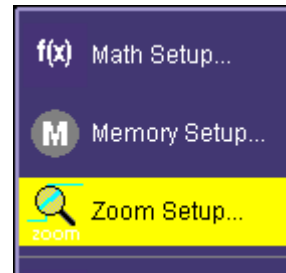
Any of these will take you to a Zoom dialog box with a right hand dialog box with Search
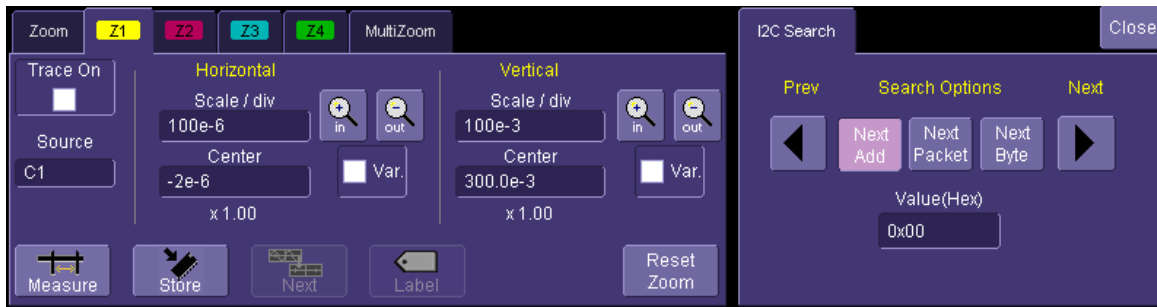
The Search capability will differ by protocol. For instance, SPI has no Address, so there is no capability to Search by Address in SPI as there is in I²C.

Use the Search Options buttons to define the type of Search you want, enter a value in Hexadecimal format, and use the left and right arrows to move your way from one message to the next.

USING THE I2CBUS OPTIONS

Overview

Both I2Cbus TD and D options contain powerful software algorithms to extract serial data information from physical layer waveforms measured on your oscilloscope. The extracted information is overlaid (annotated) on the actual physical layer waveforms, and color-coded to provide fast, intuitive understanding.

The I2Cbus TD option contains a very powerful and flexible trigger, but it is also very easy to set up for basic triggering. The I2Cbus TD option contains a conditional I^2C DATA trigger to select a range of DATA values to trigger on, not just a single DATA value. Oftentimes, I^2C utilizes DATA bytes to specify sub-addresses for accessing memory locations in EEPROMs. Conditional DATA trigger allows triggering on a range of DATA bytes that correspond to reads or writes to specific sub-address memory blocks in the EEPROM. It can also aid in monitoring DATA outputs from I^2C- based sensors, such as analog-to-digital converters, and triggering when DATA is outside a safe operating range. In both cases, verifying proper operation becomes a simple task. Other powerful and user-friendly features included in I2Cbus TD trigger include:

- Ability to define and ADDR or DATA condition in either binary or hexadecimal formats.

- Ability to define an ADDR condition in binary with the DATA condition defined in hexadecimal so as to trigger on a range of ADDR values using Don't Care bits.

- FRAME LENGTH trigger setups

- EEPROM trigger setups to trigger on up to 96 bits (12 bytes) of DATA at any location within an I^2C frame or at a user-defined location in a 2048 byte window.

- All permutations of Read, Write, or R/W Don't Care conditional setup for 7 and 10-bit addresses.

- For any I^2C message trigger, select whether an ACK condition should be ACK, NO ACK, or DON'T CARE. You can choose to trigger on a NO ACK condition by itself, or as part of a more complex ADDR/DATA trigger.

If you are not familiar with or are just learning about I^2C, begin by using the simplest trigger conditions (Start, Stop, ReStart, NoAck) to gain confidence, then set up simple ADDR only conditions. When you are confident that you understand I^2C operation, set up an ADDR+DATA condition with a condition of "DATA =". Then, try different setups using other DATA conditions (>, <, INRANGE, etc.). Lastly, experiment with the EEPROM trigger setup, which provides the most flexibility by allowing location of data, with conditions, within specific bytes of a long sequence of DATA bytes.

### Accessing Serial Triggers

The I^2C and SPI serial triggers are accessed from the oscilloscope trigger dialog. This dialog can be accessed in the following ways:

1. Touch the Trigger Descriptor Box in the lower right hand corner of the oscilloscope display. Or, touch Trigger, then Trigger Setup in the File Menu Bar at the top of the oscilloscope display.

2. Touch Serial in the Type selection.
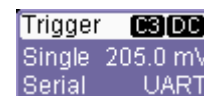
3. Select the appropriate serial trigger. Then, the menu will automatically change to a different tab in the Trigger dialogs. The tab will be named after the serial trigger that you have selected.
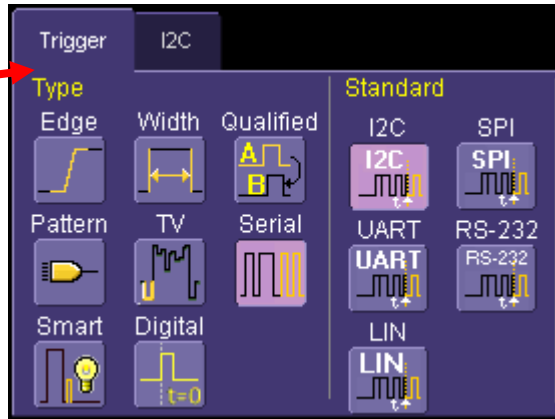
Creating an I²C Trigger Condition

The I²C Trigger dialog, with detail on some of the setup conditions, is shown in the images that follow:
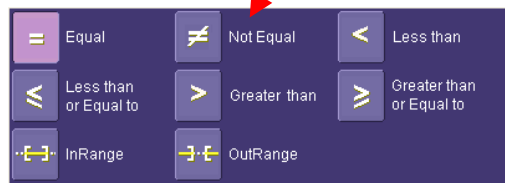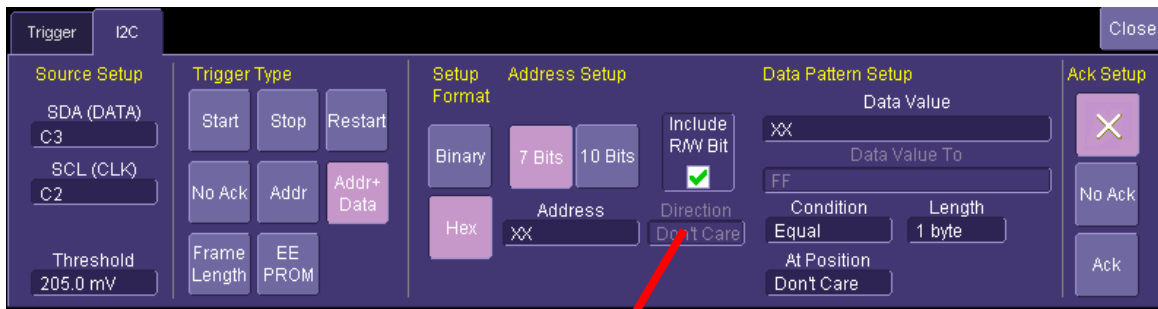
Selection of Trigger Type results in dynamic changes to the I²C Trigger dialog. Simple I²C triggers, such as Start, Stop, ReStart, and NoAck, require no additional setup, while frame-based triggers, such as ADDR, ADDR+DATA, FRAME LENGTH, and EEPROM require addition user-defined setup information.

To select a value for any of the conditions, touch the existing value (using your finger, or use a mouse pointer) to open the pop-up dialog box with a list of choices, and select one of the choices.

I²C Trigger Setup Detail

Setup Mode

Select either Binary (BIN) or Hexadecimal (Hex) setup mode. The mode selected will propagate through the entire I²C trigger setup,
A user can select BIN mode, and set up the address in binary format, then reselect HEX mode and set up the data in hexadecimal format. Toggling back and forth between the modes will not result in loss of information (binary is used internally as the core format for all triggering and decoding operations), though use of don't care bits in a binary setup will result in the display of an X (for a full nibble don't care) or a $ (for a partial nibble don't care).

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Sources Setup

DATA and CLOCK – The pop-up dialog is used to select the appropriate channel or EXT input for each. Make sure that you have these selected correctly or your trigger will not function.

Trig(ger) Threshold – Adjust the vertical level for the trigger. Much like an Edge trigger, a user must specify the level used in order to process the incoming signals and determine whether the desired serial data pattern is meeting the set trigger condition. This value is used for both DATA and CLOCK signals.

Trigger Type Selection

The I^{2}C trigger can be configured to trigger on simple conditions (i.e. the presence of a START, STOP, RESTART bit, or the absence of an ACK bit (NO ACK). In addition, more complex trigger conditions can be created using ADDR, ADDR+DATA, FRAME LENGTH, or EEPROM setups.
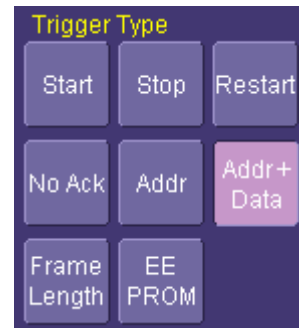
If one of the more complex trigger conditions is selected, then reference the sections below for information on Address and Data Pattern Setup.

Address Setup

These setup selections are shown if you select ADDR, ADDR+DATA, FRAME LENGTH, OR EEPROM Trigger Selections.

Address Length – I^{2}C utilizes either 7 or 10-bit formats for the address, depending on the device. Make the appropriate selection so as to be able to enter the correct address value.

If 7-bit address length is selected, another selection will appear for whether the Read/Write bit should be included as part of the address value entered. For instance, some engineers think of the address pattern as including the R/W bit (i.e. 8-bits) and others think of the address pattern as not including the R/W bit (i.e. 7-bits). "Check" the checkbox if you want to include the R/W bit in your entered Address value. If this is done, then the Direction value will auto select either Read or Write (as appropriate) and gray out as not-selectable by the user.
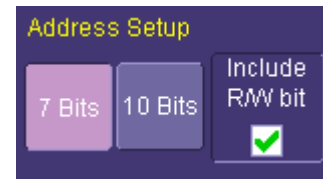
Note: There is an identical checkbox selection in the I^{2}C decode setup dialog. These two setups are dynamically linked, so selecting it one way in trigger will result in an identical selection in decode. This ensures that the trigger address format matches decoded information on the display.

Address Value Setup – Enter the Address Value in binary or hex (depending on what was selected in the Setup Mode). The pattern condition for the Address is always "equal".

Binary addresses allow use of don't care conditions in any bit position (entered as X). Hexadecimal addresses allow use of don't care conditions in any nibble position) also entered as an X. If an address is set up in Binary, then converted to Hex with a Setup Mode change, then any non-nibble length don't care values will be shown as $.

Note: Address values are always MSB format. Therefore, conversion of address values from binary to hex when don't care values are used will be on that basis.

Direction – Enter a Direction (either Read, Write, or Don't Care) for the Address value. If you have selected to use 7-bit addresses with the R/W bit included in the address value, then this selection will be grayed out and not selectable.
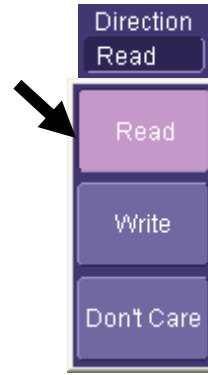
Data Setup

These setup selections are displayed if the Trigger Selection is ADDR+DATA or EEPROM.

Data Pattern Value – The pattern value is entered in either Binary or Hexadecimal mode depending on the previous selection of Setup Mode. There are two selections for pattern value – "Data Value" and "Data Value To". The second selection is exposed for entry if the Condition is set to INRANGE or OUT(of)RANGE. Otherwise, it is grayed out. Up to 12 bytes of data can be entered as a pattern value.

If less than 12 bytes of data is entered for the pattern value, the data is assumed to begin at the 0 (i.e. first) data byte in the I^2C message. If this is not desired, then add preceding or trailing don't care (X) nibbles to the pattern value.

PLEASE NOTE THE FOLLOWING:
When more than one byte of data is entered as a data pattern value, the data is treated as "Most Significant Byte (MSB) First." This is especially important to remember when setting up <=, <, >, >=, INRANGE and OUTRANGE comparisons. In Hexadecimal format, data must be entered as full bytes even though the minimum required acceptable entry is a nibble. If less than a full byte is entered, then a don't care X will precede the pattern values entered.

Condition – The DATA condition can be set many different ways. Possible conditions are <=, <, =, >, >=, not =, in a range, out of a range, or don't care.

Oftentimes, I^2C utilizes DATA bytes to specify sub-addresses for accessing memory locations in EEPROMs. Conditional DATA trigger allows triggering on a range of DATA bytes that correspond to reads or writes to specific sub-address memory blocks in the EEPROM. It can also aid in monitoring DATA outputs from I^2C-based sensors, such as analog-to-digital converters, and triggering when DATA is outside a safe operating range. In both cases, verifying proper operation becomes a simple task.

Length – The pattern length value defaults to the length, in bytes, of the pattern set in the Pattern Value selection. If you were to change the length to be less than this value, it would truncate the beginning of the pattern value. If you were to increase the pattern length, it would add don't care XX byte values to the beginning of the pattern value.
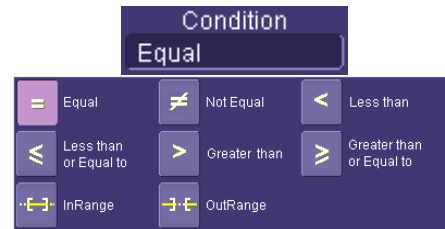
At Position, Position – These selections are present only when the Trigger Selection is EEPROM or ADDR+DATA At Position can be either VALUE or DON'T CARE. When At Position = VALUE, you must also enter a data byte number for Position (0 = the first data byte). For EEPROM triggering, use this to specify a specific location of data, such as a sub-address memory block, that the Pattern Value must occupy in order for triggering to occur. For ADDR+DATA triggering, use this to specify a specific location where the data values should be located without using don't care (X) values in the pattern value. In both cases, you can select a Position in up to a 2048 byte data pattern, starting with Byte 0.

