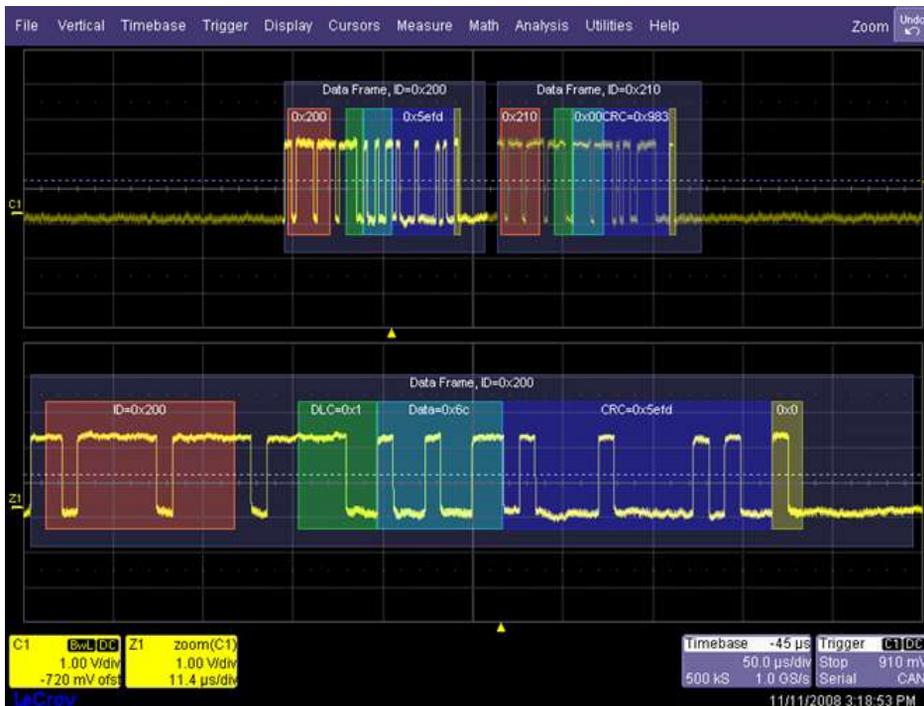




CANbus Trigger, Decode, and Measure

Software Option



Operator's Manual

December, 2008



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CANbus-TD-TDM-OM-E RevB

916940-00 RevA

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Introduction

Several communication protocol types are used in automotive applications. They are used to send data from sensors to electronic control units (ECUs) or from one ECU to another. These protocol types include **Controller Area Network (CAN)**, **Local Interconnect Network (LIN)**, and **FlexRay**. 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.

This manual focuses on the CANbus **TDM** and **TD** products. LeCroy also has separate **LIN** and **FlexRay** products and manuals.

Overview

CANbus TDM and TD options contain powerful software algorithms which 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 CANbus TD option allows triggering on CAN Frames and Errors. Frame triggering can be set to trigger on any frame, one specific Frame ID, a range of Frame IDs, Remote Frames, and Errors. Frame triggering and data triggering can be done for a single ID or message or a range of IDs and data by using the conditional trigger capabilities. Other powerful and user-friendly features included in CANbus TD include:

- The ability to trigger and decode CAN at bit rates from 10 kb/s to 1 Mb/s.
- The ability to create powerful, conditional Frame ID and Data triggers.
- Triggering on CAN protocol errors and remote frames.

If you are unfamiliar or are just learning about CAN, start by using the simplest trigger conditions (All Frames or Frame ID). Next, experiment with an ID and Data to trigger on a specific value. Then, try a conditional ID + Data trigger (ID Greater Than or In Range).

The CANbus TDM and TD Serial Data options are unique oscilloscope tools from LeCroy which greatly increase your ability to debug and analyze embedded controllers that use CAN. The TDM product include Serial Trigger, Decode and Measure/Graph capabilities, the TD product include Serial Trigger and Decode.

The CAN trigger is integrated into the oscilloscope - meaning no external hardware is used. It's selected through the normal oscilloscope trigger menus. CAN signals are sent to the oscilloscope using a differential probe like the ADP305 or AP033. Decoding is accessed from the Analysis menu. The decoding is overlaid on top of the appropriate channel, and is intuitively presented and color-coded for quick understanding. Measurement and graphing capabilities may be accessed through the Measure/Graph tab in the Decode Setup or from the Measure menu. All

CANbus Trigger, Decode, and Measure

packages contain Search capability for specific IDs, Data and Errors and a Table displays summarized protocol data underneath the oscilloscope grid.

Compatibility

The CANbus TDM option is compatible for WavePro Zi and WaveRunner Xi oscilloscopes. The CANbus TD option is compatible with the WavePro Zi, WaveRunner Xi and WaveSurfer Xs oscilloscopes. CAN triggering is completely integrated with the oscilloscope and no external hardware is required. Earlier versions of LeCroy's CANbus TDM and TD options required the use of an external trigger module, for documentation on how to use the external trigger module please see the appendix. The external trigger module is still available for use with WaveMaster 8000A, WavePro 7000A, and WaveRunner 6000A oscilloscopes.

Note: All references to Decode and Measure/Graph capabilities and functionality are identical whether the external or internal CAN trigger is being used.

Assumptions

This manual assumes a basic understanding of the FlexRay standard physical layer and protocol layer specifications, and knowledge of how FlexRay is used. Also, a basic understanding of oscilloscope operation - specifically the LeCroy oscilloscope which the FlexRay trigger, decode, and physical layer option is used with - is assumed. Wherever practical or necessary, details on specific oscilloscope features have been included in this manual.

Note: LeCroy has a policy of frequently updating software. While screen images in this manual may not exactly match what is seen on your oscilloscope display, be assured that the functionality is 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 oscilloscope, an additional icon is shown on your trigger dialog box. It allows a serial trigger condition to be set from within the oscilloscope using an easy-to-understand interface.

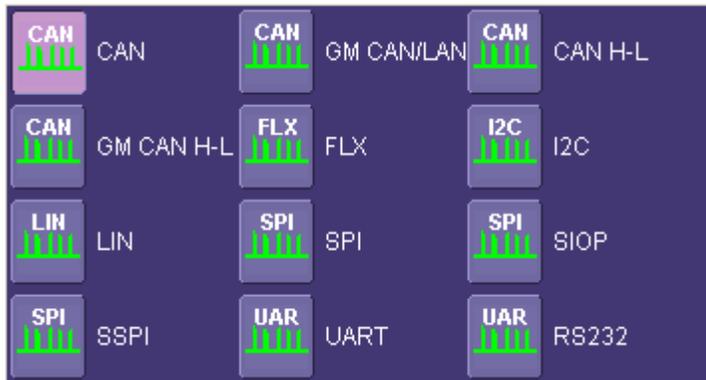


2. **Serial Decode** - If this is the first serial decode option you have installed on your scope, an additional set of Serial Decode and Decode Setup dialog boxes are provided for setup of

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.



Note: SIOP and SSPI are part of the SPIbus TD package. RS232 is part of the UART-RS232bus TD package.

The TDM Series Software

The TDP 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 oscilloscope, an additional icon is shown on your trigger dialog box. It allows a serial

CANbus Trigger, Decode, and Measure

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 are provided for setup of protocol format (as necessary) and decoding. These can be accessed from the Analysis menu.



3. **Decode Protocol Selections** - CAN is one of several signal types that can be decoded by the oscilloscope. Other standards include I2C, SPI, UART, RS-232, LIN, and FlexRay.



4. **Measure/Graph Setup** - CAN measurement and graphing functions are accessed through the Serial Decode setup by selecting the Measure/Graph Setup tab.

Using the CANbus Options

Overview of CANbus TD (Trigger and Decode)

The CANbus TD option contains 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 CANbus TD option allows triggering on CAN Frames and Errors. Frame triggering can be set to trigger on any frame, one specific Frame ID, a range of Frame IDs, Remote Frames and Errors. Frame triggering and data triggering can be done for a single ID or message or a range of IDs and data by using the conditional trigger capabilities. Other powerful and user-friendly features included in CANbus TD include:

- The ability to trigger and decode CAN at bit rates from 10 kb/s to 1 Mb/s.
- The ability to create powerful, conditional Frame ID and Data triggers.
- Triggering on CAN protocol errors and remote frames.

If you are unfamiliar or are just learning about CAN, start by using the simplest trigger conditions (All Frames or Frame ID). Next, experiment with an ID and Data to trigger on a specific value. Then, try a conditional ID + Data trigger (ID Greater Than or In Range).

Accessing Serial Triggers

The CANbus serial trigger is accessed from the oscilloscope trigger dialog. Use one of the following methods:

- Touch the Trigger Descriptor Box in the lower right hand corner of the oscilloscope display.

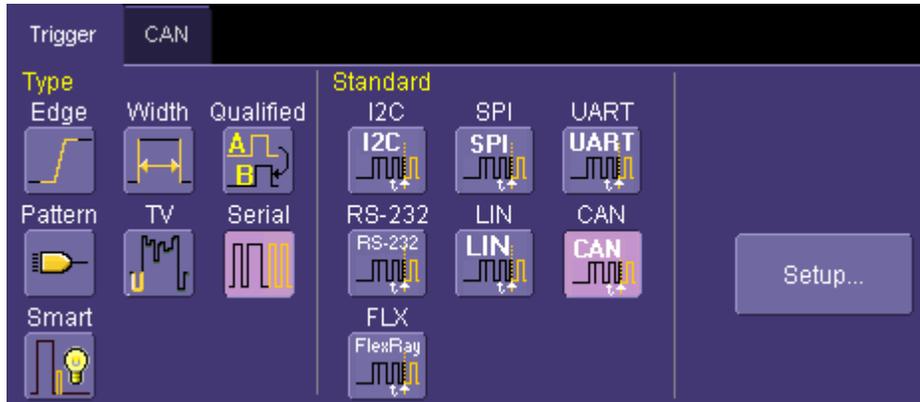


OR

- Touch **Trigger** → **Trigger Setup** from the Menu Bar. On the Trigger dialog, touch **Serial** on the Type section.

Select the appropriate serial trigger. The menu automatically changes to a different tab in the Trigger dialog reflecting the selected standard.

CANbus Trigger, Decode, and Measure



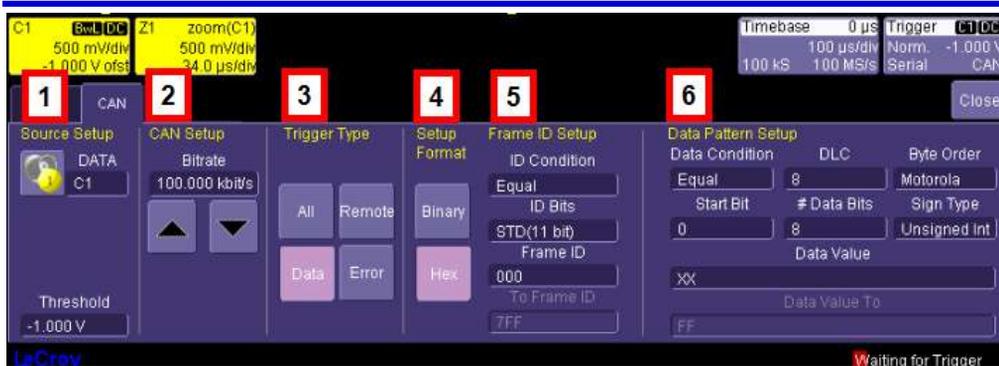
Creating a CANbus Trigger Condition

The CANbus Trigger dialog, with detail on some of the setup conditions, is shown in the following topics.