Note: The first byte is counted as Byte 0, not Byte 1.

Frame Length Setup

This setup selection is displayed if the Trigger Selection is FRAME LENGTH. It is used to trigger on a specific Address value with a defined length of data bytes.

Bytes Length – Specify a data length value between 0 and 2047. 1 is the default value.

If the Data Length Condition (see below) is selected to be either INRANGE or OUT(of)RANGE, then this selection will be for the minimum data length value (i.e. the lower value of the range you wish to include or exclude).
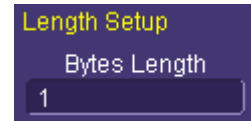
Note: All values entered in this field are always in decimal format.

Bytes Length Max – If the Data Length Condition (see below) is selected to be either INRANGE or OUT(of)RANGE, then you will also need to specify a maximum data length value (i.e. the upper value of the range you wish to include or exclude)

Length Condition – The Data Length Condition can be set to many different values, such as <=, <, =, >, >=, not =, INRANGE, or OUT(of)RANGE. Select the correct condition for your needs.
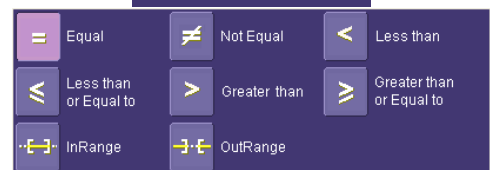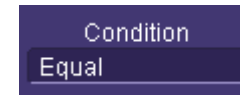
Ack Setup

Use this setup to choose whether you want to add an Acknowledge bit condition to your ADDR, ADDR+DATA, FRAME LENGTH, or EEPROM trigger condition. X (Don't Care) would be the most common setup, although ACK or NO ACK might be a useful condition to add for an unusual or hard to find I^2C problem. An example of this would be triggering on an EEPROM write (selected by an ADDR trigger) where the EEPROM failed to acknowledge a byte written.

I²C Decode Setup Detail

The I²C Decode Setup Right-Hand Dialogs (which are contained in the Decode Setup dialog box when I²C is selected as the Protocol to decode), with detail on the setup conditions, is shown in the images that follow:
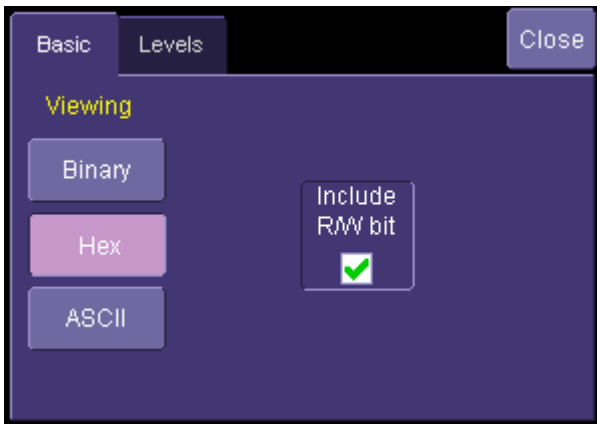
Viewing – Select to view the protocol data in either Binary, Hexadecimal, or ASCII modes.

Note: If the trigger is set up first, then the trigger settings will copy into the decode settings.

Include R/W Bit – Some engineers think of the 7-bit address pattern as including the R/W bit (i.e. 8-bits) and others think of the address pattern as not including the R/W bit (i.e. 7-bits). If you decoded I²C messages include 7-bit addresses, "check" the checkbox if you want to include the R/W bit in the decoded Address value.

Note: There is an identical checkbox selection in the I²C trigger setup dialog. These two setups are dynamically linked, so selecting it one way in decode will result in an identical selection in trigger. This ensures that the decode address format matches trigger setup information.

Level Type and **Level** - The message decoding algorithm setup is performed here. The level is normally set up in %, and defaults to 50%. To adjust the level, touch inside the number area to highlight the box title in yellow, and then use the oscilloscope front panel Adjust knob to adjust. Or touch inside the number area twice and select a value using the pop-up numeric keypad.
The set Level appears as a dotted horizontal line across the oscilloscope grid.
If initial decoding indicates that there are a number of error frames, make sure that the level is set to a reasonable value.

Note: DATA and CLOCK can have different level settings, but they are typically the same level.
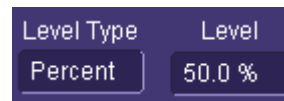
USING THE SPIBUS OPTIONS

Overview

Both SPIbus TD and D options contain powerful software algorithms to extract serial data information from physical layer waveforms measured on your oscilloscope. The extracted information is overlaid (annotated) on the actual physical layer waveforms, and color-coded to provide fast, intuitive understanding.

The SPIbus TD option contains a data trigger that can be configured for the many variants of SPI, such as SSPI (single master and slave with predetermined format settings) and SIOP. The basic SPI Type is all-inclusive and the SSPI and SIOP types are just pre-selected settings in the basic SPI trigger.

The SPI trigger does not require use of a Chip Select line. In it's place is the ability to set a minimum Interframe Time that corresponds to a time that, in AUTO mode is (typically) 4x a single bit time and less than the interframe time between different message packets. By eliminating the requirement to have a Chip Select line present, an additional oscilloscope channel is preserved for use with other analog signals – a significant feature. In addition, it also allows a user to trigger on simplified SPI (SSPI, SIOP, etc.) protocols with a single Master and Slave and no Chip Select line.

Accessing Serial Triggers

The SPI serial trigger is accessed from the oscilloscope trigger dialog. This dialog can be accessed in the following ways:

1. Touch the Trigger Descriptor Box in the lower right hand corner of the oscilloscope display. Or, touch Trigger, then Trigger Setup in the File Menu Bar at the top of the oscilloscope display.

2. Touch Serial in the Type selection.

3. Select the appropriate serial trigger. Then, the menu will automatically change to a different tab in the Trigger dialogs. The tab will be named after the serial trigger that you have selected.
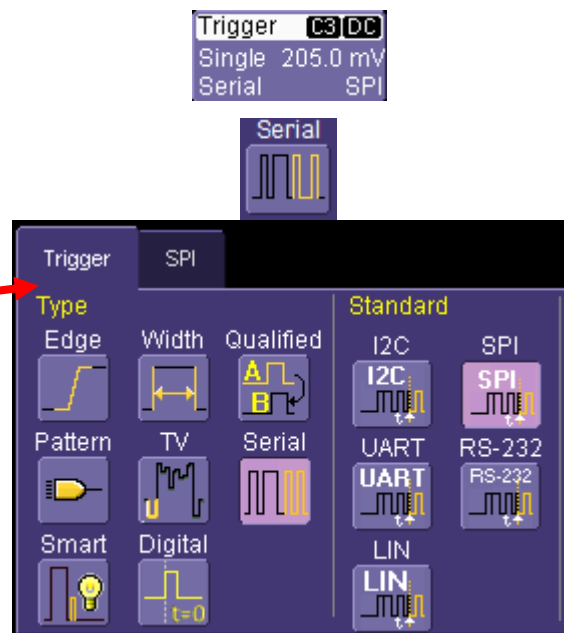
Creating a SPI Trigger Condition

The SPI Trigger dialog, with detail on some of the setup conditions, is shown in the images that follow:
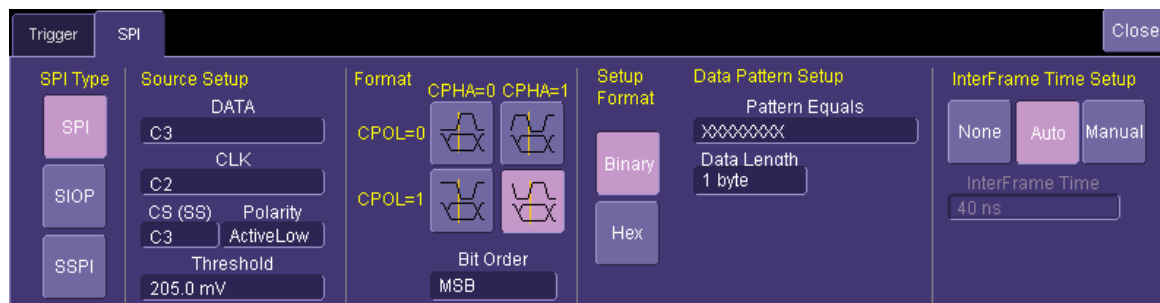
The SPI trigger dialog is very "flat" – there are few dynamic changes to the dialog based on selections within it. The one exception is the SPI Type on the far left. When selecting between SPI, SIOP, and SSPI types, the dialog to the right will change to reflect that setup type.

To select a value for any of the conditions, touch the existing value (using your finger, or use a mouse pointer) to open the pop-up dialog box with a list of choices, and select one of the choices.

SPI Trigger Setup Detail

SPI Type Selection

Unlike some other serial data standards (such as I^2C), SPI is not defined by a single standard. Rather, there are several implementations of SPI based on fixed clock polarities, phase, and whether Chip Select is present or absent. The basic SPI Type is all-inclusive and the SSPI (Simplified SPI) and SIOP (Synchronous Serial I/O Port) types are just pre-selected settings in the basic SPI trigger, provided for operator convenience. SSPI and SIOP do not use a Chip Select line, but are simply single Master and single Slave implementations of SPI.

Sources Setup

DATA and CLOCK – The pop-up dialog is used to select the appropriate channel or EXT input for each. Make sure that you have these selected correctly or your trigger will not function.
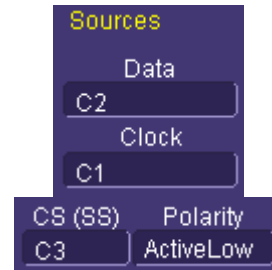
Chip Select, Polarity – Depending on SPI Type selected, this area will either be grayed out (SSPI, SIOP) or ungrayed (SPI).
If ungrayed, select a Channel or EXT, as appropriate, and make a selection for Polarity.

(Trigger) Threshold – Adjust the vertical level for the trigger. Much like an Edge trigger, a user must specify the level used in order to process the incoming signals and determine whether the desired serial data pattern is meeting the set trigger condition. This value is used for all DATA, CLOCK, and Chip Select signals.

SPI Format Setup

Clock Polarity and Phase - SPI requires that selections be made for the clock polarity and "phasing" of the data to the clock. SPI microcontrollers and peripherals have settings for CPOL (Clock Polarity) and CPHA (Clock Phase) that are published in the technical datasheets for those products. These values need to be entered in this section. Or, a visual representation may help you understand the selection.

Note: SPI Mode 0 = CPOL 0 and CPHA 0. SPI Mode 1 = CPOL 0 and CPHA 1. SPI Mode 2 = CPOL 1 and CPHA 0. SPI Mode 3 = CPOL 1 and CPHA 1.

Bit Order – Select either MSB or LSB format, as appropriate.

Note: Decoding for SPI has identical selections for Clock Polarity, Clock Phase, and Data. Since you could have more than one SPI decoder running simultaneously, the setups in trigger are not linked to decode, and vice versa. Make sure they are set correctly in each section to avoid malfunction or confusion.
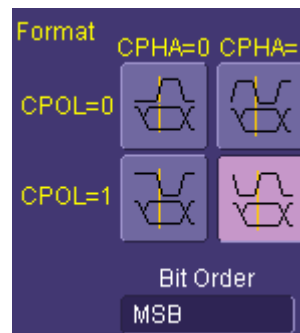
Data Format and Pattern Setup

Select either Binary (Binary) or Hexadecimal (Hex) setup format. The format selected will propagate through the entire SPI trigger setup,
Toggling back and forth between the modes will not result in loss of information (binary is used internally as the core format for all triggering and decoding operations), though use of don't care bits in a binary setup will result in the display of an X (for a full nibble don't care) or a $ (for a partial nibble don't care).

Data Pattern Setup – The pattern value is entered in either Binary or Hexadecimal mode depending on the previous selection of Setup Mode. Up to 8 bytes of data can be entered as a pattern value.
If less than 8 bytes of data is entered for the pattern value, the data is assumed to begin at the 0 (i.e. first) data byte in the SPI message. If this is not desired, then add preceding or trailing don't care (X) nibbles to the pattern value.
In order to trigger on Data in the right location, be sure to enter the appropriate values for Interframe Time Setup (see below).

Note: In Hexadecimal format, data must be entered as full bytes even though the minimum required acceptable entry is a nibble. If less than a full byte is entered, then a don't care X will precede the pattern values entered.

Interframe Time Setup – LeCroy's SPI trigger does not require a Chip Select to operate correctly. This is a great advantage as there are many simplified forms of SPI that have a single Master/Slave and no Chip Select line. By eliminating the need for a Chip Select, the utility of the SPI trigger is greatly increased.
The Interframe Time Setup allows the user to enable a powerful function that analyzes captured SPI signals in real-time to determine which bytes to group into logical sets of messages. It does this by analyzing the actual time between SPI bits, comparing that to an expected Minimum SPI Message Packet interframe time) entered by a user, and applying algorithms to compute which bytes are part of which messages. Then, with the SPI message structures determined, triggering on data in specific message locations is possible.
This functionality is enabled automatically in AUTO mode. If you wish to have greater control over the interframe time, select MANUAL model and enter an appropriate value. (i.e. the amount of time between SPI message packets, not the amount of time between bytes.) Typically, a value of 4x the bit duration is appropriate.
If you don't want to use this feature, then choose "None" for Interframe Setup Mode. However, if you choose None, then triggering may occur on bits that satisfy the binary pattern, but do not occur in a single byte.