CANbus Trigger Setup Detail

The following topics show the dialog selections for a CANbus Trigger.



The previously numbered CANbus trigger sections correspond with the following explanations.

1. Source Setup

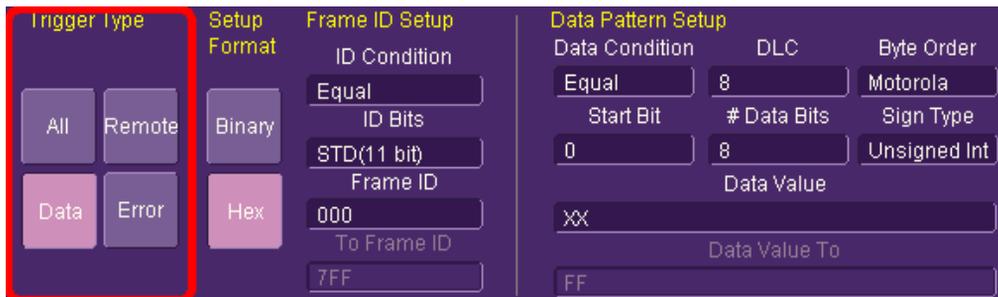
- **DATA** - The **DATA** field's pop-up dialog is used to select the appropriate channel or EXT input for each. Set this field up with caution or your trigger may not function correctly. Use the **Threshold** field to adjust the vertical level for the trigger. Much like an Edge trigger, a user must 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.

2. CAN Setup

- **Bitrate** - Use the Bitrate field to adjust the value and match the bus to which you are connected. This bitrate selection is dynamically linked to the decoding bitrate (they are always the same value). Use the arrows to move through standard bit rates (10, 25, 33.333, 50, 83.333, 100, 125, 250, 500, and 1000 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.

3. Trigger Type

Trigger Type - Depending on your Trigger Type selection, certain Frame ID and Data Pattern Setup fields are enabled or disabled as follows:



- **All** - Triggers on all signals. No Frame ID and Data Pattern ID Setup fields are enabled.

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- **Remote** - Only Frame ID Setup fields are enabled.
- **Data** - Both Frame ID and Data Pattern ID Setup fields are enabled.
- **Error** - Triggers only when an error signal occurs. No Frame ID and Data Pattern ID Setup fields are enabled.

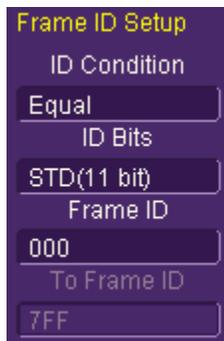
4. Setup Format

Select either **Binary** or **Hexadecimal (Hex)** setup mode. The mode selected propagates through the entire CANbus trigger setup.

Try selecting Binary mode, and set up the Frame ID in binary format, then re-select HEX mode and set up the data in hexadecimal format. Toggling back and forth between the modes does not result in loss of information.

5. Frame ID Setup

Frame ID Setup is used to trigger on a specific Frame ID value with either 11 or 29 Bits.



The screenshot shows a configuration window titled "Frame ID Setup" with a purple background. It contains several input fields: "ID Condition" with a dropdown menu showing "Equal"; "ID Bits" with a dropdown menu showing "STD(11 bit)"; "Frame ID" with a text input field containing "000"; and "To Frame ID" with a text input field containing "7FF".

When CANbus trigger selections are either Remote or Data, use the Frame ID Setup fields as follows:

- **ID Condition** - The ID condition can be set to many different values. If the ID condition is set to "=", then a data definition can also be set. Any other ID condition precludes setting up a Data condition.

The ID condition can be set to <=, <, =, >, >=, not =, in a range, out of a range, or don't care.

- **ID Bits** - The trigger can be set to trigger on CAN messages with either 11-bits (Standard CAN) or 29-bits (Extended CAN). You can also set the trigger so that it triggers on a message that meets a condition for either the 11-bit or 29-bit ID. For instance, there might be an 11-bit ID value that is present in both an 11-bit and a 29-bit ID, and by choosing ALL, you could trigger when that ID is present on either of those messages.
- **Frame ID** - Specify the desired frame ID for triggering here.

- **To Frame ID** - When using an in range or out of range ID Condition (previous), specify a To Frame ID value for triggering.

6. Data Pattern Setup

Fields on this section of the dialog are only enabled when using the Data trigger type.

Data Condition	DLC	Byte Order
Equal	8	Motorola
Start Bit	# Data Bits	Sign Type
0	8	Unsigned Int
Data Value		
XX		
Data Value To		
FF		

- **Data Condition** - The Data Condition can be set to many different values. The Data condition can be set to \leq , $<$, $=$, $>$, \geq , $\text{not } =$, in a range, out of a range, or don't care.
- **DLC** - The DLC (data length code) can be set to any integer value from 0 to 8. It should match the DLC of the CAN message you want to trigger on. If you set it to a value less than 0, it will default to 0. If you set it to a value greater than 8, it will default to 8.
- **Byte Order** - Choose from either Motorola (default) or Intel byte orders.
- **Start Bit and # Data Bits** - The CANbus trigger allows you to trigger on up to 64 contiguous data bits (8 data bytes). This maximum 64-bit string can start at any location in the CAN message data field - it is not limited to the start of a full byte or a nibble.

The Start Bit can be any value from 0 to 63. If you enter a value less than 0, it will default to 0. If you enter a value more than 63, it will default to 63. The Start Bit value is always in LSB format (i.e., the bit number as shown on the decoded waveform, with bit 0 being at the far left and bit 63 being at the far right of the data string). Remember that the 1st data byte is bits 0-7, the 2nd data byte is bits 8-15, etc. Also, make sure that your Start Bit value makes sense in relation to the DLC Value. For instance, a Start Bit value of 32 with a DLC Value of 4 is not going to result in a successful trigger.

The # Bits can be any value from 1 to 64. If you enter a value less than 1, it will default to 1. If you enter a value more than 64, it will default to 64.

- **Sign Type** - Choose between signed and unsigned integer format.
- **Data Value and Data Value To** - The Data Value is set in Binary or Hexadecimal format. For Hexadecimal, if desired, you can precede the ID value with "0x", but this is not necessary. Be sure to enter a Data Value that matches the DLC Value.

CANbus Trigger, Decode, and Measure

When using an in range or out of range Data Condition (previous), specify a **Data Value To** value for triggering.

CANbus Decode Setup Detail

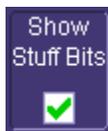
CANbus Decode Setup Right-Hand Dialogs are shown when CAN is selected as the decode protocol. It provides detailed fields and setup conditions as follows:



- **Viewing** - The decode format is displayed here as Hexadecimal for CANbus.
- **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 (10, 25, 33.333, 50, 83.333, 100, 125, 250, 500, and 1000 kb/s) and make a selection. Or, touch the number twice (with a finger, or using a mouse) and open the pop-up keypad to enter the value directly. Any value from 10-1000 kb/s may be entered in this way.



- **Show Stuff Bits** – Use this checkbox to indicate whether you want stuff bits highlighted on each CAN message frame.

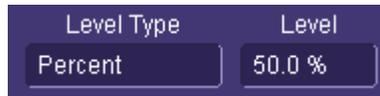


- **Level Type** and **Level** - The message decoding algorithm setup is performed here. The level is normally set up in %, and defaults to 50%. To adjust the level, touch inside the number area to highlight the box title in yellow, then use the oscilloscope front panel

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.



Measuring CANbus Performance Using CANBUS TDM

Overview of CANbus TDM (Trigger, Decode, Measure/Graph)

Basic oscilloscope tools can be extremely helpful to understand single-shot events. However, their utility in measuring performance of a CAN Bus system can be very limited. It is usually necessary to obtain large quantities of data before you can be sure that system performance is within specified limits. The following are typical examples of actions to assess CAN Bus system performance:

- **Measure Timing Δ Between CAN and Analog Signals & Accumulate Statistics** - Measure the time difference between an analog signal and CAN signal generated in response to it (or vice-a-versa). View the mean, minimum, and maximum timing values, the number of samples, and the standard deviation of the measurements.
- **Measure Timing Δ Between Two CAN Messages & Accumulate Statistics** - Same as previous, but with two CAN signals.
- **Measure Timing Δ From the Trigger Point to a CAN Message** - Same as previous, but the trigger point can be anything - a CAN message, an Analog signal, a Pattern of signals, a Dropout condition, etc.
- **Measure Timing, Accumulate Statistics, View Distribution** - Instead of just looking at numerical values, graph/plot the distribution as a histogram to better understand the shape of the distribution, the quantity of extreme events, and determine underlying cause.
- **Graph/Plot CAN Data Values from a Single Acquisition** - Extract CAN Data values in decimal format and compare them to an analog signal in a time-correlated fashion.
- **Graph/Plot CAN Data Values Over Multiple Acquisitions** - Extract CAN Data values in decimal format and graph/plot them over multiple acquisitions.
- **Measure CAN Bus Load, Graph/Plot** - Understand how bus loading relates to other CAN and Analog signal events.

CANbus Trigger, Decode, and Measure

Some of this information could be gathered using standard oscilloscope tools, but the accumulation of the data would take hours or days. It is more likely that the engineer would instead gather a very small sample set and skip the statistical evaluation in order to save time. The result is reduced product quality and corresponding greater risk of shipping product that functions incorrectly in some situations.

CANbus TDM contains specific CAN measurement parameters that allow you to quickly and easily accumulate statistical information on a wide variety of events, and graphical display tools to visualize the data on your oscilloscope screen. These sophisticated measurement and graphical display tools are the “missing link” between standard oscilloscope and protocol analyzer capability. The CANbus TDM tools provide the capability to trigger on defined CAN Bus events, observe actions/reactions, measure timing among CAN and Analog signals, and view results in a graphical fashion directly on the oscilloscope display with no complicated export of data. Data on tens of thousands of events can be automatically and quickly gathered and analyzed in a fraction of the time it takes to manually perform the same testing.

CANbus TDM contains additional CAN specific measurement, graphing, and statistical analysis capability as the following topics explain.

CANBUS TDM Parameters

	CAN Message to Analog Signal timing (CANtoAnalog)
	Analog Signal to CAN Message timing (CANtoAnalog)
	CAN Message to CAN Message Signal Timing (CANtoCAN)
	Time from trigger to a specific CAN message (Time@CAN)
	CAN Bus Message Load Percentage (CANLoad)
	Extract CAN Message Data to a Decimal Value (CANtoValue)

CANbus TDM Graphing and Statistical Analysis

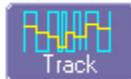
- **Histogram** - The Histogram displays a statistical distribution of a measurement parameter. Histogram is helpful to understand the modality of a measurement parameter, and to debug the root cause of excessive variation.



- **Trend** - The Trend statistical tool visualizes the evolution of a timing parameter over time in the form of a line graph. The graph's vertical axis is the value of the parameter; its horizontal axis is the order in which values were acquired. Trend is typically used for a multi-shot acquisition. Trend is analogous to a chart recorder.