Note: The limitations when sent to None also apply in Hex pattern setup since Hexadecimal values entered are converted to Binary values by the trigger circuitry.
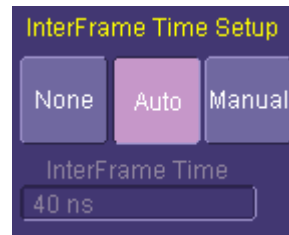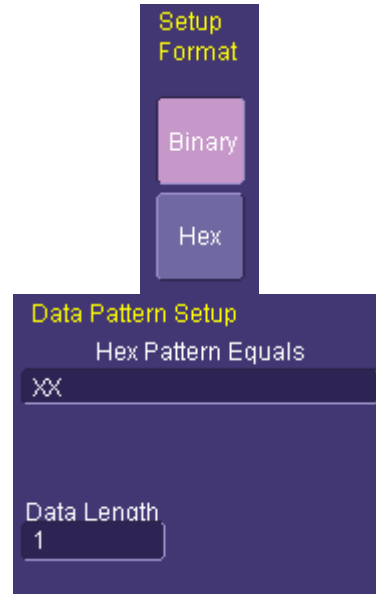
SPI Decode Setup Detail

The SPI Decode Setup Right-Hand Dialogs (which are contained in the Decode Setup dialog box when SPI is selected as the Protocol to decode), with detail on the setup conditions, is shown in the images that follow:
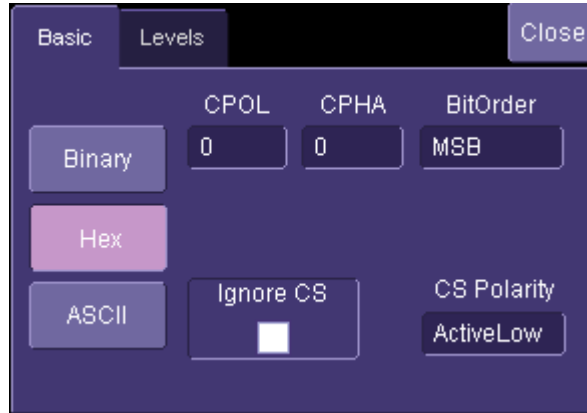
A similar dialog is shown when SSPI or SIOP are selected; however, these protocols do not use a Chip Select, so the Chip Select selections are omitted.

Viewing – Select to view the protocol in either Binary, Hexadecimal, or ASCII formats.
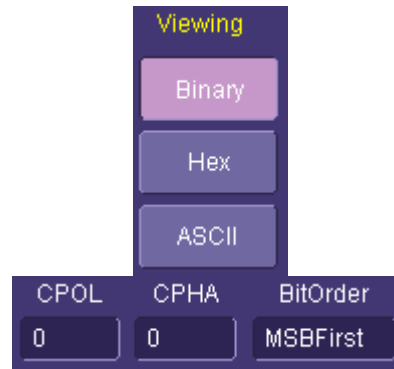
Clock Polarity and Phase - SPI requires that selections be made for the clock polarity and "phasing" of the data to the clock. SPI microcontrollers and peripherals have settings for CPOL (Clock Polarity) and CPHA (Clock Phase) that are published in the technical datasheets for those products. These values need to be entered in this section.

Bit Order – Select either MSB or LSB format, as appropriate.

PLEASE NOTE THE FOLLOWING:

SPI Mode 0 = CPOL 0 and CPHA 0. SPI Mode 1 = CPOL 0 and CPHA 1. SPI Mode 2 = CPOL 1 and CPHA 0. SPI Mode 3 = CPOL 1 and CPHA 1.

Trigger for SPI has identical selections Note: Trigger for SPI has identical selections for Clock Polarity, Clock Phase, and Data. If you have a single SPI decoder set up, these settings copy over from the trigger setup, and vice versa. If you have multiple SPI decoders setup, these settings copy over to the lowest numbered SPI Decoder from the trigger setup, and vice versa.

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Ignore CS (Chip Select) and **CS Polarity –** Set the Chip Select Polarity to either Active Low or Active High. In addition, check the box for "Ignore CS" if you want to decode all SPI bytes instead of those active during the Chip Select.

Level Type and **Level** - The message decoding algorithm setup is performed here. The level is normally set up in %, and defaults to 50%. To adjust the level, touch inside the number area to highlight the box title in yellow, then use the oscilloscope front panel Adjust knob to adjust. Or touch inside the number area twice and select a value using the pop-up numeric keypad.

The set Level appears as a dotted horizontal line across the oscilloscope grid.

If your initial decoding indicates that there are a number of error frames, make sure that the level is set to a reasonable value.
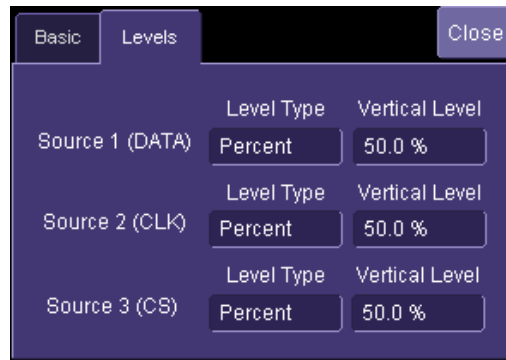
USING THE UART-RS232BUS OPTIONS

Overview

Both UART-RS232bus TD and D options contain powerful software algorithms to extract serial data information from physical layer waveforms measured on your oscilloscope. The extracted information is overlaid (annotated) on the actual physical layer waveforms, and color-coded to provide fast, intuitive understanding.

The UART-RS232bus TD option allows triggering on both DATA conditions and Parity ERRORS. DATA triggering can be set conditionally to select a range of DATA values to trigger on, not just a single DATA value. Other powerful and user-friendly features included in UART-RS232bus TD trigger include:

- Ability to define the UART byte with 9-bit DATA, with the 9th DATA bit functioning as an "alert" bit with a value settable to 0, 1, or X.

- Ability to define as few as 5 bits of DATA in the UART byte.

- Polarity settable to either IdleLow or IdleHigh.

- Decoding in Binary, Hexadecimal, or ASCII formats.

- Triggering on up to 12 bytes of DATA in a data string up to 2048 bytes long.

- Ability to define the "frame" the UART byte messages into a single long message packet for purposes of triggering.

- Shortcut setup for RS-232 triggering and decoding.

If you are not familiar with or are just learning about UART or RS-232, begin by using the simplest trigger conditions (single data byte, any position). Then, experiment with the Interframe Time Setup to "frame" the UART messages into message packets, and trigger on a specific byte value at a known location. Lastly, try triggering on multiple bytes conditionally (INRANGE, or GREATER THAN) in a known location.

Accessing Serial Triggers

The UART and RS-232 serial triggers are accessed from the oscilloscope trigger dialog. This dialog can be accessed in the following ways:

1. Touch the Trigger Descriptor Box in the lower right hand corner of the oscilloscope display. Or, touch Trigger, then Trigger Setup in the File Menu Bar at the top of the oscilloscope display.

2. Touch Serial in the Type selection.
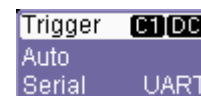
3. Select the appropriate serial trigger. Then, the menu will automatically change to a different tab in the Trigger dialogs. The tab will be named after the serial trigger that you have selected.

Creating a UART or RS-232 Trigger Condition

The UART Trigger dialog, with detail on some of the setup conditions, is shown in the images that follow (The RS-232 Trigger dialog is nearly the same, but contains less flexibility; therefore, only the UART Trigger dialog will be described):
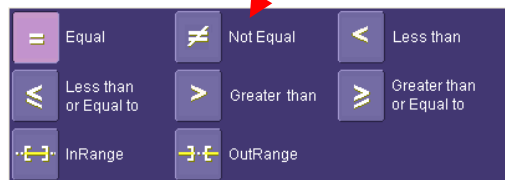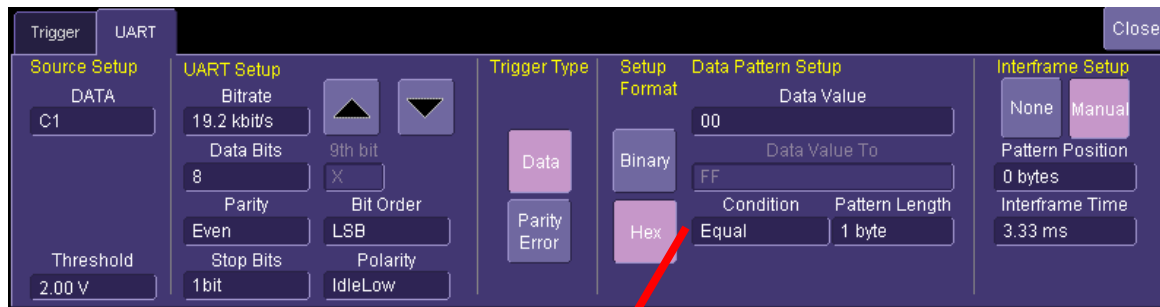
The Source and UART Setup information must be defined. The datasheet for your part should contain the information you need to properly setup the UART Trigger.

Selection of Trigger Type results in dynamic changes to the UART Trigger dialog. Simple Parity ERROR triggering requires no additional setup, while DATA triggers require definition of the Data Pattern, selection of Condition, etc. In addition, if the exact Position of DATA is required, then the Interframe Time must be defined.

To select a value for any of the conditions, touch the existing value (using your finger, or use a mouse pointer) to open the pop-up dialog box with a list of choices, and select one of the choices.

UART and RS-232 Trigger Setup Detail

Source Setup

DATA – The pop-up dialog is used to select the appropriate channel or EXT input. Make sure that you have these selected correctly or your trigger will not function.
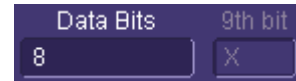
Trig(ger) Threshold – Adjust the vertical level for the trigger. Much like an Edge trigger, a user must specify the level used in order to process the incoming signals and determine whether the desired serial data pattern is meeting the set trigger condition.

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UART or RS-232 Setup

BitRate – Adjust the bit rate value here to match the bit rate on the bus you are connected to. This bit rate selection is dynamically linked to the decoding bit rate (they are always the same value). Use the arrows to move through standard bit rates (300 b/s, 1.2, 2.4, 4.8, 9.6, 19.2, 28.8, 38.4, 57.6, 76.8, 115.2, 230.4, 460.8, 921.6, kb/s, 1.3824 1.8432, 2.7648 Mb/s) and make a selection. Or, touch the number twice (with a finger, or using a mouse) and open a pop-up keypad and enter the value directly.
Data Bits – Select the number of data bits per byte (not including the START, STOP, or PARITY bits). If you wish to trigger on UART with a 9th DATA bit used as an "Alert" bit, simply select Data Bits = 9, then define the 9th Alert bit as a 0, 1, or X (don't care) as required.
Parity – Choose from Odd, Even, or None in the Parity selection box. If Parity is selected as NONE, then the Parity Error Trigger Type will be unselectable.
**Stop Bits** – Choose 1, 1.5, or 2 Stop Bits in this selection box.

Bit Order – Choose either Most Significant Bit (MSB) or Least Significant Bit (LSB) bit order in this selection box. For RS-232 trigger, this is defaulted to LSB and cannot be changed.
Polarity – Choose Polarity of the UART signal as either IdleLow (i.e. Data 1 = High) or IdleHigh (i.e. Data 1 = Low). For RS-232 trigger, this is defaulted to IdleLow and cannot be changed.

Trigger Type Selection

The UART or RS-232 trigger can be configured to either trigger on DATA Patterns or Parity ERRORS. If Parity is selected as NONE in the UART/RS-232 Setup, then Parity ERROR triggering is not possible.
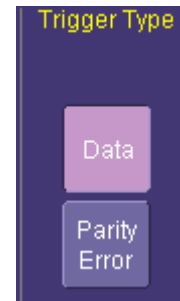
Setup Format

Select either Binary or Hexadecimal setup format. The format selected will propagate through the entire UART or RS-232 trigger setup, Toggling back and forth between the formats will not result in loss of information (binary is used internally as the core format for all triggering and decoding operations), though use of don't care bits in a binary setup will result in the display of an X (for a full nibble don't care) or a $ (for a partial nibble don't care).

Data Pattern Setup

These setup selections are displayed if the Trigger Type Selection is DATA.
Data Pattern Value – The pattern value is entered in either Binary or Hexadecimal mode depending on the previous selection of Setup Mode. There are two selections for pattern value – "Data Value" and "Data Value To". The second selection is exposed for entry if the Condition is set to INRANGE or OUT(of)RANGE. Otherwise, it is grayed out. Up to 12 bytes of data can be entered as a pattern value.
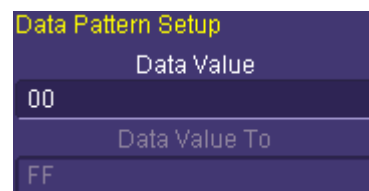
If less than 12 bytes of data is entered for the pattern value, the data is assumed to begin at the 0 (i.e. first) data byte in the I^{2}C message. If this is not desired, then add preceding or trailing don't care (X) nibbles to the pattern value.

When using conditional DATA triggering (<=, <, >, >=, INRANGE and OUTRANGE), be sure to take into account the Bit Order (LSB or MSB).