- **Track** - The Track displays a time-correlated accumulation of values for a single acquisition. Track can be used to plot the values of CAN data and compare them to a corresponding analog signal, or observe changes in timing. Track is typically used for a single-shot acquisition. A long acquisition with many parameter measurements analyzed with Track could provide information about the modulation of the parameter.



CANbus Trigger, Decode, and Measure

In addition to the Histogram graphing capability, there are also 19 different measurement parameters that apply specifically to Histograms. These are listed below (more information is contained in Appendix D):

- **fwhm** - full width (of largest peak) at half the maximum bin
- **fwxx** - full width (of largest peak) at xx% the maximum bin
- **hist ampl** - histogram amplitude between two largest peaks
- **hist base** - histogram base or leftmost of two largest peaks
- **hist max** - value of the highest (right-most) populated bin in a histogram
- **hist mean** - average or mean value of data in the histogram
- **hist median** - value of the x-axis of a histogram that divides the population into two equal halves
- **hist min** - value of the lowest (left-most) populated bin in a histogram
- **hist rms** - rms value of data in histogram
- **hist sdev** - standard deviation of values in a histogram
- **hist top** - histogram top or rightmost of two largest peaks
- **max populate** - population of most populated bin in histogram
- **mode** - data value of most populated bin in histogram
- **percentile** - data value in histogram for which specified 'x'% of population is smaller
- **peaks** - number of peaks in histogram
- **pop @ x** - population of bin for specified horizontal coordinate
- **range** - difference between highest and lowest data values
- **total pop** - total population in histogram
- **x at peak** - x-axis position of specified largest peak

These measurement parameters are available in the **Statistics** category in the measurement selection pop-up dialog.

General Setup of CANbus TDM Parameters

There are two different ways to set up CAN related measurements. The easiest way is to use the **Measure** tab in the **CAN Analysis** dialogs to access the **CAN Measure** dialog. This dialog is specifically tailored to meet the needs of an engineer who is debugging CAN-based systems. It contains different categories of CAN, pulse, statistical, etc. measurement parameters that are commonly used to measure CAN system performance.

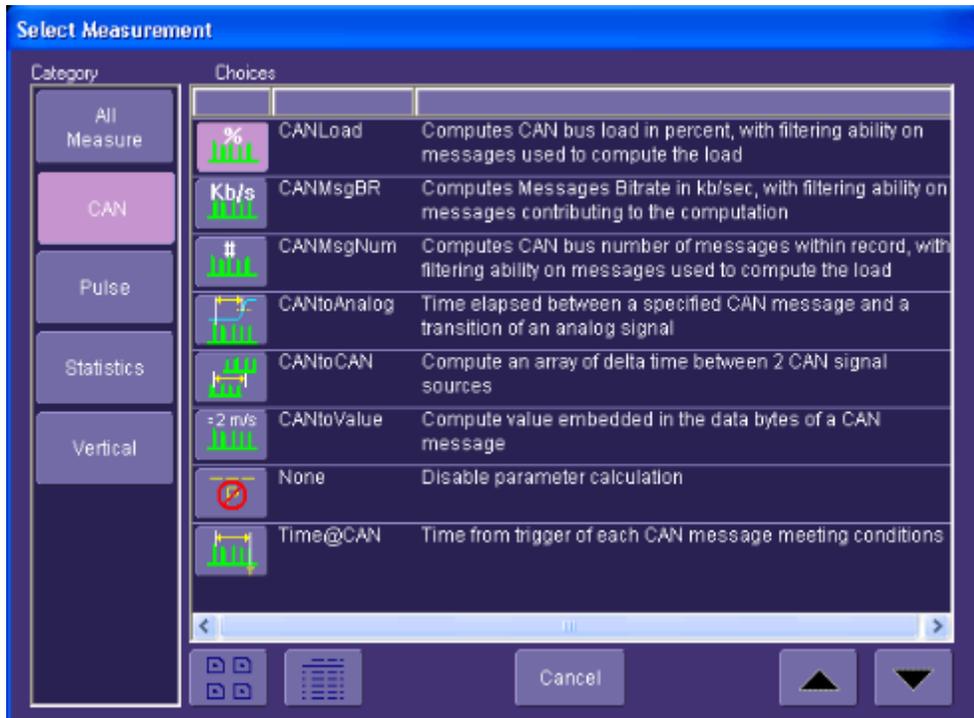
Setting Up CANbus Parameters using the Serial Decode option

1. Touch the Measure/Graph Setup tab in the CAN Serial Decode dialogs. There are four parameter measurements displayed (P1 through P4).



CANbus Trigger, Decode, and Measure

- For a specific measurement parameter, touch the parameter icon or parameter name to access the CAN Measurement Select pop-up dialog.



- From the CAN **Select Measurement** window, choose a parameter. Touch an icon to select the measurement.
- Touch the source field to open the **Select Source** pop-up dialog. Select a category to display the available sources, then select the appropriate source.

Note:The source for the CAN measurements should be Decode1, Decode2, Decode3 or Decode4 depending on which serial data decode is being used to decode the bus you are trying to measure.

- The **View and Load Table** checkbox is checked automatically when you select your parameters. Uncheck it to turn measurements OFF.

Note: Measurement parameter and source selections that are set up in the CAN Measure menu are copied to the oscilloscope standard Measure menu.

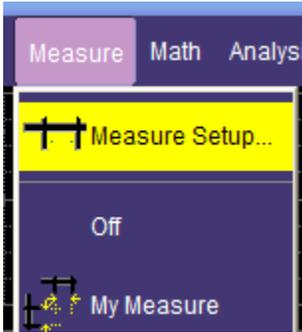
6. Many parameters (and all CAN-specific parameters) require some additional setup information to be entered in order to work correctly. To access the setup dialog, touch the **Setup** button.

CANbus Trigger, Decode, and Measure

Setting Up CANbus Parameters using the Measure Setup option

You can also set up measurement parameters using the Measure menu as follows:

Touch **Measure**→**Measure Setup**. select the appropriate CAN or other parameter. For more information, see **Parameter Setup** in the oscilloscope's Online Help or Operator's Manual.



Note: All CAN measurement parameters (with the exception of CAN Load %) calculate as many values as possible during each acquisition. If there are 10 timing events that meet the set condition during a specific acquisition, 10 timing event measurements will be returned. However, the VALUE shown in the measurement table is the last measurement made. To view statistical data (i.e., number of measurements made, mean, min, max, std. dev.), turn Statistics ON.

CAN Load % returns only one value during each acquisition, since it is evaluating the load % for the entire acquisition time.

CAN-to-Analog or Analog-to-CAN Measurement Parameter

CAN Message to Analog Signal timing (CANtoAnalog)



This measurement parameter is used to measure timing from either a CAN Message to an Analog Signal, or from an Analog Signal to a CAN Message. The Frame Type, ID, DATA, etc. conditions for the CAN message can be fully defined, as can the slope, level, etc. conditions for the analog signal transition.

If measuring from CAN to Analog, the timing is always measured from the End of Frame of CAN message to the analog signal transition. If measuring from Analog to CAN, the timing is always measured from the analog signal transition to the Start of Frame of the CAN message.

Note: Source 1 should always be defined as the CAN Decode source and Source 2 should always be defined as your Analog Signal (either a channel, memory, etc.), regardless of whether you wish to measure from CAN to Analog or Analog to CAN. Analog to CAN values will simply be reported as negative values.

CANbus Trigger, Decode, and Measure

CAN-to-Analog Parameter Setup

To access the setup dialog, touch **Setup** for that particular parameter on the CAN Measure/Graph Setup dialog. The Px Parameter dialog will be displayed. On the right side of this dialog box, there is an additional setup dialog:

The screenshot shows the 'CAN Message' tab of a parameter setup dialog. At the top, there are four tabs: 'CAN Message', 'Analog Signal', 'More', and 'Close'. The 'CAN Message' tab is selected. Below the tabs, the following fields are visible: 'Frame Type' set to 'Data', 'Data Condition' set to '=', 'ID' set to '0x00', and 'DLC' set to '0'. Below these are eight input fields for bytes, labeled 'Byte #0' through 'Byte #7', each containing the value '0x00'.

The CAN Message tab defines the CAN Message Setup. The Analog Signal tab defines the Analog Signal Setup.

Note: The CAN Message tab always defines the CAN Message Setup and the Analog Signal tab always defines the Analog Signal setup even if you are measuring time from an Analog Signal to a CAN Message. The CAN Message setup is nearly identical to the setup of the CAN message in the [CAN Trigger dialog](#), so details will not be repeated here.

The Analog Signal setup dialog is shown below:

The screenshot shows the 'Analog Signal' tab of a parameter setup dialog. At the top, there are four tabs: 'CAN Message', 'Analog Signal', 'More', and 'Close'. The 'Analog Signal' tab is selected. Below the tabs, the following fields are visible: 'Level is' set to 'Percent', 'Percent level' set to '50 %', 'Slope' set to 'Pos', and 'Hysteresis' set to '500 mdiv'. A 'Find Level' button is located to the right of the 'Percent level' field.

Select the measurement level as **Percent** or **Absolute**, and set a value. Then select the slope of the edge to which you want to measure. The **Hysteresis** selection imposes a limit above and below the measurement Level, which precludes measurements of noise or other perturbations within this band. The width of the band is specified in milli-divisions. Guidelines for using Hysteresis are as follows:

- Hysteresis must be larger than the maximum noise spike you want to ignore.
- The largest value of hysteresis usable is less than the distance from the level to the closest extreme value of the waveform.
- Unless you know the largest noise and closest extreme level that will ever occur on any cycle, leave some margin on both sides of the level.

Note: Various pathological conditions can block the computation of the CANtoAnalog and CANtoCAN parameters. In all cases, the cause of the condition can be viewed on the message line by clicking on the yellow icon , below the measurement parameter values.

The simplest, and most common, reason for non-computation of the CAN timing parameters is that none of the CAN Message or Analog Signal conditions defined in the right-hand dialog is encountered in the whole record processed by the algorithm. In this case the error message will be "Cannot find Start and/or End condition on input of CAN2CAN or CAN2Analog."

Another possible cause is that the time frames of the 2 inputs specified do not overlap at all. The error message will be "No Common Time Span exists between inputs"

Finally, the sequence of occurrence of the CAN Message or Analog Signal conditions defined in the right-hand dialog setup tab can lead to ambiguous results. (Too many CAN conditions for each Analog condition, nested CAN and Analog conditions). In this case the message line will show: "Ambiguous Start/End time relationship for CAN2CAN or CAN2Analog".

CAN Message-to-CAN Message Measurement Parameter

CAN Message-to-CAN Message timing (CANtoCAN)

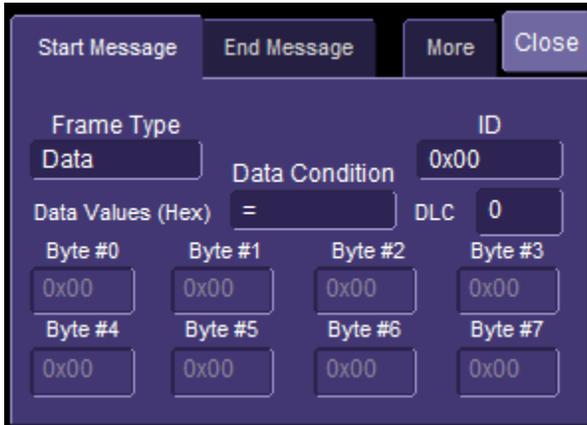


This measurement parameter is used to measure timing values between two CAN Messages. The Frame Type, ID, DATA, etc. conditions for the CAN message can be fully defined for both CAN messages. The timing is always measured from the End of Frame of the first CAN message to the Start of Frame (SOF) of the second CAN message.

CANbus Trigger, Decode, and Measure

CANtoCAN Measurement Parameter Setup Detail

To access the setup dialog, touch **Setup** for that particular parameter on the **CAN Measure/Graph Setup** dialog. The Px Parameter dialog is displayed. On the right side of this dialog box, there is a setup dialog labeled with the measurement parameter name. Touch the tab with the parameter name on it to access the following dialog:



Start Message	End Message	More	Close
Frame Type	Data Condition		ID
Data	=		0x00
Data Values (Hex)	DLC 0		
Byte #0	Byte #1	Byte #2	Byte #3
0x00	0x00	0x00	0x00
Byte #4	Byte #5	Byte #6	Byte #7
0x00	0x00	0x00	0x00

The Start Message tab defines the first CAN Message Setup. The End Message tab defines the second CAN Message Setup.

Note: The CAN Message setup is nearly identical to the setup of the CAN message in the [CAN Trigger dialog](#), so details will not be repeated here.

The two CAN message definitions can be different, or they can be the same. If they are different, the time value measured will be from the first CAN message to the second, with a positive value indicating that the second message occurred after the first message, and a negative value indicating that the second message occurred before the first.

If you wish to measure the time between two identical CAN messages, the Data Condition must be set to “Don’t Care.” Then, if there are “n” CAN messages that satisfy the condition, you will get “n-1” measurements. Measurements would be made between all adjacent pairs that satisfy the condition.

Note: Various pathological conditions can block the computation of the CANtoAnalog and CANtoCAN parameters. In all cases, the cause of the condition can be viewed on the message line by clicking on the yellow icon , below the measurement parameter values.

The simplest, and most common, reason for non-computation of the CAN timing parameters is

that none of the Start or End condition defined in the right-hand dialog is encountered in the whole record processed by the algorithm. In this case the error message will be "Cannot find Start and/or End condition on input of CAN2CAN or CAN2Analog."

Another possible cause is that the time frames of the 2 inputs specified do not overlap at all. The error message will be "No Common Time Span exists between inputs"

Finally, the sequence of occurrence of the Start or End conditions defined in the right-hand dialog can lead to ambiguous results. (Too many Start conditions for each End condition, nested Start and End conditions). In this case the message line will show: "Ambiguous Start/End time relationship for CAN2CAN or CAN2Analog."

Extract CAN Message Data to a Decimal Value

Extract CAN Message Data to a Decimal Value (CANtoValue)



This measurement parameter is used to extract CAN message data in any sequential byte/bit location and display it as a decimal value that is rescaled to specific operator set units of measure. Essentially, it allows the conversion of a bit field embedded into a CAN message into a value with user-definable units.

CANtoValue Measurement Parameter Setup Detail

To access the setup dialog, touch **Setup** for that parameter in the CAN Measure/Graph Setup dialog. The Px Parameter dialog box is displayed. On the right side of this dialog box, there is a setup dialog labeled with the measurement parameter name. Touch the tab with the parameter name on it, and you will access the following dialog:

CAN to Value Gate Accept Close

Transforms data byte(s) of CAN messages into a value with units

ID bits Coefficient

ID Term

Format Unit

Type

Start bit Bit Width

CANbus Trigger, Decode, and Measure

You must specify the ID length and ID Value for the CAN Messages that you wish to extract data from. The measurement parameter will process all messages meeting the ID condition in the acquisition, and apply the same conversion to them.

The conversion process requires the **Format** in which the value is embedded (Intel or Motorola), the **Type** of value (Integer or Float) and the bit window occupied by the value. The window is specified with a **Start Bit** and a **Bit Width** for integers. Floating point values always use a Bit Width of 32.

Finally, the last stage of the conversion process transforms the raw value into a physical value with units, using a linear transformation of the type $\text{Parameter Value} = \text{Coefficient} * \text{Raw Value} + \text{Term}$. Units can be specified as well, provided they belong to the list given in "Rescaling and Assigning Units" under Waveform Math. The unit specified here will propagate throughout the system to the parameter value, subsequent Tracks and Trends, and cursor readout on any derived function.

Note: The default coefficient and term will apply no transformation to units of the raw value.

All the entries required in this dialog are usually provided by sensor or actuator manufacturers, or can be read out of commercially available tools using DBC files.

Using this measurement parameter, you can graph data using the [Trend or Track function](#).

CAN Bus Message Load Percent Measurement Parameter

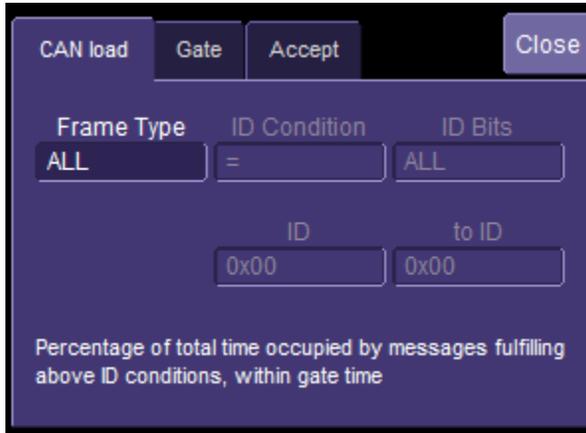
CAN Bus Message Load Percentage (CANLoad)



This measurement parameter is used to measure total bus load within the captured record for messages that meet a defined set of conditions. The "load" formula is the sum of the message length(s) from SOF to EOF divided by total acquisition length.

CANLoad Measurement Parameter Setup Detail

To access the setup dialog, touch **Setup** for that parameter in the **CAN Measure/Graph Setup** dialog. The Px Parameter dialog box is displayed. On the right side of this dialog box, there is a setup dialog labeled with the measurement parameter name. Touch the tab with the parameter name on it, and you will access the following dialog:



Frame type can be ALL, Remote, Data, or Error type. ID conditions can be set, and IDs specified. The operation is much the same as the [CAN Trigger setup](#), so the detail will not be repeated here.

CANbus Trigger, Decode, and Measure

Time from Trigger Point to CAN Message Parameter

Time from Trigger Point to CAN Message (Time@CAN)



This measurement parameter is used to measure the time from the trigger point to the defined CAN message. The trigger could be a CAN message, a simple edge trigger, or something more complicated, like a Pattern or a Dropout SMART Trigger. This makes it a very powerful tool to understand the time delay from the occurrence of a certain set of conditions to the start of a CAN message.

Time@CAN Measurement Parameter Setup Detail

To access the setup dialog, touch **Setup** for that parameter in the **CAN Measure/Graph Setup** dialog. The Px Parameter dialog box is displayed. On the right side of this dialog box, there is a setup dialog labeled with the measurement parameter name. Touch the tab with the parameter name on it, and you will access the following dialog:



Characterizing CANbus System Performance

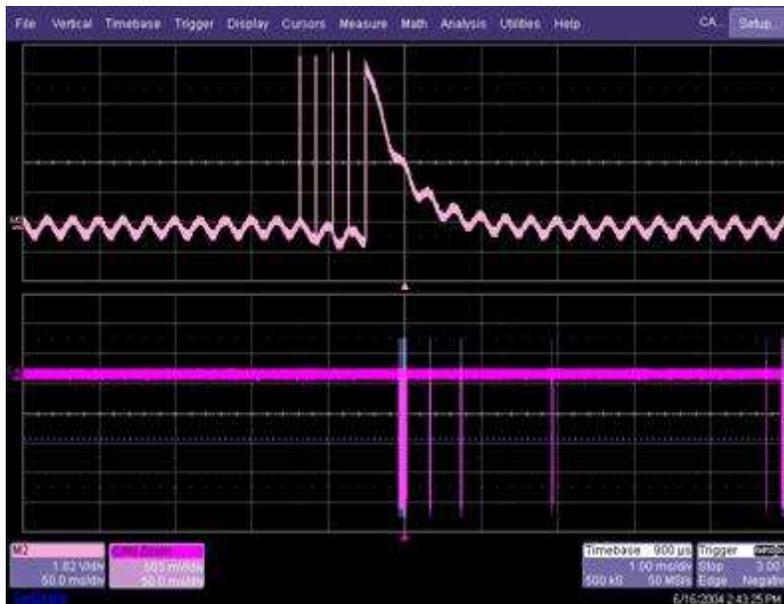
System Performance Characterization Overview

The oscilloscope contains a number of built-in tools, such as cursors, measurement parameters, statistics, and optional graphical analysis tools that you can use to characterize your CANbus system's performance. These can be used on the CAN Trace and CAN Zoom just like they are used on any channel. 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 CAN message.

You can 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 helpful to determine the underlying integrity of the CAN physical signal.

CANbus Trigger, Decode, and Measure

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 channels and the CAN Trace to view the signal with enough detail. This is a good method for single-shot / single measurements.



CANbus Trigger, Decode, and Measure

Using Measurement Parameters

You can use measurement parameters to make signal integrity or timing measurements of your CAN Bus system. 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 a CAN Trigger to an analog signal). Delta Trig Time is ideal for measuring the time between segments of a Sequence Mode acquisition.



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 bimodal waveform, such as a 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.



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.



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.



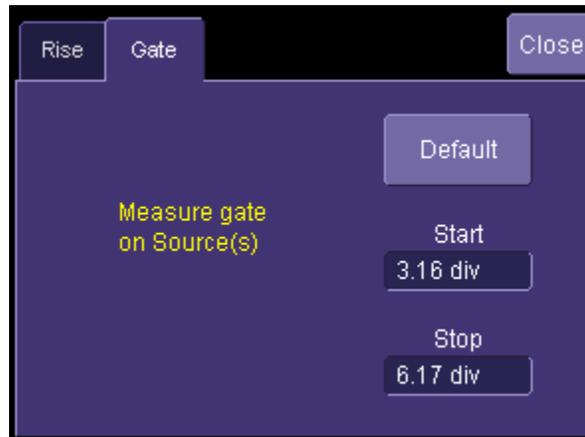
Rise (10-90), Rise (20-80), Rise@Level - Transition time on the rising edge. Three selections are available for the user to determine at which vertical level the measurement is made.



Top - Value of the uppermost state in a bimodal waveform, such as a CAN Message.

Measurement Gating

Gating is available on each 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.



1. Touch the the appropriate measurement (P1, P2, etc.) or choose **Measure→Measure Setup** and then touch the appropriate measurement tab (P1, P2, etc.).
2. Touch the **Gate** tab and enter the start and stop for the gate.

Using Statistics and Graphing

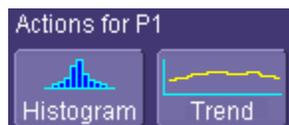
Statistics and Histicons are included with every LeCroy oscilloscope. They allow you to gather numerical and visual information on the distribution of your various measurements.