Note: In Hexadecimal format, data must be entered as full bytes even though the minimum required acceptable entry is a nibble. If less than a full byte is entered, then a don't care X will precede the pattern values entered.

Condition – The DATA condition can be set many different ways. Possible conditions are <=, <, =, >, >=, not =, in a range, out of a range, or don't care.

Pattern Length – The pattern length value defaults to the length, in bytes, of the pattern set in the Pattern Value selection. If you were to change the length to be less than this value, it would truncate the beginning of the pattern value. If you were to increase the pattern length, it would add don't care XX byte values to the beginning of the pattern value.

Interframe Time Setup – LeCroy's UART and RS-232 triggers allow the ability to trigger on data in specific byte locations in long strings of UART bytes. This is especially helpful since UART is often used as a "backbone" for proprietary standards, or for other industry standards. However, in order for the UART and RS-232 trigger to know where the byte location is, it must know something about the spacing between "frames" of UART bytes. The Interframe (Time) Setup allows the trigger to understand which bytes to group into logical sets of UART "frames". When an Interframe time is specified, the trigger considers that elapsed amount of time to signal the beginning of a new UART message "frame" and it resets the trigger condition. Thus, with the UART frame structures determined, triggering on data in specific message locations is possible.

This functionality is enabled in MANUAL mode. Simply enter the minimum Interframe Time that you expect for your UART message frames.

Since the Position of the data in a frame can only be set if the Interframe Time is also entered, the Position value is located in this area. Set this to be any from byte position 0 to 2047.
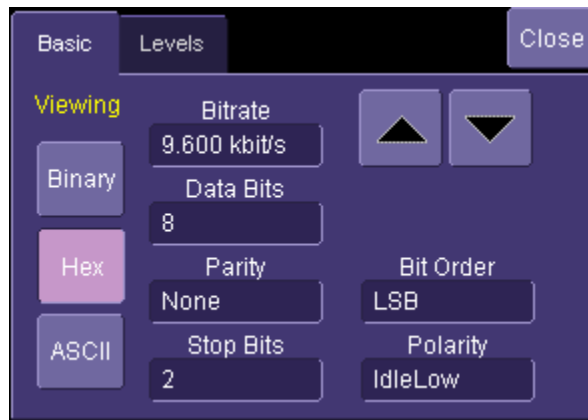
If you don't want to use this feature, then choose "None" for Interframe Setup Mode. However, if you choose None, then triggering may occur on bits that satisfy the binary pattern, but do not occur in a single byte.

Note: The limitations when sent to None also apply in Hex pattern setup since Hexadecimal values entered are converted to Binary values by the trigger circuitry.
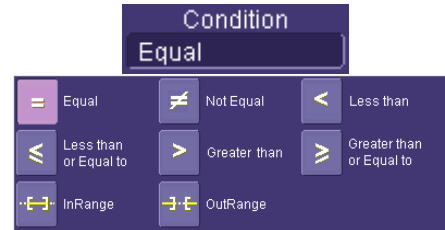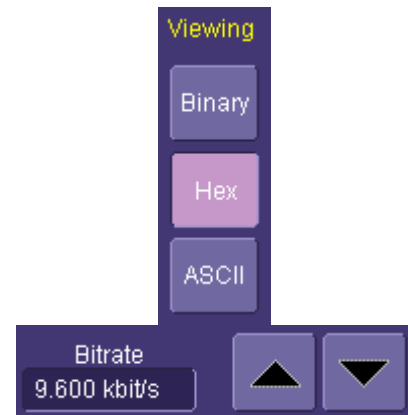
UART and RS-232 Decode Setup Detail

The UART and RS-232 Decode Setup Right-Hand Dialogs (which are contained in the Decode Setup dialog box when UART or RS-232 is selected as the Protocol to decode), with detail on the setup conditions, is shown in the images that follow:

Viewing – Select to view the protocol data in either Binary, Hexadecimal, or ASCII modes.

Note: If the trigger is set up first, then the trigger settings will copy into the decode settings.

BitRate – Adjust the bit rate value here to match the bit rate on the bus you are connected to. This bit rate selection is dynamically linked to the decoding bit rate (they are always the same value). Use the arrows to move through standard bit rates (300 b/s, 1.2, 2.4, 4.8, 9.6, 19.2, 28.8, 38.4, 57.6, 76.8, 115.2, 230.4, 460.8, 921.6, kb/s, 1.3824 1.8432, 2.7648 Mb/s) and make a selection. Or, touch the number twice (with a finger, or using a mouse) and open a pop-up keypad and enter the value directly.

Data Bits – Select the number of data bits per byte (not including the START, STOP, or PARITY bits). If you wish to decode on UART with a 9th DATA bit used as an "Alert" bit, select Data Bits = 9.

Parity – Choose from Odd, Even, or None in the Parity selection box.

Stop Bits – Choose 1, 1.5, or 2 Stop Bits in this selection box.

Bit Order – Choose either Most Significant Bit (MSB) or Least Significant Bit (LSB) bit order in this selection box. For RS-232 decode, this is defaulted to LSB and cannot be changed.

Polarity – Choose Polarity of the UART signal as either IdleLow (i.e. Data 1 = High) or IdleHigh (i.e. Data 1 = Low). For RS-232 decode, this is defaulted to IdleLow and cannot be changed.
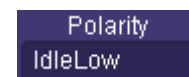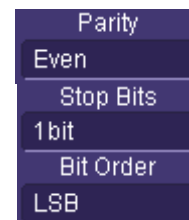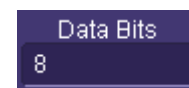
Level Type and **Level** - The message decoding algorithm setup is performed here. The level is normally set up in %, and defaults to 50%. To adjust the level, touch inside the number area to highlight the box title in yellow, then use the oscilloscope front panel Adjust knob to adjust. Or touch inside the number area twice and select a value using the pop-up numeric keypad.

The set Level appears as a dotted horizontal line across the oscilloscope grid.

If your initial decoding indicates that there are a number of error frames, make sure that the level is set to a reasonable value.

USING THE LINBUS OPTIONS

Overview

Both LINbus TD and D options contain powerful software algorithms to extract serial data information from physical layer waveforms meas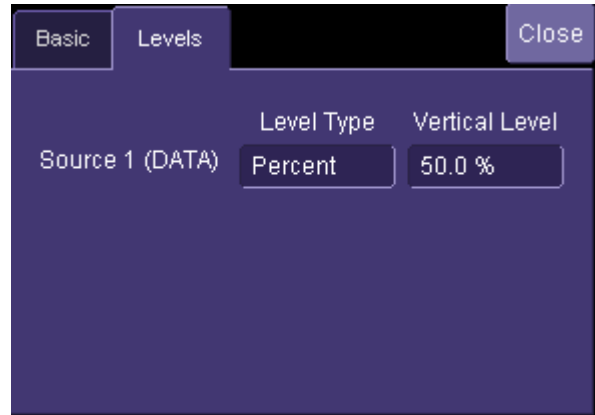ured on your oscilloscope. The extracted information is overlaid (annotated) on the actual physical layer waveforms, and color-coded to provide fast, intuitive understanding. This is especially helpful for LIN, a newer serial data standard that many engineers are just starting to use.

The LINbus TD option allows triggering on both Sync Breaks (Start of Frame), Frame ID, Frame ID+DATA, and some ERROR condition. DATA triggering can be set conditionally to select a range of DATA values to trigger on, not just a single DATA value. Other powerful and user-friendly features included in LINbus TD trigger include:

- Ability to trigger and decode LIN Version 1.3, 2.x, and SAE J2602 formats, even when LIN bus traffic contains mixed versions.

- Ability to decode LIN in either Binary or Hexadecimal formats.

- Triggering on Checksum, Header Parity, and Sync Byte Errors

If you are not familiar with or are just learning about LIN, begin by using the simplest trigger conditions (Break, or Frame ID). Then, experiment with an ID+DATA condition with DATA "Equal" to a specific value. Then, try a conditional ID+DATA trigger (DATA "Greater Than" or "In Range").

Accessing Serial Triggers

The LIN serial trigger is accessed from the oscilloscope trigger dialog. This dialog can be accessed in the following ways:

1. Touch the Trigger Descriptor Box in the lower right hand corner of the oscilloscope display. Or, touch Trigger, then Trigger Setup in the File Menu Bar at the top of the oscilloscope display.

2. Touch Serial in the Type selection.
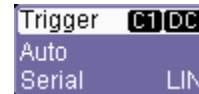
3. Select the appropriate serial trigger. Then, the menu will automatically change to a different tab in the Trigger dialogs. The tab will be named after the serial trigger that you have selected.

Creating a LIN Trigger Condition

The LIN Trigger dialog, with detail on some of the setup conditions, is shown in the images that follow:
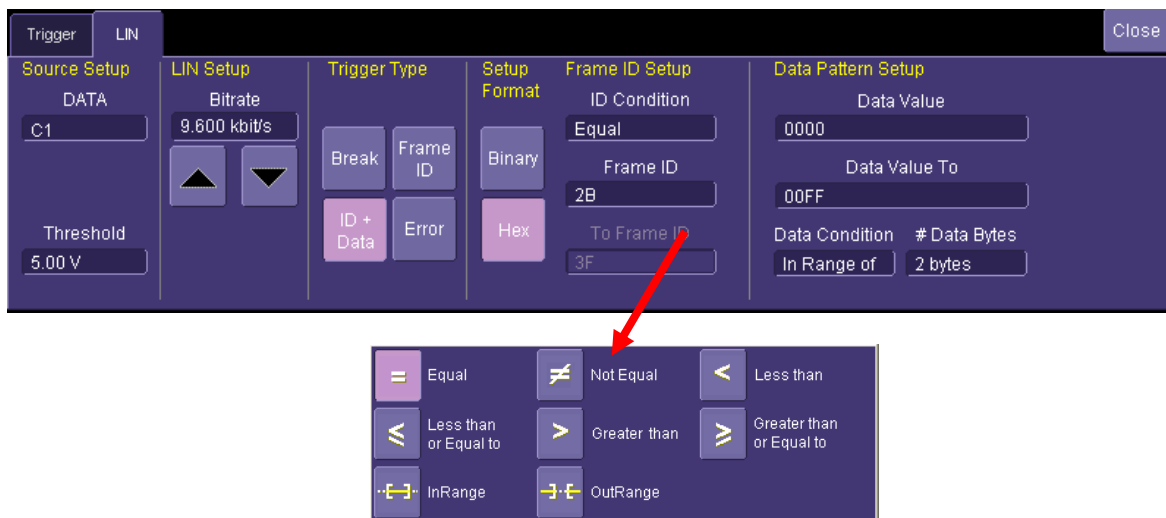
The Source Setup information must be defined. The datasheet for your part should contain the information you need to properly setup the LIN Trigger.

Selection of Trigger Type results in dynamic changes to the LIN Trigger dialog.
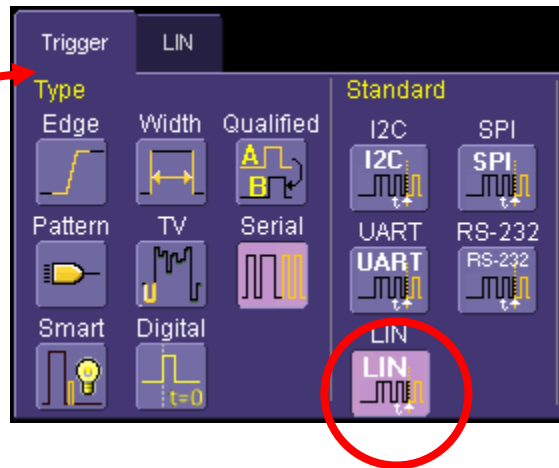
To select a value for any of the conditions, touch the existing value (using your finger, or use a mouse pointer) to open the pop-up dialog box with a list of choices, and select one of the choices.

LIN Trigger Setup Detail

Source Setup

DATA – The pop-up dialog is used to select the appropriate channel or EXT input for each. Make sure that you have these selected correctly or your trigger will not function.

Trig(ger) Threshold – Adjust the vertical level for the trigger. Much like an Edge trigger, a user must specify the level used in order to process the incoming signals and determine whether the desired serial data pattern is meeting the set trigger condition.

LIN (Bit Rate) Setup

The LIN trigger can be configured to trigger on LIN busses at several different bit rates including 1.2 kb/s, 2.4kb/s, 4.8kb/s, 9.6 kb/s, 10.417kb/s and 19.2kb/s.

Trigger Type Selection

The LIN trigger can be configured to trigger on simple Start of Frame (Break) conditions, ID only, or complete ID+DATA conditions with DATA conditions other than "equals". In additi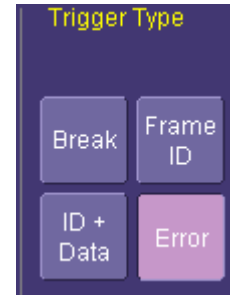on, some Error Frame triggering is supported. Select the Trigger Type desired. The trigger dialog will change dynamically based on the selections made.

Setup Format

Select either Binary or Hexadecimal setup format. The format selected will propagate through the entire LIN trigger setup,
Toggling back and forth between the formats will not result in loss of information (binary is used internally as the core format for all triggering and decoding operations), though use of don't care bits in a binary setup will result in the display of an X (for a full nibble don't care) or a $ (for a partial nibble don't care).