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

CANbus Trigger, Decode, and Measure



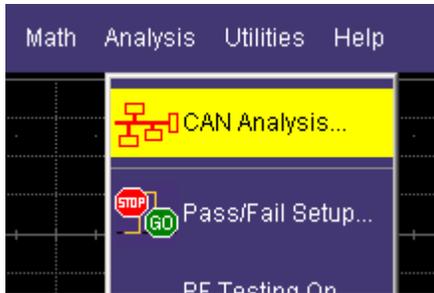
In addition, some optional LeCroy programs add the capability to produce larger histograms and trends of your measurement parameters. If you have this capability, then you can access it through the Measurement Parameter setup dialog (the Px tab).



Pass/Fail Analysis with Measurement Parameters

Pass/Fail analysis using measurement parameters is simple to set up and 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, 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.

Touch **Analysis**→**Pass/Fail Setup** to set up pass/fail conditions.



Isolating and Analyzing CANbus Activity

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.

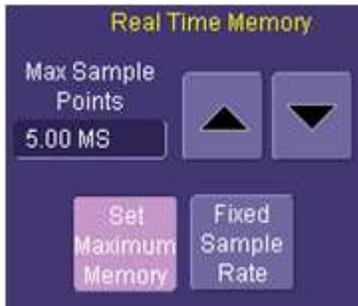
Some common Serial Data analysis needs and methods are discussed below:

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.

CANbus Trigger, Decode, and Measure



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. Touch **Set Maximum Memory** to decrease the memory usage in order to not sample at rates you specify as being too high (high sample rates can slow down the decoding algorithm). Then adjust your time timebase setting to the length needed to capture the event.

Note: Make sure your combined timebase and memory length settings do not result in too low of a sample rate. Otherwise, adequate capture and decode is not performed.

4. Touch **Fixed Sample Rate** to specify a fixed rate. It's common to fix the sample rate to a specified value so you have the necessary oversampling to capture your Serial Data messages (at least 4X the bit rate). This also allows for a high enough sample rate to capture transients you may want to see on your Serial Data and analog signals (at least 2X the frequency of any expected transients, preferably 10X).

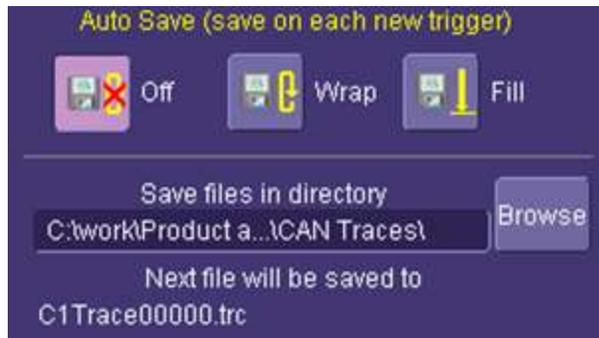
Reference your oscilloscope's Online Help for more information on these common settings.

Trigger Repeatedly, Save Data to a Hard Drive

You may want 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, there is significant trigger "dead time" when using this method. To minimize dead time, use the method described in **Trigger Repeatedly, Store all Triggers (Sequence Mode)**.

1. Set up your desired serial data (or other) trigger condition.
2. Choose **File → Save Waveform** from the menu bar. A dialog is shown where you can set Save Waveform conditions as follows:
 - **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

- **FILL** - Auto Save occurs until the hard drive is filled



PLEASE NOTE THE FOLLOWING:

- Choose a Binary file format if you want 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.
- This method is not guaranteed to capture all of your trigger events, since there is 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. Minimize dead time by using Sequence Mode.

Trigger Repeatedly, Store all Triggers (Sequence Mode)

LeCroy oscilloscope's have a powerful capability called Sequence Mode that allows 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).

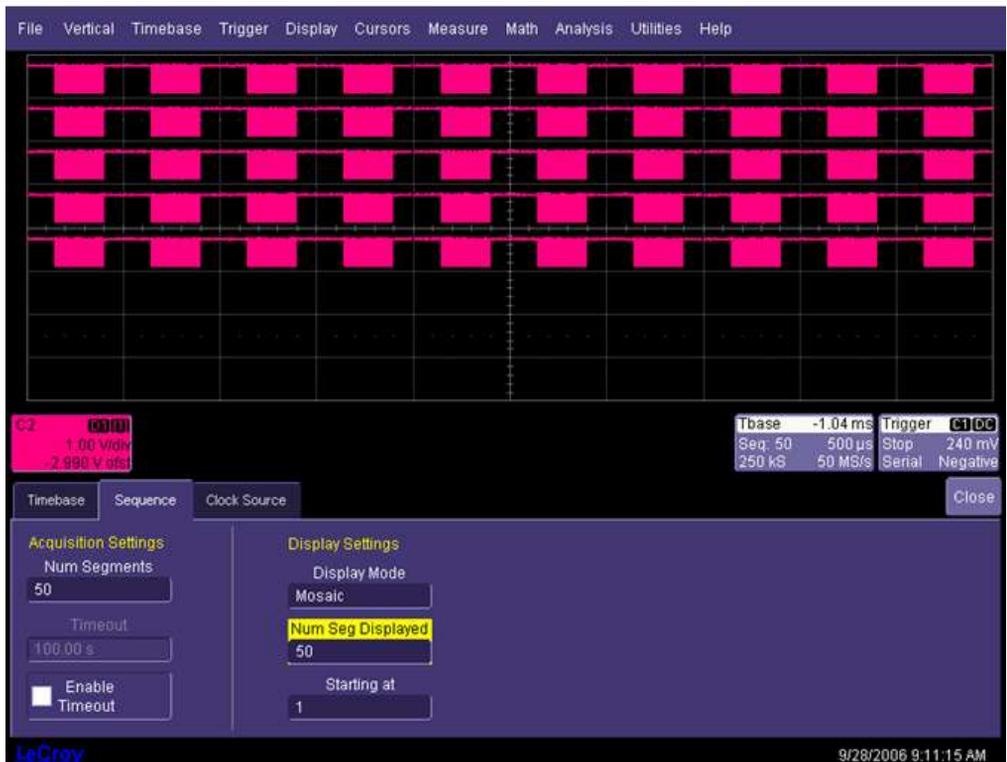
Sequence Mode uses long acquisition memory that is divided into “segments.” As triggered events are acquired, they are stored in acquisition “segments” to be recalled at a later date. The length of each sequence mode acquisition segment and the total number of segments allowed is roughly determined by the total acquisition memory in the oscilloscope. For instance, a WaveRunner Xi with VL memory can acquire 10,000 segments each a maximum of 625 samples long or 10 segments 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 (as 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.

CANbus Trigger, Decode, and Measure

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**. Touch the **Sequence** tab.
3. On 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 at which to start the display.
5. Set up the Serial Trigger to capture an event. 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 I2C Start trigger. To begin the sequence mode acquisition, press the front panel SINGLE trigger button. Each time the trigger condition is met, the TRIG'D light on the front panel flashes. When you've acquired the set number of segments, the trigger STOPS and the following display is shown (this is a 50 segment acquisition in Mosaic display mode).



6. Display an individual segment separately from the main channel display by selecting **Math**→**Math Setup** from the menu bar. Then, choose a math trace to define as a Segment (here we're defining F1 as a Segment of C2).

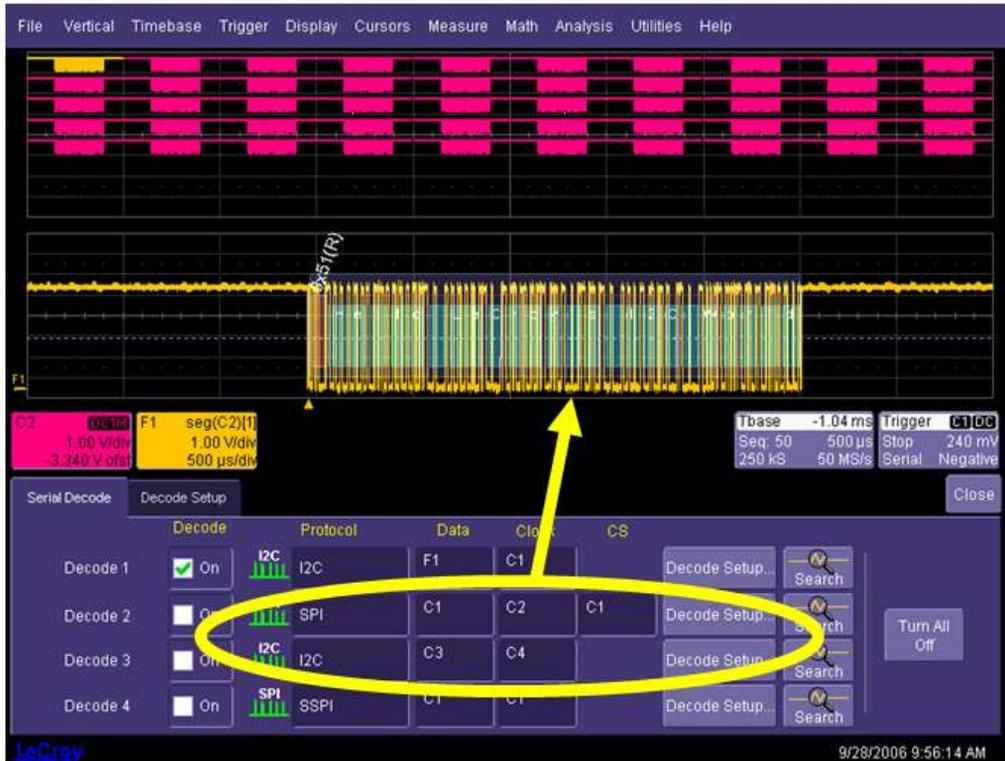
CANbus Trigger, Decode, and Measure

Use the channel the serial data was acquired on as a source (in this case Channel 2). Check the **TRACE ON** checkbox to display the trace. Select a segment to view by touching the **Select** tab and use either the pop-up keypad or the front panel adjust knob.



7. Set up the Decode to use the Math trace as the source for Data in order to view decoded data on the individual segment (in this case F4 is the source).

To change the decoded segment, select a new segment from the Math trace dialog (as shown in the preceding step).



8. Conserve display space, by turning off the Channel and selecting only the segment you want to view.

CANbus Trigger, Decode, and Measure



9. View the timestamps for each segment by selecting **Vertical**→**Channels Status** on the menu bar. On the **Show Status** portion of the dialog, select Time. A display of timestamp information for each segment in the sequence acquisition is shown.
10. Ten timestamps fit on the display at a time. You can choose which 10 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.

Reference

CANbus TD and TDM Specifications

Note: Specifications are subject to change without notice.

Definition	CANbus TD and TDM
Protocol Setup	Select Bitrate (10, 25, 33.333, 50, 83.333, 100, 125, 250, 500, 1000 kb/s or user-defined between 10-1000 kb/s).

Decode Capability	CANbus TD and TDM
Format	Hexadecimal
Decode Setup	Threshold definition required. Default is to Percent amplitude. Select BitRate.
Decode Input	Any analog Channel, Memory or Math trace.
Number 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. (Use multi-grid if there is more than one decoder ON)
Visual Aid	Color Coding for FRAME, ID, DLC, DATA, CRC, Ack, Stuff Bits and Errors. Decode information is intelligently annotated based on timebase setting.