Frame ID Setup

ID Condition, Frame ID(s) - If Frame ID, ID+DATA, or Error Frame Trigger Type is selected, then a Frame ID entry must be made. The ID value is entered in either Binary or Hexadecimal mode depending on the previous selection of Setup Mode.
The Frame ID condition can be set many different ways. Possible conditions are <=, <, =, >, >=, not =, In Range of, or Out of Range.
If ID condition is In Range of or Out of Range, then you will also need to select a "To Frame ID" value to specify the full ID range for the trigger.
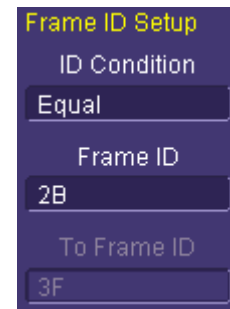
Note: If Frame ID is equal to 3C or 3D, then # Data Bytes will default to 8.

Data Pattern Setup

Data Pattern Value – The pattern value is entered in either Binary or Hexadecimal mode depending on the previous selection of Setup Mode. There are two selections for pattern value – "Data Value" and "Data Value To". The second selection is exposed for entry if the Condition is set to INRANGE or OUT(of)RANGE. Otherwise, it is grayed out. Up to 8 bytes of data can be entered as a pattern value.
If less than 8 bytes of data is entered for the pattern value, the data is assumed to begin at Data Byte 1 in the LIN message. If this is not desired, then add preceding or trailing don't care (X) nibbles to the pattern value.
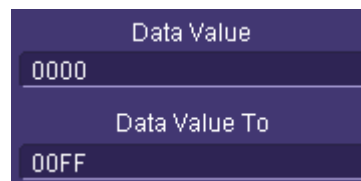
Note: In Hexadecimal format, data must be entered as full bytes even though the minimum required acceptable entry is a nibble. If less than a full byte is entered, then a don't care X will precede the pattern values entered.

Condition – The DATA condition can be set many different ways. Possible conditions are <=, <, =, >, >=, not =, in a range, out of a range, or don't care.
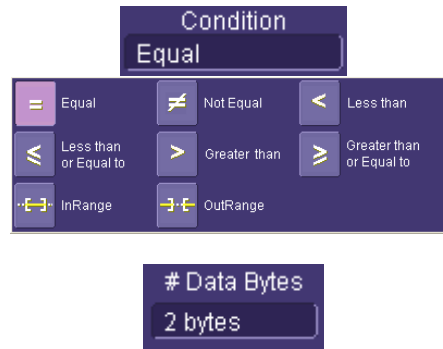
 # Data Bytes – The Number of Data Bytes value defaults to the length, in bytes, of the pattern set in the Pattern Value selection. If you were to change the length to be less than this value, it would truncate the beginning of the pattern value. If you were to increase the pattern length, it would add don't care XX byte values to the beginning of the pattern value. The maximum number of data bytes is 8, per the LIN standard.

Error Frame Setup

Error Frame Checkbox Selection – If Trigger Type "Error" is selected, then this set of checkboxes will become available to check or uncheck. Check or uncheck each one, as desired, to include or not include that specific type of error in the Error Frame trigger.
If Checksum Error is "checked", then the LIN Spec and # Data Bytes entry boxes will become ungrayed. This error frame type requires the user to input this information since the checksum depends on the LIN version and the number of data bytes in the LIN message.
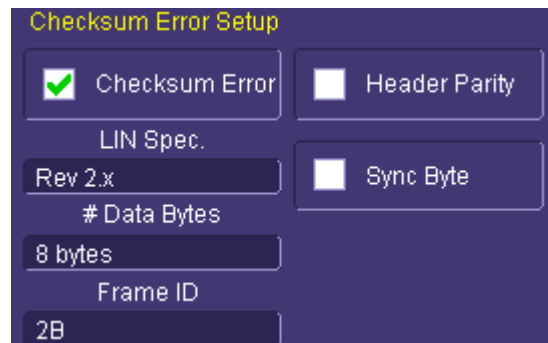
PLEASE NOTE THE FOLLOWING:

Frame IDs 3C-3F always use the Classic Checksum for all LIN 1.x and 2.x specifications.

Reference the LIN standards for more detail on the Error Frame conditions.

Make sure to enter also enter a Frame ID for the Error Frame setup, even if the Frame ID is "don't care".

LIN Spec, # Data Bytes, Frame ID – If Checksum Error triggering is desired, enter the correct values for each of these entries.
Any value entered here for # Data Bytes will be dynamically copied to the Data Pattern Setup entry for # Data Bytes.

LIN Decode Setup Detail

The LIN Decode Setup Right-Hand Dialogs (which are contained in the Decode Setup dialog box when LIN is selected as the Protocol to decode), with detail on the setup conditions, is shown in the images that follow:
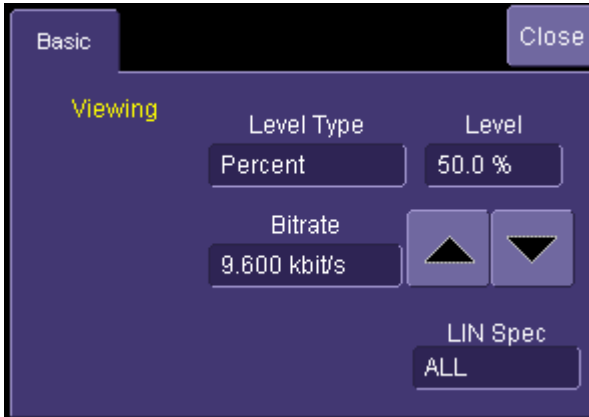
Viewing – Select to view the protocol data in either Binary or Hexadecimal formats.

> **Note:** If the trigger is set up first, then the trigger settings will copy into the decode settings.

BitRate – Adjust the bit rate value here to match the bit rate on the bus you are connected to. This bit rate selection is dynamically linked to the decoding bit rate (they are always the same value). Use the arrows to move through standard bit rates (1.2, 2.4, 4.8, 9.6, 10.417, or 19.2 kb/s) and make a selection. Or, touch the number twice (with a finger, or using a mouse) and open a pop-up keypad and enter the value directly. Any value from 1-20 kb/s may be entered in this way.

LIN Spec – It is common for LIN to have mixed versions of LIN devices on the same bus. The LINbus TD decoder can detect what version each message is using, and decode it properly.
If you desire to have decoding done completely on mixed LIN systems, simply select ALL.
If you desire to have only certain versions of LIN decoded, select that version of LIN in the pop-up entry box.

> **Note:** If you do not decode ALL messages, but decode only particular LIN versions, then LIN messages that are of a different version than the one selected will show an Error condition.

Level Type and **Level** - The message decoding algorithm setup is performed here. The level is normally set up in %, and defaults to 50%. To adjust the level, touch inside the number area to highlight the box title in yellow, then use the oscilloscope front panel Adjust knob to adjust. Or touch inside the number area twice and select a value using the pop-up numeric keypad.
The set Level appears as a dotted horizontal line across the oscilloscope grid.
If your initial decoding indicates that there are a number of error frames, make sure that the level is set to a reasonable value.

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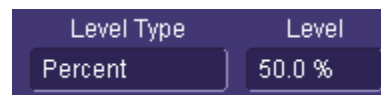
USING THE FLEXRAY BUS OPTIONS

Overview

Both FlexRaybus TD and D options contain powerful software algorithms to extract serial data information from physical layer waveforms measured on your oscilloscope. The extracted information is overlaid (annotated) on the actual physical layer waveforms, and color-coded to provide fast, intuitive understanding. This is especially helpful for FlexRay, an emerging standard that many engineers are just starting to use.

The FlexRaybus TD option allows triggering on TSS (Start), Frame, Symbol or Errors. Frame triggering can be set conditionally to select a range of Frame ID values to trigger on, not just a single ID. Other powerful and user-friendly features included in FlexRaybus trigger include:

- Ability to trigger and decode FlexRay protocol version 2.1 at 10 Mb/s, 5 Mb/s or 2.5 Mb/s

- Ability to create powerful Frame triggers including Cycle Count and Frame Qualifiers

- Triggering on FSS, BSS, FES, Header CRC and Payload CRC errors as well as CID, CAS/MTS and Wakeup Patter Symbols

If you are not familiar with or are just learning about FlexRay, begin by using the simplest trigger conditions (TSS, or Frame ID). Then, experiment with an ID + Count "Equal" to a specific value. Then, try a conditional ID + Cycle Count trigger (ID "Greater Than" or "In Range").

Accessing Serial Triggers

The FlexRay serial trigger is accessed from the oscilloscope trigger dialog. This dialog can be accessed in the following ways:

1. Touch the Trigger Descriptor Box in the lower right hand corner of the oscilloscope display. Or, touch Trigger, then Trigger Setup in the File Menu Bar at the top of the oscilloscope display.

2. Touch Serial in the Type selection.

3. Select the appropriate serial trigger. Then, the menu will automatically change to a different tab in the Trigger dialogs. The tab will be named after the serial trigger that you have selected.
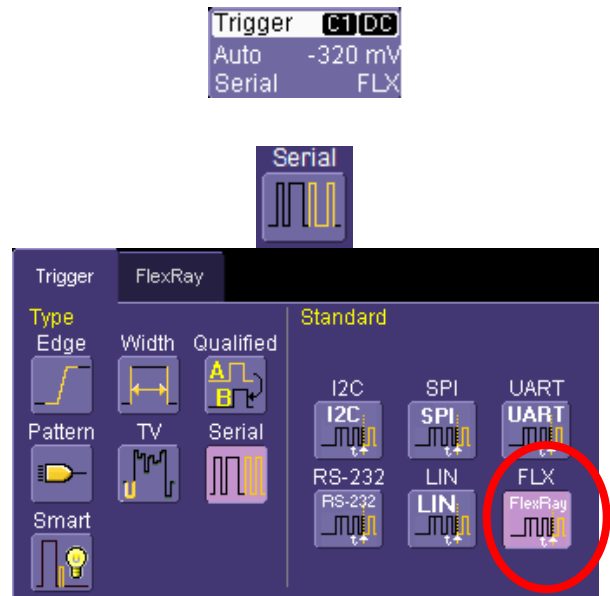
Creating a FlexRay Trigger Condition

The FlexRay Trigger dialog, with detail on some of the setup conditions, is shown in the images that follow:

The Source Setup information must be defined. The datasheet for your part should contain the information you need to properly setup the FlexRay Trigger.

Selection of Trigger Type results in dynamic changes to the FlexRay Trigger dialog.

To select a value for any of the conditions, touch the existing value (using your finger, or use a mouse pointer) to open the pop-up dialog box with a list of choices, and select one of the choices.

FlexRay Trigger Setup Detail

Source Setup

DATA – The pop-up dialog is used to select the appropriate channel or EXT input for each. Make sure that you have these selected correctly or your trigger will not function.
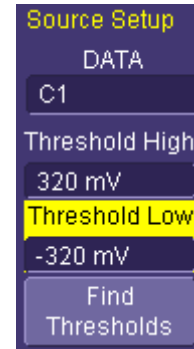
Threshold – Adjust the vertical level thresholds for the trigger. FlexRay is a tri-level signal and requires the user to set 2 voltage thresholds to enable the oscilloscope to distinguish between 1 and 0. Much like an Edge trigger, a user must specify the level used in order to process the incoming signals and determine whether the desired serial data pattern is meeting the set trigger condition. For simplicity an automated Find Threshold function is built in which will detect and set appropriate thresholds

FlexRay Bit Rate Setup

The FlexRay trigger can be configured to trigger on FlexRay signals at 2.5 Mb/s, 5 Mb/s and 10 Mb/s as defined in the FlexRay specification

Trigger Type Selection

The FlexRay trigger can be configured to trigger on simple TSS (Start), FlexRay Frame (ID, Cycle Count, Frame Qualifiers) or FlexRay Symbols (CID, CAS/MTS and Wavekeup Patter) In addition Error Frame triggering is supported for FSS, BSS and FES, Header CRC and Payload CRC errors. Select the Trigger Type desired. The trigger dialog will change dynamically based on the selections made.
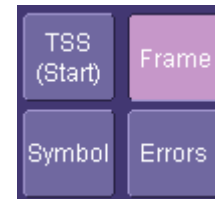
Setup Format

Select either Binary or Hexadecimal setup format. The format selected will affect the Frame ID only. The cycle count trigger will always be a Decimal value from 0 to 63, the Frame Qualifiers will always be Binary with choices of 1, 0 or Don't Care.

Toggling back and forth between the formats will not result in loss of information (binary is used internally as the core format for all triggering and decoding operations), though use of don't care bits in a binary setup will result in the display of an X (for a full nibble don't care) or a $ (for a partial nibble don't care).

Frame Trigger Setup

Frame ID – Enter the desired Frame ID in the field labeled Value, touching the field brings up the keypad for data entry. Entering X signifies Don't Care, the default ID is XXX.

The Frame ID condition can be set many different ways. Possible conditions are <=, <, =, >, >=, not =, In Range of, or Out of Range. The default setting is Equal.

If ID condition is In Range of or Out of Range, then you will also need to select a "To" value to specify the full ID range for the trigger.

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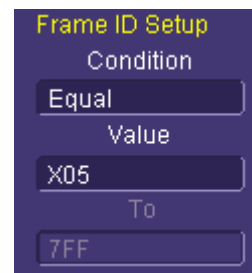
Cycle Count – The Cycle Count is combined with the Frame ID to enable powerful FlexRay triggering.
The Cycle Count is a decimal value between 0 and 63 correlating to the FlexRay Cycle Count numbering system. The default Value is Cycle Count 0. If the cycle count is not intended to be part of the Frame triggering the
The Cycle Count condition can be set many different ways. Possible conditions are <=, <, =, >, >=, not =, In Range of, or Out of Range. The default setting is Equal.
If Cycle Count condition is In Range of or Out of Range, then you will also need to select a "To" value to specify the full ID range for the trigger.
If the Cycle Count condition is set to Equal the Repetition Factor can be set to a value of 1, 2, 4, 8, 16, 32 or 64 to allow for triggering when Cycle multiplexing is being used.

Condition – The condition for Frame ID and Cycle Count can be set many different ways. Possible conditions are <=, <, =, >, >=, not =, in a range, out of a range, or don't care.

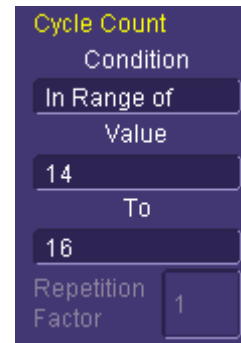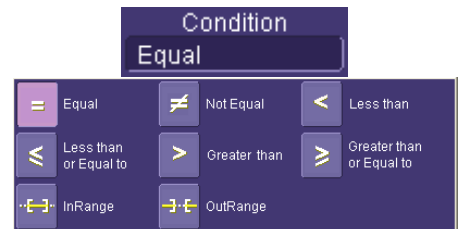**Frame Qualifiers –** The final aspect of Frame trigger setup is the Frame Qualifiers which are defined in the FlexRay specification. Frame Qualifiers allow for an additional level of complexity to create a powerful FlexRay trigger. The default setting for each of the Qualifiers is Don't Care, each can be set to One, Zero or Don't Care as independent variables in the trigger setup.

Symbol Trigger Setup

If Symbol is selected as the trigger type then this set of checkboxes will appear. The FlexRay specification calls out several symbols that are included in the FlexRay protocol. The symbol trigger allows for triggering on any Frame that includes one or more of these symbols.
Channel Idle Delimiter (CID)
Collision Avoidance Symbol (CAS)
Media Access Test Symbol (MTS)
Wakeup Pattern (WUP)
Check or uncheck each one, as desired, to include or not include that specific Symbol. Selecting more than one symbol will set the oscilloscope to trigger on any of the Symbols selected
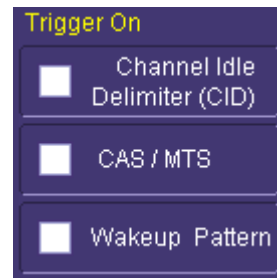
Error Trigger Setup

If Error is selected as the trigger type then this set of checkboxes will appear. The errors are broken in to 2 categories, Protocol Errors and CRC Errors.

Protocol Errors:
- Frame Start Sequence (FSS)
- Byte Start Sequence (BSS)
- Frame End Sequence (FES)

CRC Errors:
- Header CRC
- Payload CRC
- The correct channel must be selected when triggering on CRC errors
- Check or uncheck each one, as desired, to include or not include that specific type of error in the trigger.
- For convenience Select and Deselect All buttons are available when using Error triggering.
- Detailed description of the Error Triggers is found in Appendix C.
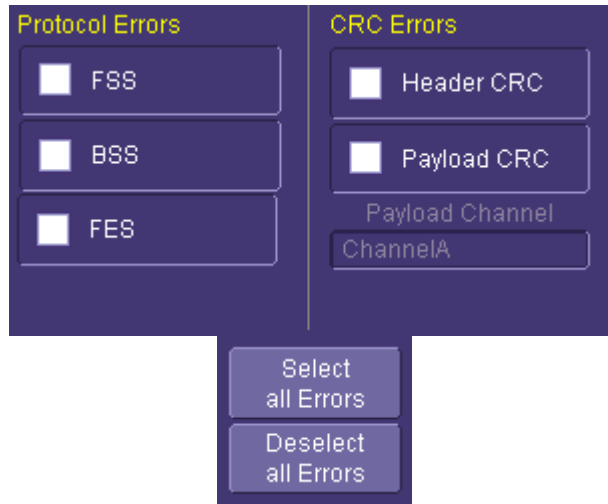
FlexRay Decode Setup Detail

The FlexRay Decode Setup Right-Hand Dialogs (which are contained in the Decode Setup dialog box when FlexRay is selected as the Protocol to decode), with detail on the setup conditions, is shown in the images that follow:
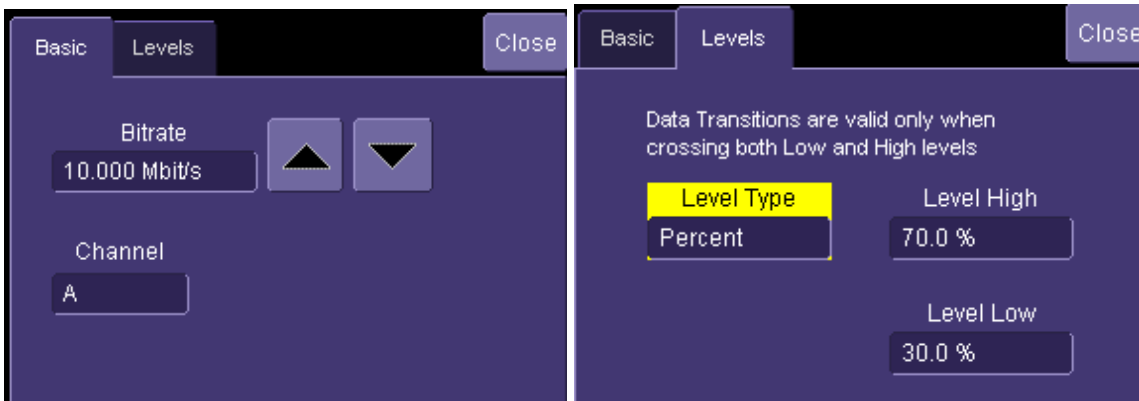
BitRate – Adjust the bit rate value here to match the bit rate on the bus you are connected to. This bit rate selection is dynamically linked to the decoding bit rate (they are always the same value). Use the arrows to move through standard bit rates (2.5, 5.0 or 10.0 Mb/s) and make a selection. Or, touch the number twice (with a finger, or using a mouse) and open a pop-up keypad and enter the value directly.
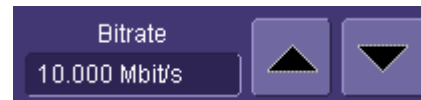
Channel – Select the appropriate channel to decode depending if signal being decoded is coming from Channel A or Channel B of the FlexRay bus. The channel selection only drives the CRC computation. If the wrong channel is selected, the decode will still work but will exhibit CRC errors. In this case simply switching the channel will fix the decoding.
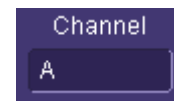
Level Type and **Level** - The message decoding algorithm setup is performed here. FlexRay is a tri-level signal and requires 2 levels for the oscilloscope to distinguish between 1 and 0. The level is normally set up in %, and defaults to 70% and 30%. To adjust the level, touch inside the number area to highlight the box title in yellow and then use the oscilloscope front panel Adjust knob to adjust. Or touch inside the number area twice and select a value using the pop-up numeric keypad. Switching the level type to Absolute allows for entry of voltage levels instead of percentages
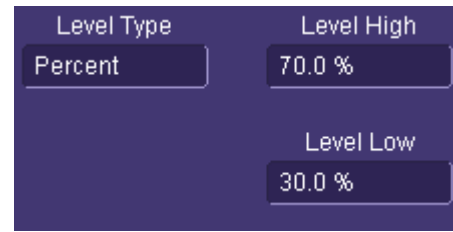
The set Level appears as a dotted horizontal line across the oscilloscope grid.

If your initial decoding indicates that there are a number of error frames, make sure that the level is set to a reasonable value.

Level Type	Level High
Percent	70.0 %
	Level Low
	30.0 %

USING THE TD PACKAGES: CHARACTERIZE EMBEDDED CONTROLLER PERFORMANCE

Overview

The standard oscilloscope contains a number of built-in tools, such as cursors, measurement parameters, and statistical analysis. These can be used to characterize performance for serial data signals just as they would be used to characterize performance on any other signals. You may want to use cursors for making single-shot timing measurements, and measurement parameters when you need to accumulate statistical data over many different acquisitions. In addition, measurement parameters are also helpful to determine the underlying integrity of the serial data physical signals.

All TD packages provide basic tools to characterize embedded controller performance. These tools can be used on the decoded channels, memories, zooms, functions, etc. just like they are used on any undecoded channels, memories, zooms, functions, etc. In addition, you can use normal Edge or SMART Triggers on an analog channel input to trigger the oscilloscope when a certain analog signal occurs, and then measure to a particular serial data message using the decoded info as your guide.

Note: The examples shown below are using CAN bus messages, but similar needs exist for I^2C and SPI, and the included oscilloscope tools described in the following sections can be applied in the same way.

For instance, take the example below of an analog signal creating a burst of CAN messages.
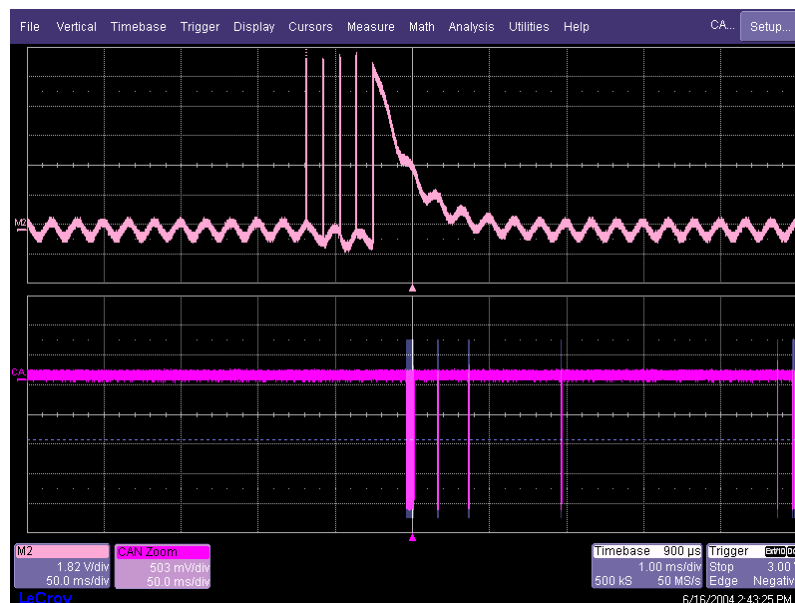
This data was acquired over a 500 ms duration. It is likely that you want to understand whether the analog signal input to your electronic control unit (ECU) is creating the desired CAN message output from the ECU. There are a number of ways that this could be done.

Using Cursors

Use horizontal cursors to mark locations on the waveform where the time measurement should be done, then read the cursor values to establish the measurement. As necessary, adjust the timebase or create zooms of the decoded trace(s) so as to be able to view the signal with enough detail. This is a good method for single-shot / single measurements.

Using Measurement Parameters

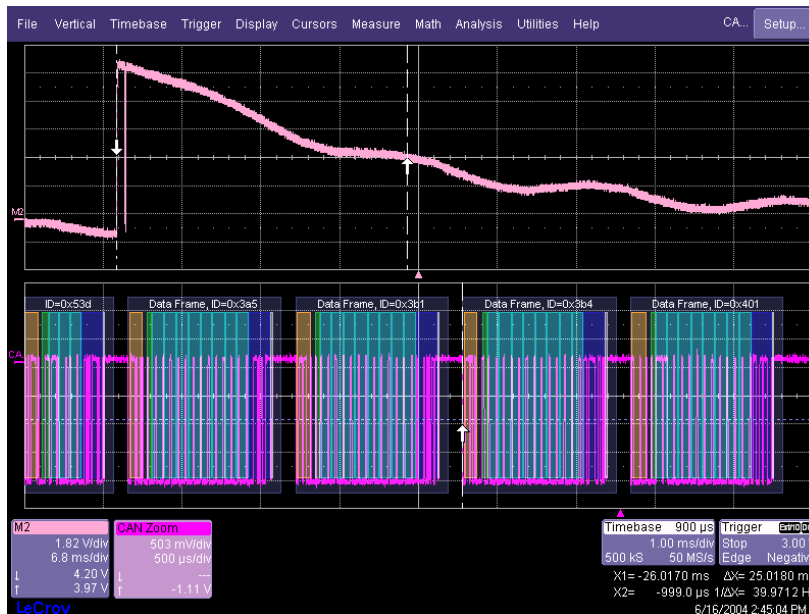Measurement parameters can be used to make signal integrity or timing measurements of your serial data signals. Basic parameters, such as Amplitude, Rise, Fall, Overshoot, etc. are ideal for signal integrity checks. Timing parameters, such as Delay, Delta Delay, Delta Time @ Level, etc., are ideal for measuring timing from trigger to other signals (such as from an I^2C or SPI Trigger to an analog signal). Delta Trig Time is ideal for measuring the time between segments of a Sequence Mode acquisition (Reference the chapter on Isolating and Analyzing Serial Bus Activity for more information on Sequence mode).

Amplitude – Noise and overshoot resistant measurement of the amplitude of the signal (measurement of amplitude from Top to Base).

Base – Value of the lowermost state in a bi-modal waveform, such as an I^2C, SPI, or CAN Message.

Delay – Time from the trigger to the first transition at the 50% amplitude crossing.

Delta Delay – Time between the 50% crossing of the first transition of two waveforms.

Delta Time @ Level – Time between selectable levels of two waveforms. (Not available on WaveSurfer Series)

Delta Trig Time – The time from last trigger to this trigger (usually used in Sequence mode).

Fall (90-10), Fall 80-20, Fall@Level – Transition time on the falling edge. Three selections are available for the user to determine at which vertical level the measurement is made. (Fall@Level is not available on WaveSurfer Series)

Maximum – Highest value in the input waveform.

Mean – Average of all data values.