Trigger Capability	CANbus TD and TDM
Format	Hexadecimal or Binary
Trigger Setup	Trigger on All Frames, Frame ID, ID with Data, Remote Frames, or Error Frames.
Address (ID) Condition Setup	Specify one Frame ID or a range of Frame IDs. Frame ID trigger can be combined with Data.
Conditional Trigger Setup	Conditional Frame ID and Conditional Data triggering available. Choose from <=, <, =, >, >=, <>, in range, out of range or don't care conditions.
Data Setup	Hexadecimal:

CANbus Trigger, Decode, and Measure

Trigger Capability	CANbus TD and TDM
	<p># Data Bytes = 0 to 8. Data can be defined by nibble. Triggers on that data pattern regardless of position.</p> <p>Binary: Any combination of 0,1, or X for 1-64 bits. Triggers on that data pattern regardless of position.</p>
Bit Rates	10, 25, 33.333, 50, 83.333, 100, 125, 250, 500, 1000 kb/s or user-defined between 10-1000 kb/s.
Trigger Input	Any analog Channel or the EXT input.
Trigger Design	Internal to oscilloscope, settable like any other oscilloscope trigger.

Search Capability	CANbus TD and TDM
Search Options	Search for Any Frame, Any Error or Frame ID in Hexadecimal format.

Measure and Graph Capability	CANbus TD	CANbus TDM
CAN Timing Measurements	Not Applicable	CAN-CAN, CAN-Analog, Time@CAN, CAN Message Bitrate.
CAN Data Extraction	Not Applicable	CAN-Value.
CAN Bus Load Measurements	Not Applicable	CAN Bus Load %.
Graphing Functions	Not Applicable	Track, Trend and Histogram of CAN measurements.

Safety Requirements



WARNING

To avoid personal injury and to prevent damage to this product or any products connected to it, review the following safety precautions. To avoid potential hazards, use this product only as specified. Before using the CANbus TD, ensure that its operating environment will be maintained within these parameters:

Operation:	In-door Use
Temperature:	5 to 40 °C
Humidity:	≤ 80% RH (non-condensing)



WARNING

To avoid fire or personal injury, comply with the following:

- Do not use the CANbus TD Series hardware in wet or explosive atmospheres.
- Do not use the CANbus TD Series hardware if any part is damaged. All maintenance should be referred to qualified service personnel.
- Use of the CANbus TD Series hardware and/or the oscilloscope it is connected to in a manner other than specified may impair the protection mechanisms.

Appendix A: External Trigger Hardware

CANbus TD Standard Hardware

The Standard Hardware consists of the following items:



Qty. 1: **Trigger Module** -- The Trigger Module is basically a CAN Node that is set to filter (and provide a triggering signal) when certain conditions are met. It contains a 32-bit, 64 MHz microcontroller and two Philips SJA1000 CAN controllers. A Trigger Coupler (CAN transceiver) needs to be installed in the trigger module to connect to the appropriate bus. A 251 Trigger Coupler is provided standard on input 1, and a second can be installed on input 2. As necessary, the trigger couplers can be interchanged to suit your specific needs. The Trigger Module receives triggering instructions, as defined in the CAN Trigger dialog, through the USB2.0 cable (connected to the LeCroy oscilloscope), and outputs a trigger pulse through the 3-pin connector when the CAN trigger condition is met. The trigger pulse is a negative going edge from 5 V to 0 V.



Qty. 1: **Oscilloscope Interface Module** -- This module connects to the Trigger Module via the 3-pin connector. The module is LeCroy ProBus[®] compatible. When plugged into a LeCroy oscilloscope, it is automatically recognized and proceeds with appropriate setup for CAN triggering. The OIM can be connected to any channel, but is more commonly connected to the EXT input (to reserve a channel for an analog signal). Once connected, it sets the following:

- sets the oscilloscope trigger to a negative going Edge with a trigger level of 3 V (to trigger on the output pulse when the CAN trigger condition is met) and no trigger holdoff condition.
- displays the CAN trigger dialog
- applies a skew correction to all channels (to ensure that the trigger point aligns with the EOF point of the

	<p>triggered CAN message.</p> <ul style="list-style-type: none">• sets the horizontal settings to real-time sample mode using 4 channels.• if connected to a channel, it also resets various channel settings (interpolation, variable gain, scale and offset, averaging, etc.) to a default value.
	<p>Qty. 1: USB2.0 Cable -- Provides power to the Trigger Module. Also downloads CAN trigger conditions from the oscilloscope's CAN Trigger dialog to the Trigger Module.</p>
	<p>Qty. 2: 120 Ω Terminations -- A 9-pin to 9-pin DSUB connector with an internal 120 Ω termination between pins 2 and 7 (to convert a low-speed cable to a high-speed cable).</p>
	<p>Qty. 1: CAN Bus Connection Cable (High-speed)</p>

CANbus Trigger, Decode, and Measure



Qty. 1: **CAN Bus Connection Cable** (Low-speed and Single-Wire)

Qty. 1: **Quick Reference Guide**

Qty. 1: **Operator's Manual**

Qty. 1: **Carrying Case**

Accessories

Various accessories are also available to use with the CANbus TD. These are listed below:

- **Trigger Couplers** – Trigger Couplers are CAN Transceivers. The Trigger Coupler in the Trigger Module must match the CAN transceiver in the circuit that you are connecting the Trigger Module to. Trigger Couplers can be easily interchanged in the Trigger Module as the need requires. The following Trigger Couplers are available from LeCroy:
 - CAN 251 High-speed (Included with Trigger Module)
 - CAN 1050 High-speed
 - CAN 1041 High-speed (Wake-Up)
 - CAN 1054 Low-speed
 - CAN 5790c Single-Wire

All Trigger Couplers are optically isolated and feature optical decoupling between the CANbus TD Trigger Module and the CAN Bus. Galvanic isolation of the transceiver voltage supply is realized using a DC/DC converter.

Note: ISO 11992-1 prescribes at least a 16 V voltage supply (VS) for 24 V systems. Therefore, it is required to use the TC 10011OPTO Trigger Coupler with an external voltage supply. This voltage supply should be between 16 V and 36 V, and applied to pin 9. No other trigger couplers require an external voltage supply.

- **Cables** – A variety of connection cable sets for high-speed and low-speed CAN are available. These cable sets provide all that is needed to connect to 9-pin terminated CAN in many situations. In addition, a low-speed Y-connection cable is also available, which makes it easy to connect to a third-party CAN simulation or analysis tool, such as Vector's CANalyzer or CANoe.

Connecting to a CANbus Circuit

Overview

The CANbus TD/TDM Trigger Module operates as a “node” on the CAN Bus. It contains a Microcontroller, CAN controller, and Transceiver (Trigger Coupler) and interfaces to the CAN circuit just like any other node on the bus. However, the Trigger Module only provides triggering capability. In order to “view” the actual CAN physical signal on the oscilloscope display, you must also probe the CANH and CANL signals with single-ended probes, or a differential probe (such as the LeCroy ADP305 or AP033) and input this probe signal(s) to an oscilloscope channel.

CANbus Trigger, Decode, and Measure

Connecting the Trigger Module to the Oscilloscope

Connect the CANbus TD/TDM Trigger Module and Oscilloscope Interface Module (OIM) to the instrument as follows:



1. Connect the USB2.0 Cable to one of the instrument's PC-USB ports.



2. Connect the other end of the USB2.0 Cable to the CANbus TD/TDM Trigger Module.



3. Connect the CANbus TD/TDM Oscilloscope Interface Module (OIM) to the EXT input of the instrument. Make sure that the top (OIM labeled side) is facing up.

Note: Make sure that the OIM is at a right angle to the connector.



4. Connect the 3-pin plug end of the OIM to the Trigger Module.

Installing Trigger Couplers

UNDERSTANDING WHICH TRIGGER COUPLER IS INSTALLED IN THE TRIGGER MODULE

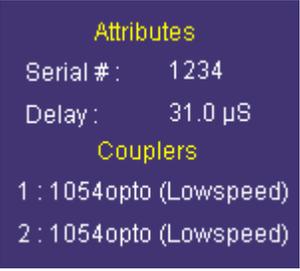
The Trigger Coupler is a CAN Transceiver. Therefore, the Trigger Coupler in the Trigger Module must match the transceiver in the CAN circuit you wish to connect to. If it does not match, the CAN trigger will not function properly.

To identify the coupler(s) that are installed, do the following:

Trigger	ExtTDM
Stop	3.00 V
Edge	Negative

1. Open the CAN Trigger dialog by touching the Trigger descriptor box (or by pushing the front panel "Bus Analysis" push button on Vehicle Bus Analyzers, and then selecting the CAN Trigger

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	dialog). With the Trigger Module connected to the instrument, the Trigger Dialog will default to the CAN Trigger tab.
 <p>Attributes Serial #: 1234 Delay: 31.0 μS</p> <p>Couplers 1: 1054opto (Lowspeed) 2: 1054opto (Lowspeed)</p>	<ol style="list-style-type: none">2. On the right hand side of the CAN Trigger dialog, there is a listing of Trigger Couplers. Note the Input # and the Type. If the correct Type of Trigger Coupler is installed, make sure you connect that Trigger Module Input to your circuit using the appropriate cable.
 <p>Input: 1 Ack: <input checked="" type="checkbox"/></p>	<ol style="list-style-type: none">3. Trigger Module Input (and hence, Trigger Coupler) used for triggering may be selected from the CAN Trigger dialog "Input" selection.

INSTALLING OR REMOVING A TRIGGER COUPLER

You will probably only need to use one or two different Trigger Couplers, so this will probably be something that you only have to do once, or very infrequently. In any case, it is simple to do.

The CANbus TD/TDM Trigger Module housing can be opened easily. Follow the instructions below to open the Trigger Module and install or remove a Trigger Coupler.



1. Unplug the USB2.0 and OIM cable (if they are plugged in).



2. The housing is shipped with two of the plastic end caps (that cover the screws) uninstalled. If these have been installed by you or someone else, you will need to remove them with a small screwdriver or knife.



3. Unscrew the screws on the DSUB-9 connector side of the Trigger Module using a Philips #1 screwdriver.



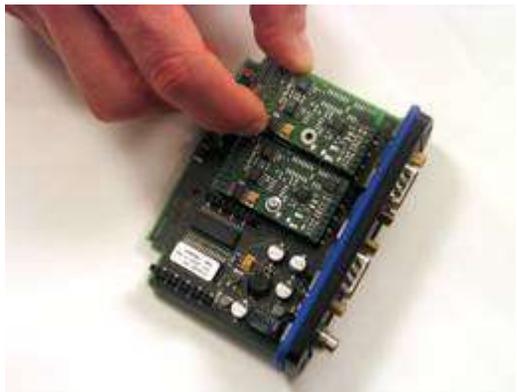
4. Slide the tray out of the housing (you may have to pull with some force if it has not been opened before).

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Note: Be sure to avoid touching the bottom or top of the Trigger Couplers or the Trigger Module main boards. If you are unsure, use normal static grounding techniques.



5. The Trigger Coupler is held down with a screw and locknut. Use a Philips #1 screwdriver to remove them. If necessary, carefully remove a Trigger Coupler from the main board, taking care not to touch the bottom of the Trigger Coupler. Store the Trigger Coupler in one of the static sensitive boxes (provided).



6. Install a new Trigger Coupler, making sure that the two-row connector and one-row connector are properly aligned and that the pins are fitting correctly. Refasten screw and locknut.



7. Slide the tray back into the housing, making sure that when the tray is re-installed the USB connector is showing.
8. Push the tray and the housing together, with light pressure. Tighten the screws firmly but not excessively.

Connecting the Trigger Module to the CAN Bus

Since the Trigger Module is a “node” on the CAN Bus, all of the normal connection rules apply. The bus must be terminated correctly, and CANH, CANL, GND, etc. must be connected to the correct locations. If you don’t make corrections to the bus correctly, the CANbus TD/TDM Trigger Module may generate error frames, may load down your signal, and will not trigger.

Fortunately, LeCroy provides a number of standard cables to enable you to easily make connections to high-speed, low-speed, and single-wire CAN Buses. These cables have 9-pin DSUB socket connectors with 2 or 4 wires that are stripped and may be connected to in-circuit wiring, banana plugs, alligator clips, etc., as necessary to connect to the CAN Bus circuit. The part numbers for these cables are 902381-00 and 902382-00. They are usable for most applications.

First, understand whether your CAN circuit is low-speed, high-speed, or single-wire. Then, plug the correct cable’s 9-pin DSUB connector into the Trigger Module, and connect the wires to the CANH, CANL, and other (as necessary).

Reference the tables below for information on the cables:

Cable Part Number 902382-00

DSUB (9-pin) Pin #	Definition	Wire Color
2	CANL	White
3	GND (low-speed) or VB- (single-wire)	Brown

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7	CANH	Yellow
8	VB+ or VB _{BATT}	Red

Notes:

Connect Pin 3 as necessary, depending on whether it is low speed or single-wire CAN
 Use for low-speed (1054) or single-wire (GM-LAN, 5790c) CAN
 (ISO 11898-3, ISO 11519, SAE J2411)

Cable Part Number 902381-00

DSUB (9-pin) Pin #	Definition	Wire Color
2	CANL	White
7	CANH	Yellow

Notes:

A 120 ohm terminating resistor is connected across pins 2 and 7, in accordance with ISO 11898.

Use for high-speed (251, 1050, 1041) CAN
 (ISO 11898-2)

VERIFYING PROPER TRIGGER MODULE CONNECTION TO THE CAN BUS

The CANbus TD/TDM Trigger Module has several LEDs on the front of the module. These LEDs will light to indicate CAN message direction and error frame activity. There is one set of LEDs for each input (or Trigger Coupler). The LEDs will light as follows:

LED	Indication
RX	Flashes when messages are being received

TX	Flashes when messages are being transmitted
Err	Flashes when errors occur on the bus

If the RX or TX light is flashing when there is CAN traffic on the bus, then you can assume that the Trigger Module connection to the bus is correct.

If the Err light is flashing, or if there are no lights flashing, then there is something wrong with the connection of the Trigger Module to the bus. Re-examine your wiring connection, make sure that you are using the correct cable and/or correct termination, and make sure that the bit rate is set correctly in the CAN Trigger dialog.



If you see either or both of these error messages (shown in the picture to the right) in the CAN Trigger dialog, then you need to re-examine the connections to the Trigger Module and make sure that they are correct. This message will be replaced by Trigger Module attributes and trigger coupler information when the Trigger Module is properly connected.

There are also optional cable sets that may be purchased for both high-speed and low-speed CAN. These cables have 9-pin DSUB to 9-pin DSUB connectors, and are useful if your embedded controller has a 9-pin connection for CAN. It is also simple to build these cables. The cables and cable sets are described below (schematic detail is provided in Appendix A)

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Cable Set Part Number 902329-00

Quantity	Description
1	0.3 m cable with 9-pin DSUB socket connectors on each end, and with pins 2 and 7 connected, including 120 ohm terminations on each end.
1	2 m cable with 9-pin DSUB socket connectors on each end, and with pins 2, 3 and 7 connected (but without 120 ohm terminations). One end has a “Y” connection for parallel connection of multiple nodes.
1	0.5 m cable with 9-pin DSUB socket connector on one end, and wires for pins 2, 3, and 7. No 120 ohm terminations.
2	CAN adapter with one 9-pin DSUB plug connector and one 9-pin DSUB socket connector with all pins connected. Includes 120 ohm termination between pins 2 and 7.

Note: This cable set is ideal for high-speed CAN. (ISO 11898-2)

Cable Set Part Number 902330-00

Quantity	Description
1	0.3 m cable with 9-pin DSUB socket connectors on each end, and with pins 2, 3 and 7 connected.
1	2 m cable with 9-pin DSUB socket connectors on each end, and with pins 2, 3, and 7 connected (but without 120 ohm terminations). One end has a “Y” connection for parallel connection of multiple nodes.
1	0.5 m cable with 9-pin DSUB socket connector on one end, and wires for pins 2, 3, and 7. No 120 ohm terminations.

Note: This cable set is ideal for low-speed CAN. (ISO 11898-3, ISO 11519, SAE J2411)

Viewing the CAN Bus Signal on the Instrument

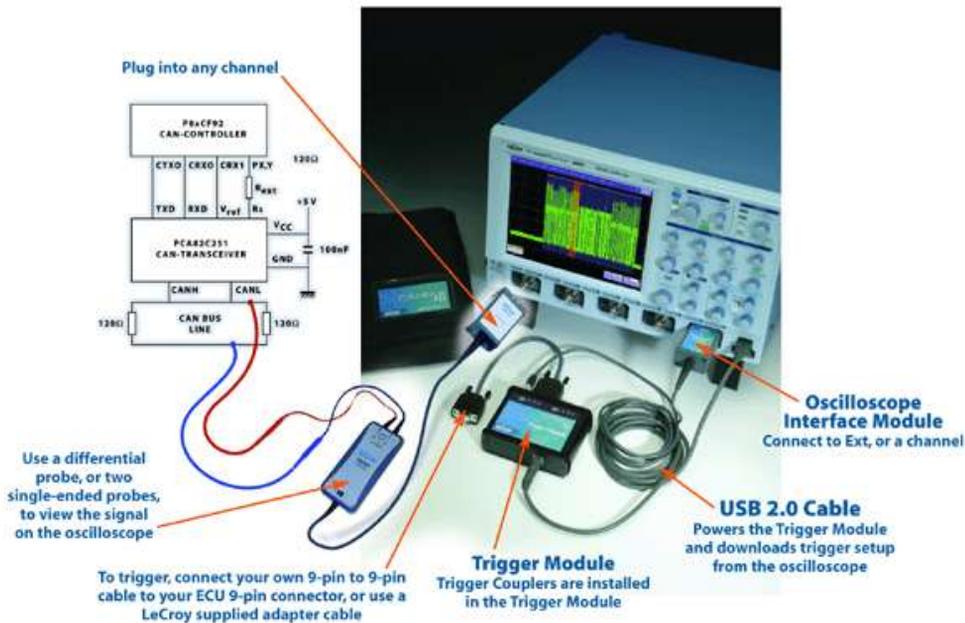
The CANbus TD/TDM Trigger Module input is only providing a trigger signal to the instrument. It doesn't "pass through" an analog CAN signal to the scope for viewing. Therefore, you must use a probe to connect to the CANH and CANL lines on the CAN Bus.

A differential probe is ideal since CAN is a differential signal. And a differential probe, such as the LeCroy AP033 or ADP305, does not require you to connect to system ground, and may provide better signal fidelity. It also uses only one channel on the instrument, which is a benefit if you want to view the CAN signal and many other analog signals on the instrument.

If you do not have a differential probe, two single-ended probes may be used instead. Be sure that the probes are grounded properly, and that the CAN Trace is properly configured for single-ended probe usage. Also, for best results, make sure that the gain and offset settings for the two probes are identical.

The Complete System Connection

When your system is completely connected, it will look like the photo and drawing that follows:



CANbus Trigger, Decode, and Measure

BASIC INSTRUMENT OPERATION

For information on setting up the instrument to view CAN (or other) signals, reference your instrument's on-line help system.

Trigger Setup

Overview

The instrument has a very powerful and flexible CAN trigger that is extremely easy to set up for triggering, using a DBC file and the CAN Symbolic Trigger setup. In addition, Hexadecimal setup is provided. Connecting the CANbus TD/TDM Series trigger hardware to your circuit is described in the preceding chapters.

Some basic knowledge of CAN physical bus connections is helpful in order to ensure that you can connect the trigger correctly. Proper care must be taken to ensure that CANH, CANL, GND, etc. are connected and terminated correctly (just like any other node on the CAN Bus), or else you may load the bus, fail to trigger, or generate error frames on the bus. Following the few simple rules described previously should ensure success.

Trigger Hardware

The CANbus TD/TDM Series Trigger Module operates as a “node” on the CAN Bus. It contains a Microcontroller, two CAN controllers, and up to two Transceivers (Trigger Couplers) that interface to the CAN circuit just like any other node on the CAN bus. A trigger condition, set from within the instrument, is downloaded to the Trigger Module, and the CAN controller within the Trigger Module “filters” on the condition. When the trigger condition is met, the Trigger Module outputs a pulse on Pin 2 of the three pin connector that connects to the Oscilloscope Interface Module (OIM). This pulse occurs 31 microseconds after the trigger condition is met (+/-1/8 bit time due to normal CAN controller operation). The pulse has a 5 V normal level, with a minimum level of 0 V and decay back to 5 V. The Oscilloscope or Vehicle Bus Analyzer actually triggers on this physical signal edge and not on the protocol CAN message.



CAUTION

The Trigger Module can contain enough circuitry for two complete nodes. Even though this would theoretically provide the capability to both simulate and trigger on signals simultaneously, this is not recommended. The processor could get overloaded if asked to both simulate and trigger, and the result could be missed trigger conditions.

Like any other CAN node, the Trigger Module converts physical layer signal data into protocol data. The trigger condition is downloaded to the Trigger Module in a protocol data format, with the CAN transceiver (Trigger Coupler) interfacing to the CAN controller in the Trigger Module. Using a sample point of approximately 65% (depending on the bit rate, the sampling rate could

actually be anywhere from 61% to 69%), the CAN controller converts the physical layer signal into protocol layer data. It is this protocol layer data that the Trigger Module is matching to the downloaded trigger condition in order to determine whether to output a trigger pulse.

The USB2.0 Cable provides power to the Trigger Module. It also permits downloading of trigger conditions from the instrument to the Trigger Module.