Minimum – Lowest value in the input waveform.

Overshoot Negative – Overshoot following a falling edge.

Overshoot Positive – Overshoot following a rising edge.

Peak to Peak – Difference between the Maximum and Minimum data values.

Rise (10-90), Rise (20-80), Rise@Level –Transition time on the rising edge. Three selections are available for the user to determine at which vertical level the measurement is made. (Rise@Level is not available on WaveSurfer Series).

Top – Value of the uppermost state in a bi-modal waveform, such as an I^2C, SPI, or CAN Message.

Measurement Gating

Gating is available on each standard parameter to allow you to set a measurement window that the parameter should be active in. This allows you to eliminate unwanted portions of the acquisition from your measurement.

Select gating from the Measure dialog by selecting the tab for the appropriate measurement (P1, P2, etc.) and then setting the start and stop for the gate. Reference the oscilloscope's on-line Help for more information on how to set gating.
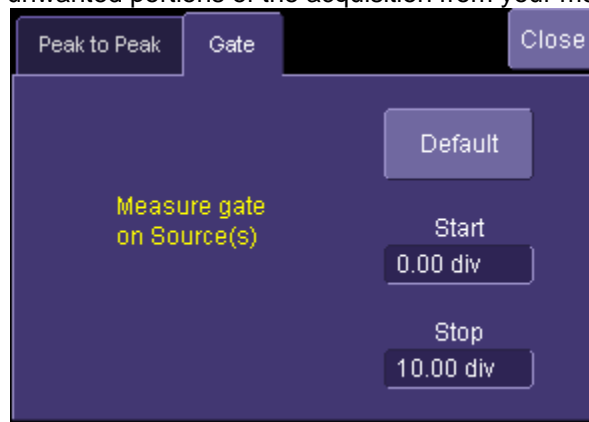
Using Statistics and Graphing

Statistics and Histicons are included with nearly every LeCroy oscilloscope (Histicons are not available with WaveSurfer Series). They allow you to gather numerical and visual information on the distribution of your various measurements.

You can turn on Statistics and Histicons separately in the Measure dialog. Simply touch the appropriate box to checkmark it and turn it ON, or touch it again to turn it OFF.

In addition, some optional LeCroy programs (such as JTA2) add capability to produce larger histograms, trends, and tracks of your measurement parameters. If you have this capability, then you can access it through the Measurement Parameter setup dialog (the Px tab).
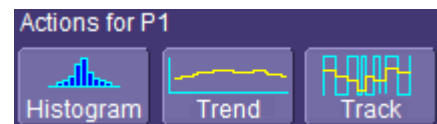
Pass/Fail Analysis with Measurement Parameters

Pass/Fail analysis using measurement parameters is quite simple to set up and quite powerful. For instance, you can define a timing measurement, define the limits for the timing measurement, and then run the oscilloscope in a Normal trigger mode, capturing thousands of measurement events. Then, for example, Pass/Fail can be used to save the Waveform in the event of a Fail, or send an email in the event of a fail.

Set up Pass/Fail conditions by touching Analysis in the menu bar, then selecting Pass/Fail Setup. Reference the oscilloscope's on-line Help for more detail on pass/fail setup.
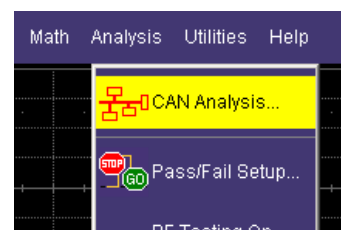
ISOLATE AND ANALYZE SERIAL BUS ACTIVITY

The combination of Serial Data Triggering, Decoding, and normal oscilloscope features is a powerful combination of tools that can make it very easy to find latent Serial Data HW or SW problems in your circuit. No longer is the oscilloscope a tool just for the hardware engineer. Now the software engineer can also easily visualize the Serial Data signals and relate it to programming code and operation. The TD options can enable the HW Engineer and SW Engineer to "speak the same language" when it comes to system debugging and performance checking. Some common Serial Data analysis needs and methods are discussed below:

Capture Long Pre-Trigger Time

LeCroy oscilloscopes are available with optional very long acquisition memory. For instance, the WaveRunner Xi Series oscilloscopes can capture up to 12.5 Mpts on 4 channels, or 25 Mpts on 2 channels. If your Serial Data signals are 1 Mb/s, and you sample at the minimum required and available sample rate (5 MS/s, you would be able to capture 5 seconds of Serial Data traffic. If you wish, this can be 100% pre-trigger, 100% post-trigger, or something in between.

1. Adjust Pre-Trigger and Post-Trigger time by adjusting the Delay knob on the oscilloscope's front panel.

2. Optimize your Sample Rate or Memory Length by accessing the Horizontal Dialog in your oscilloscope and selecting either Set Max Memory mode or Fixed Sample Rate mode.

3. If you choose to Set Max Memory, you can decrease the memory usage so that you will not sample at too high a sample rate (too high a sample rate will slow down the decoding algorithm). Then adjust your time timebase setting to as long as necessary to capture the event. Note that you must make sure that your timebase setting and memory length combined do not result in too low of a sample rate, or adequate capture and decode will not be performed.

4. More commonly, you will probably choose to fix the sample rate to a specific value that provides you with the oversampling you need to capture your Serial Data messages (at least 4X the bit rate) and also allow you to have a high enough sample rate to capture any transients that you may want to see on your Serial Data and analog signals (at least 2X the frequency of any expected transients, preferably 10X).

Reference your oscilloscope's on-line Help for more information on these common settings.

Trigger Repeatedly, Save Data to a Hard Drive

You may wish to set up your oscilloscope to capture a short or long memory acquisition for a certain trigger condition, then save data to a hard drive or memory stick whenever the trigger condition is met. This can be easily done in most LeCroy oscilloscopes. However, you must realize that there is significant trigger "dead time" when using this method. To minimize dead time, use the method described under Trigger Repeatedly, Store all Triggers (Sequence Mode).

1. First, set up your desired serial data (or other) trigger condition.

2. Then, from the menu bar, choose File, Save Waveform. This will open a dialog that will allow you to set up the Save Waveform conditions. You can choose to have this OFF (no Auto Saving occurs), WRAP (Auto Save occurs until the hard drive is filled, then discards the oldest data to write the newest data), or FILL (Auto Save occurs until the hard drive is filled).

3. Be sure to choose a Binary file format if you wish to recall the traces into a LeCroy oscilloscope for later analysis.
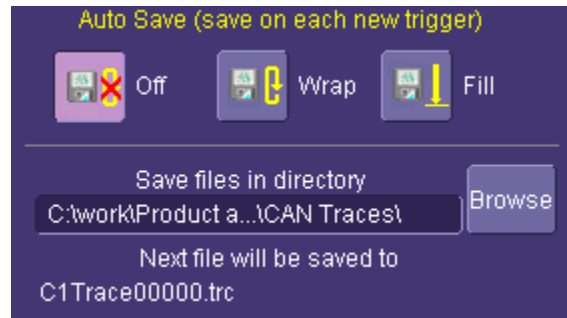
Even though the LeCroy oscilloscope hard drives are very large, it is a good idea to make sure that your trigger condition is set correctly before beginning your acquisitions.

Note: This method is not guaranteed to capture all of your trigger events, since there will be a large amount of "dead time" between triggers as the acquisition is captured, displayed, and stored to the hard drive before the scope is re-armed for a new trigger. To minimize dead time, use Sequence Mode.

## Trigger Repeatedly, Store all Triggers (Sequence Mode)

LeCroy oscilloscope's have a powerful capability called Sequence Mode that will allow you to store all triggered events by minimizing the dead time between triggers to < 800 nanoseconds. This is ideal for finding repetitive causes of problems on your serial data buses or associated signals. (Not available in WaveSurfer Series). Sequence Mode uses long acquisition memory that is divided into "segments." As triggered events are acquired, they are stored in acquisition "segments" to be recalled at a later date. The length of each sequence mode acquisition segment and the total number of segments allowed is roughly determined by the total acquisition memory in the oscilloscope. For instance, for a WaveRunner Xi with VL memory, you can get 10,000 segments that are each a maximum of 625 samples long, or 10 segments that are each a maximum of 1.25 megasamples long, or something in between. Different acquisition memory lengths have different ranges of segments and segment lengths. You can define any number of segments from 2 to the maximum for that memory length (reference your oscilloscope's on-line Help), and any length of segment (so long as there is sufficient acquisition memory). After acquisition of all segments is complete, you can recall them one-by-one and view them in decoded format on the oscilloscope screen.

Acquisition dead time is kept to a minimum because there are no operations performed during the acquisition. All data for each triggered event is written only into high-speed acquisition memory. Until the entire sequence is completed, there is no updating of the oscilloscope display, or other operations that cause unnecessary dead time. This is ideal for situations when you cannot take a chance on losing data.

In the example shown below, we have only acquired Channel 1 (the CAN signal) in sequence mode. We could also acquire additional analog or other signals as desired or as necessary to do a proper analysis.

1. Touch the Timebase descriptor box to open the Timebase dialog.
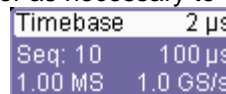
2. In the Sampling Mode area, select Sequence Mode. A tab labeled "Sequence" will appear next to the Timebase tab. Touch that tab.
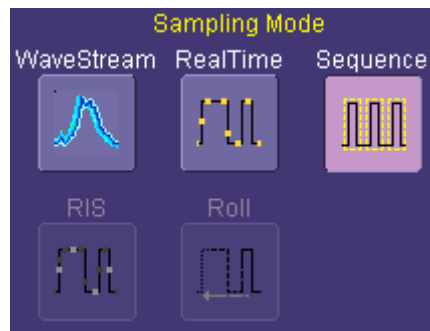
3. In the Sequence tab, select the Display Mode. Select the Number of Segments Displayed at one time.

4. If you have acquired more segments than you can display at one time, you can choose the segment to begin the display at.

Display Settings

Display Mode
Adjacent

Num Seg Displayed
10

Starting at
1

5. As described in a previous chapters, set up the Serial Trigger to capture the event you desire. For instance, for instance, you might want to trigger on a specific address or data value, and capture long pre-trigger time to determine what precedes that message. In this example, we've used a simple I^2C Start trigger. To begin the sequence mode acquisition, press the front panel SINGLE trigger button. Each t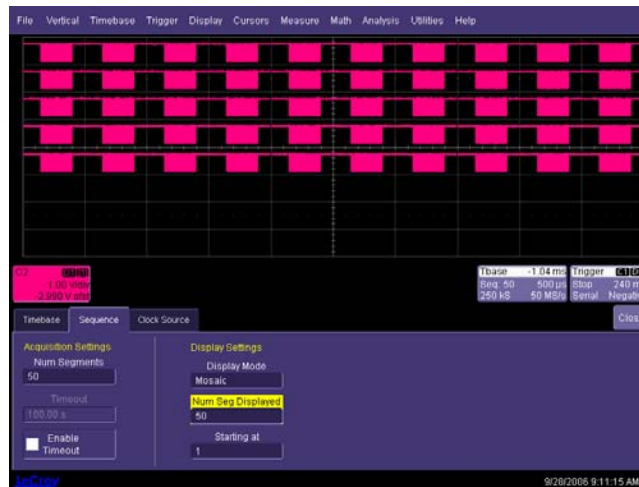ime the trigger condition is met, the TRIG'D light on the front panel will flash. When you've acquired the set number of segments, the trigger will STOP and the display will appear as below (this is a 50 segment acquisition in Mosaic display mode).
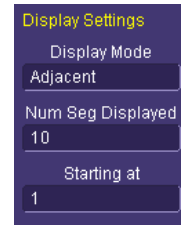
6. To display an individual segment separately from the main channel display, select Math, Math Setup from the menu bar, and choose a math trace to define as a Segment (in this case, we chose to define F1 as a Segment of C2). As a source, use the channel that your serial data was acquired on (in this case Channel 2). To display the trace, check the TRACE ON checkbox. To select the segment to view, touch the Select tab and select a segment using the pop-up keypad or the front panel adjust knob.
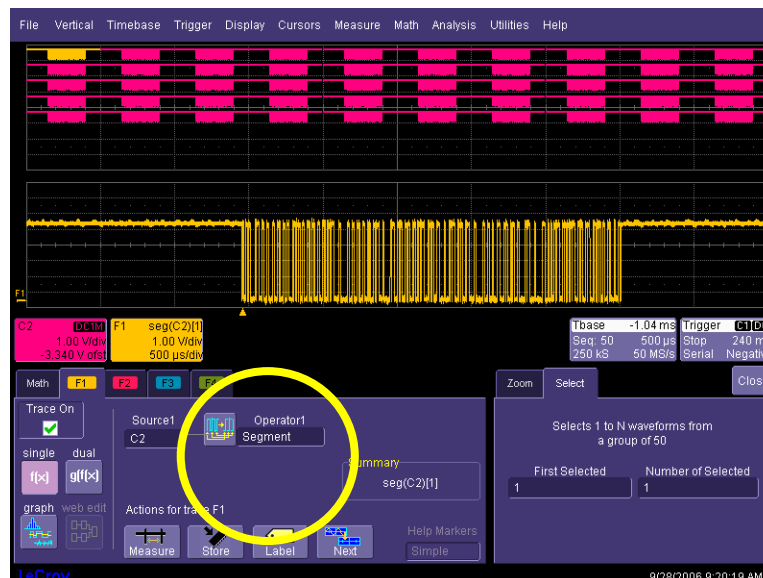
7. To view decoded data on the individual segment, set up the Decode to use the Math trace as the source for Data (in this case F4 is the source). If you wish to change the segment that is decoded, just select a new segment from the Math trace dialog (as shown in the preceding step).
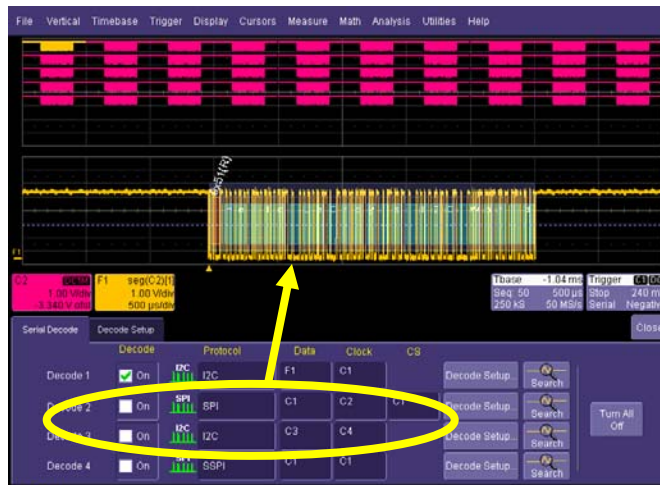
8. To conserve display space, you could turn off the Channel and just select the segment that you wish to view.

9. To view the timestamps for each segment, select Vertical, Channels Status in the menu bar, then in the Show Status portion of the dialog, select Time (as shown to the right). Then, you will see a display of timestamp information for each segment in the sequence acquisition, as shown below:
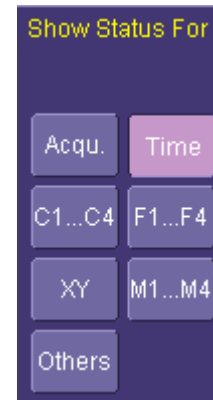
Seg	Time	since Segment 1	between Segment
1)	16-June-2004 11:53:35		
2)	16-June-2004 11:53:37	1.617166812 s	1.617166812 s
3)	16-June-2004 11:53:37	1.718687863 s	101.521050 ms
4)	16-June-2004 11:53:37	1.919879959 s	201.192096 ms
5)	16-June-2004 11:53:37	2.423745193 s	503.865234 ms
6)	16-June-2004 11:53:38	3.333904655 s	910.159462 ms
7)	16-June-2004 11:53:40	5.247904552 s	1.913999897 s
8)	16-June-2004 11:53:40	5.347525592 s	99.621040 ms
9)	16-June-2004 11:53:42	7.263465499 s	1.915939907 s
10)	16-June-2004 11:53:43	7.566198649 s	302.733150 ms

10. Ten timestamps will fit on the display at one time. You can choose which ten to display by using the Select Segment control. You can also page through the segments one at a time by using the Adjust knob on the front panel.

APPENDIX A – I2CBUS TD & SPIBUS TD SPECIFICATIONS (REV 3.11)

	I2Cbus TD	SPIbus TD
Definition		
Protocol Setup	Not Applicable	Select CPOL (Clock Polarity 0 or 1), CPHA (DATA Polarity 0 or 1), DATA = MSB or LSB. Also, may select SIOP or SSPI defaults.
Decode Capability		
Format	Hexadecimal, Binary, ASCII	Hexadecimal, Binary, ASCII
Decode Setup	Threshold definition required. Default is to Percent amplitude. Choose to Decode address values including/not including the R/W bit in address value.	Threshold definition required. Default is to Percent amplitude. Select CPOL, CPHA, DATA = MSB or LSB,
Decode Input	Any analog Channel, Memory or Math trace. Clock channel may be turned OFF and data will still decode (reduces screen clutter)	Any analog Channel, Memory or Math trace. Clock and/or Slave Select channel may be turned OFF and data will still decode (reduces screen clutter)
# of Decoded Waveforms	**Up to 4 buses may be decoded at one time.** In addition, zooms can be displayed (with decoded information).	**Up to 4 buses may be decoded at one time.** In addition, zooms can be displayed (with decoded information).
Location	Overlayed over DATA waveform, on Grid. (Note: Use multi-grid if there is more than one decoder ON)	Overlayed over DATA waveform, on Grid. (Note: Use multi-grid if there is more than one decoder ON)
Visual Aid	Color Coding for FRAME, START/ReSTART bit, ADDR, R/W, DATA, ACK, and STOP bit. Decode information is intelligently annotated based on timebase setting.	Color Coding for FRAME and DATA. Decode information is intelligently annotated based on timebase setting.

Trigger Capability		
Format	Hexadecimal or Binary ADDRESS and DATA can be set up with different formats.	Hexadecimal or Binary
Trigger Setup	Trigger on START, ReSTART, STOP, Missing ACK, ADDR, DATA, ADDR+DATA, ADDR+DATA Length, EEPROM	Trigger on DATA for any of the four SPI Modes with either MSB/LSB and with or without Slave Select.
ADDRESS (ID) Condition Setup	Specify One ADDRESS with condition of = 7 or 10 bit ADDRESS supported with full Read, Write, or R/W="Don't Care" selectability on both 7 and 10 bit ADDRESSes. Choose to Trigger on address values that include/don't include R/W bit in address value.	Not Applicable
DATA Condition Setup	<=, <, =, >, >=, <>, in range, out of range, don't care.	=
DATA Setup	Hexadecimal: # Data Bytes = 0 to 12. Data can be defined by nibble. Binary: Any combination of 0,1, or X for 1-96 bits Data pattern can be set to start on any byte in a 2048 byte window (EEPROM mode).	Hexadecimal: # Data Bytes = 0 to 8. Data can be defined by nibble. Triggers on that data pattern regardless of position. Binary: Any combination of 0,1, or X for 1-64 bits. Triggers on that data pattern regardless of position.
ACK Condition Setup	For any ADDR, ADDR+DATA, ADDR+DATA LENGTH, or EEPROM frame setup, select an ACK Condition of ACK, NO ACK, and DON'T CARE.	Not Applicable
Bit Rates	Full range over I2C specification for Standard, Fast, Fast-Mode Plus, and High-Speed modes. Auto-detected	Any. Auto-detected
Trigger Input	Any analog Channel or the EXT input. Clock may be input to EXT to conserve available analog Channels.	Any analog Channel or the EXT input. Clock or Slave Select may be input to EXT to conserve available analog Channels.
Trigger Design	Internal to oscilloscope, settable like any other oscilloscope trigger	Internal to oscilloscope, settable like any other oscilloscope trigger
Search Capability		
Pattern Search	Search by ADDRESS or DATA in Hexadecimal formats	Search by DATA in Hexadecimal formats

Other		
Compatible With…	TD (Trigger & Decode) Option fully compatible with WRXi and WSXs (retrofit kits available) D (Decode) Option fully compatible with WR6000, WP7000, and WM8000 Series.	TD (Trigger & Decode) Option fully compatible with WRXi and WSXs (retrofit kits available) D (Decode) Option fully compatible with WR6000, WP7000, and WM8000 Series.

APPENDIX B – LINBUS TD & UART-RS232BUS TD SPECIFICATIONS (REV. 3.11)

	UART-RS232bus TD	LINbus TD
Definition		
Protocol Setup	**For UART** Select BitRate Select # Data Bits (5-9) Select Parity (Odd, Even, None) Select # Stop Bits (1, 1.5, 2) Select Bit Order (MSB or LSB) Select Polarity (IdleLow or IdleHigh) **For RS-232** Select BitRate Select # Data Bits (5-8) Select Parity (Odd, Even, None) Select # Stop Bits (1, 1.5, 2)	Select LIN Version 1.3, 2.x, or SAE J2602. Select BitRate (1.2, 2.4, 4.8, 9.6, 10.417, 19.2 kb/s, or user-defined 1-20 kb/s) Decodes LIN messages on buses with mixed LIN Versions
Decode Capability		
Format	Hexadecimal, Binary, ASCII	Hexadecimal, Binary
Decode Setup	Threshold definition required. Default is to Percent amplitude. Select BitRate, # Data Bits, Parity, # Stop Bits, Bit Order, and Polarity (for RS-232, no Bit Order or Polarity setup)	Threshold definition required. Default is to Percent amplitude. Select BitRate.
Decode Input	Any analog Channel, Memory or Math trace.	Any analog Channel, Memory or Math trace.
# of Decoded Waveforms	**Up to 4 buses may be decoded at one time.** In addition, zooms can be displayed (with decoded information).	**Up to 4 buses may be decoded at one time.** In addition, zooms can be displayed (with decoded information).
Location	Overlayed over DATA waveform, on Grid. (Note: Use multi-grid if there is more than one decoder ON)	Overlayed over DATA waveform, on Grid. (Note: Use multi-grid if there is more than one decoder ON)
Visual Aid	Color Coding for Start Bit, Stop Bit, Parity Bit, and DATA. Decode information is intelligently annotated based on timebase setting.	Color Coding for Frame, Break, Synch, ID, ID Parity, Data, CRC. Decode information is intelligently annotated based on timebase setting.

Trigger Capability		
Format	Hexadecimal or Binary	Hexadecimal or Binary
Trigger Setup	Trigger on DATA or Parity ERROR	Trigger on (Sync) Break (Start of Message), Frame ID, Frame ID+DATA, Error Frame (Any combination of Checksum, Header Parity, or Sync Byte error frames)
ADDRESS (ID) Condition Setup	Not Applicable	Specify One ADDRESS with condition of =
DATA Condition Setup	<=, <, =, >, >=, <>, in range, out of range, don't care.	<=, <, =, >, >=, <>, in range, out of range, don't care.
DATA Setup	Hexadecimal: # Data Bytes = 0 to 12. Data can be defined by nibble. Binary: Any combination of 0,1, or X for 1-96 bits. May specify particular data position anywhere in a 2048 byte sequence.	Hexadecimal: # Data Bytes = 0 to 8. Data can be defined by nibble. Triggers on that data pattern regardless of position or in user settable location. Binary: Any combination of 0,1, or X for 1-64 bits. Triggers on that data pattern regardless of position or in user settable location.
Bit Rates	Any from 300 b/s to 10 Mb/s (User settable)	1.2, 2.4, 4.8, 9.6, 10.417, 19.2 kb/s selectable. Any value from 1 kb/s to 20 kb/s may be entered.
Trigger Input	Any analog Channel or the EXT input.	Any analog Channel or the EXT input.
Trigger Design	Internal to oscilloscope, settable like any other oscilloscope trigger	Internal to oscilloscope, settable like any other oscilloscope trigger
Search Capability		
Pattern Search	Search by DATA in Hexadecimal format, or search for Next ERRORs.	Search by Next Frame, Next ID, or Next Error Frame in Hexadecimal formats
Other		
Compatible With…	TD (Trigger & Decode) Option fully compatible with WRXi and WSXs (retrofit kits available and required for some WRXi and WSXs oscilloscopes). D (Decode) Option fully compatible with WR6000, WP7000, and WM8000 Series.	TD (Trigger & Decode) Option fully compatible with WRXi and WSXs (retrofit kits available and required for some WRXi and WSXs oscilloscopes). D (Decode) Option fully compatible with WR6000, WP7000, and WM8000 Series.

FlexRaybus TD	
Definition	
Protocol Setup	Select BitRate (2.5, 5 or 10 Mb/s) Select FlexRay Channel A or Channel B
Decode Capability	
Format	All decoding is hexadecimal except for Cycle Count which is decoded using a decimal format
Decode Setup	Two threshold definitions required. Default is to Percent amplitude. Select BitRate. Select FlexRay Chanel A or Channel B
Decode Input	Any analog Channel, Memory or Math trace.
# of Decoded Waveforms	Up to 4 buses may be decoded at one time. In addition, zooms can be displayed (with decoded information).
Location	Overlaid over DATA waveform, on Grid. (Note: Use multi-grid if there is more than one decoder ON)
Visual Aid	Color Coding for TSS, FSS, Frame Qualifiers, Slot ID, Payload Length, Header CRC, Cycle Count, Data, BSS, Payload CRC and FES Decode information is intelligently annotated based on timebase setting.

Trigger Capability	
Format	Hexadecimal or Binary for Frame ID Decimal for Cycle Count
Trigger Setup	Trigger on TSS (Start), Frame ID, Cycle Count, Symbols and Errors Symbols: Channel Idle Delimiter (CID) Symbol, Collision Avoidance Symbol (CAS), Media Access Test Symbol (MTS), Wakeup Pattern (WUP) Errors: Frame Start Sequence (FSS) Error – triggers when the logic high time between the TSS and the first byte is too long Byte Start Sequence (BSS) Error – triggers anytime the BSS pattern is not seen between bytes where expected Frame End Sequence (FES) Error – triggers when the FS is not seen after the last byte
Frame ID and Cycle Count Condition Setup	<=, <, =, >, >=, <>, in range, out of range, don't care.
DATA Setup	Hexadecimal: # Data Bytes = 0 to 8. Data can be defined by nibble. Triggers on that data pattern regardless of position or in user settable location. Binary: Any combination of 0,1, or X for 1-64 bits. Triggers on that data pattern regardless of position or in user settable location.
Bit Rates	2.5, 5.0 or 10 Mb/s selectable.
Trigger Input	Any analog Channel or the EXT input.
Trigger Design	Internal to oscilloscope, settable like any other oscilloscope trigger
Search Capability	
Pattern Search	Search by Next ID, Next Frame, or Next Error in Hexadecimal formats
Other	
Compatible With…	TD (Trigger & Decode) Option fully compatible with WRXi (retrofit kits available and required for some WRXi oscilloscopes). D (Decode) Option fully compatible with WR6000, WP7000, and WM8000 Series.