The Oscilloscope Interface Module (OIM) contains intelligence to identify the Trigger Module to the instrument, and transmits the trigger edge to the instrument input. As part of its “identification” function, the OIM does the following when it is plugged into a channel or the EXT input on the instrument:

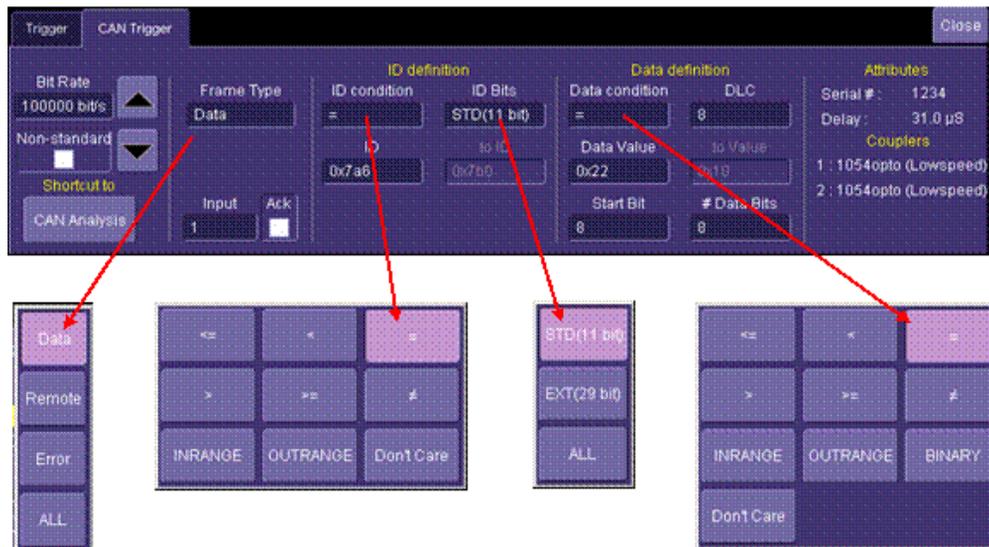
- Automatically sets the instrument trigger to a negative-going Edge and a 3 V trigger level. The trigger source is also automatically set to the channel or Ext input that the OIM is connected to.
- Automatically opens the instrument main dialog, so that it is quick and easy to set up the CAN trigger.
- Automatically applies a deskew (time shift of the signal) of 31 microseconds to any channel that the OIM is not connected to. This makes it easy to time correlate CAN signals with other analog signals, and sets the instrument trigger point indicator to the End of Frame (EOF) of the CAN message that is being triggered on. When the OIM is disconnected, the deskew is set back to zero seconds.
- Reads attributes of the Trigger Module, such as the types of installed Trigger Couplers.

Note: The Trigger Module only provides triggering capability. In order to “view” the actual CAN physical layer signal on the instrument display, you must also probe the CANH and CANL signals with the single-ended probes, or a differential probe (such as the LeCroy ADP305 or AP033) and input the probe signals to an instrument channel.

CANbus Trigger, Decode, and Measure

Creating a Trigger Condition

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

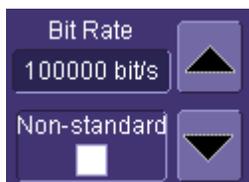


follow:

Selection of Frame Type, ID Condition, and Data Condition results in dynamic changes to the CAN Trigger dialog. However, for simplicity's sake, we will not describe all the possible combinations in this manual.

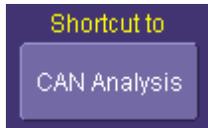
To select a value for any of the conditions, touch the existing value (using your finger, or use a mouse pointer) to open the pop-up dialog box with a list of choices, and select one of the choices.

Trigger Setup Detail

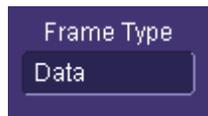


Bit Rate -- Adjust the bit rate value here to match the bit rate on the bus you are connected to. This bit rate selection is dynamically linked to the decoding bit rate (they are always the same value). Use the arrows to move through standard bit rates (10, 25, 33.333, 50, 83.333, 100, 125, 250, 500, and 1000 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. Note that if you select a value that is higher than that supported by the installed Trigger Coupler, you will not be able to trigger, and will create error frames on your bus. Non-standard bit rates (such as 102.4 kb/s) can be entered by

checking the “Non-Standard” box and then entering a value using the pop-up keypad. The non-standard bit rates that are available are calculated from the bit timing register values specific to the particular Trigger Coupler (transceiver) that is installed in the Trigger Module. If you enter a value that is not supported, it will default to the closest supported value.



Shortcut to Analysis -- This button provides quick access to the CAN Analysis dialog. Once you are finished defining your trigger condition, use this button to continue with your CAN Analysis (Decode) There is a corresponding shortcut to Trigger in the Decode dialog..



Frame Type -- Select either a Data, Remote or Error Frame to trigger on. When selected, the remaining CAN Trigger fields change to reflect what needs to be defined for that frame type. For instance, Remote Frames don't have a DATA condition to set up, and Error Frames don't have an ID or DATA condition to set up.

If you wish to trigger on any CAN message (Data, Remote, or Error Frame) that is on the bus, you can use the All Frame selection.



Trigger Coupler Input and ACK -- The Trigger Module can be outfitted with two different Trigger Couplers. The type of Trigger Coupler that is installed in Trigger Module inputs 1 and 2 is listed on the far right of the CAN Trigger dialog. Select the correct Trigger Module input to use as the trigger.

Since the Trigger Module is also a CAN node, you can choose to have the Trigger Module acknowledge CAN messages or not acknowledge CAN messages. This might be helpful if you are connected to a single CAN node and need the Trigger Module to provide the acknowledge for the other node. The default setup is to not acknowledge. If you wish for it to acknowledge, check the “Ack” box.



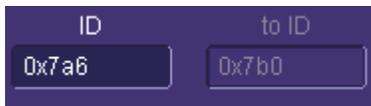
ID Condition -- The ID condition can be set to many different values. If the ID condition is set to “=”, then a data definition can also be set. Any other ID condition precludes setting up a

CANbus Trigger, Decode, and Measure

Data condition.

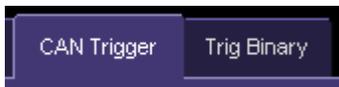
The ID condition can be set to \leq , $<$, $=$, $>$, \geq , not $=$, in a range, out of a range, or don't care.

ID Bits -- The trigger can be set to trigger on CAN messages with either 11-bits (Standard CAN) or 29-bits (Extended CAN). You can also set the Trigger Module to trigger on a message that meets a condition for either the 11-bit or 29-bit ID. For instance, there might be an 11-bit ID value that is present in both an 11-bit and a 29-bit ID, and by choosing ALL, you could trigger when that ID is present on either of those messages.

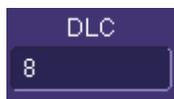


ID Value -- The ID value is set in Hexadecimal format. If you wish, you can precede the ID value with a "0x", but this is not necessary. Make sure to enter an ID value that matches the number of bits selected in **ID Bits** (i.e. enter an 11-bit ID here if you are setting up to trigger on an 11-bit ID). If you have set the **ID Condition** to INRANGE or OTRANGE, then you will enter two ID values.

Data Condition -- The Data Condition can be set to many different values. The Data condition can be set to \leq , $<$, $=$, $>$, \geq , not $=$, in a range, out of a range, or don't care.



In addition, you can select a "Binary" condition which will allow you to set up the rest of the data values in a Binary field. If you select a Binary data condition, an additional tab will appear next to the CAN Trigger tab, which will allow you to set up the data field bit-by-bit. This will be covered in more detail later in this chapter.



DLC Value -- The DLC (data length code) can be set to any integer value from 0 to 8. It should match the DLC of the CAN message you want to trigger on. If you set it to a value less than 0, it will default to 0. If you set it to a value greater than 8, it will default to 8.

Data Value -- The Data Value is set in Hexadecimal format. If you wish, you can precede the ID value with a "0x", but this is not necessary. Make sure to enter a Data Value that matches the DLC Value. If you have set the **Data Condition** to INRANGE or OVRANGE, then you will enter two Data Values.

If you wish to set the Data Value in a Binary format, reference the separate section on how to do this.

Data Value	to Value
0	0x20

CAN data can be formatted in several different formats – MSB (Most Significant Byte) or LSB (Least Significant Byte). In all cases, bit data is lsb (least significant bit, bitwise to the left, or the 7th bit in the byte appearing at the far left of the byte, and the 0th bit at the far right of the byte).

The CAN controller used in the Trigger Module formats data in MSB and lsb (bitwise to the left) format.

Note: The decoding algorithm always decodes the CAN signal (in hexadecimal nibbles and bytes) using an LSB and lsb condition.

Start Bit and # Bits -- The CANbus TD trigger allows you to trigger on up to 24 contiguous data bits (3 data bytes). This maximum 24-bit string can start at any location in the CAN message data field --- it is not limited to the start of a full byte or a nibble.

Start Bit	# Data Bits
8	8

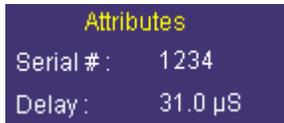
The Start Bit can be any value from 0 to 63. If you enter a value less than 0, it will default to 0. If you enter a value more than 63, it will default to 63. The Start Bit value is always in LSB format (i.e., the bit number as shown on the decoded waveform, with bit 0 being at the far left and bit 63 being at the far right of the data string). Remember that the 1st data byte is bits 0-7, the 2nd data byte is bits 8-15, etc. Also, make sure that your Start Bit value makes sense in relation to the DLC Value. For instance, a Start Bit value of 32 with a DLC Value of 4 is not going to result in a successful trigger.

Reference the Trigger Setup Examples section for more information on setting up a trigger where the start bit is not the

CANbus Trigger, Decode, and Measure

beginning of a data byte.

The # Bits can be any value from 1 to 24. If you enter a value less than 1, it will default to 1. If you enter a value more than 24, it will default to 24. If you need to trigger on a data pattern longer than 24-bits, you will need to use the binary trigger setup (reference the separate section on how to set this up).



Attributes -- When the Trigger Module is correctly connected to the oscilloscope, the serial number and delay setting are displayed, for operator convenience. The delay setting is the value of deskew applied to all oscilloscope channels (except for the channel that the OIM may be connected to).

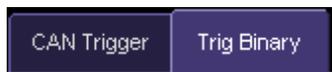


Trigger Couplers -- When the Trigger Module is correctly connected to the oscilloscope, the Trigger Input (1 or 2) and the Trigger Coupler type are identified. This makes it easy to understand which Trigger Couplers are installed, and which trigger input to use when connected to the bus.

Trigger Setup with Binary Data

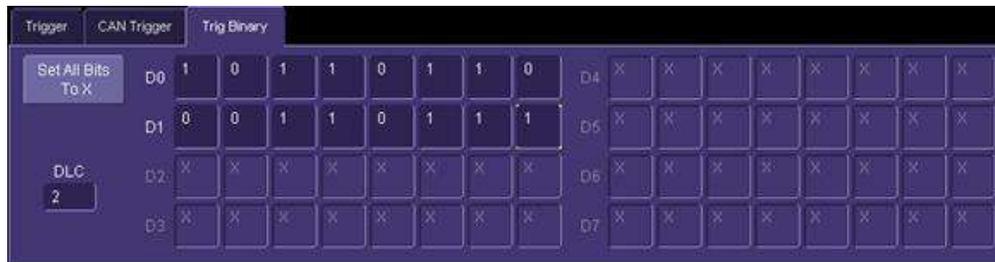


Binary Data Condition – The CAN trigger can be set up in binary format by selecting a “Binary” Data Condition in the Data Definition section of the CAN Trigger dialog. You might want to choose binary format setup when you want to trigger on less than full nibbles of data, or when you want to trigger on more than 24-bits of data.



When the Data Condition is set to “Binary”, an additional tab is created in the Trigger Dialog. You will need to touch this tab (shown at right) to get access to the Binary data setup dialog.

The Binary setup dialog is shown below:



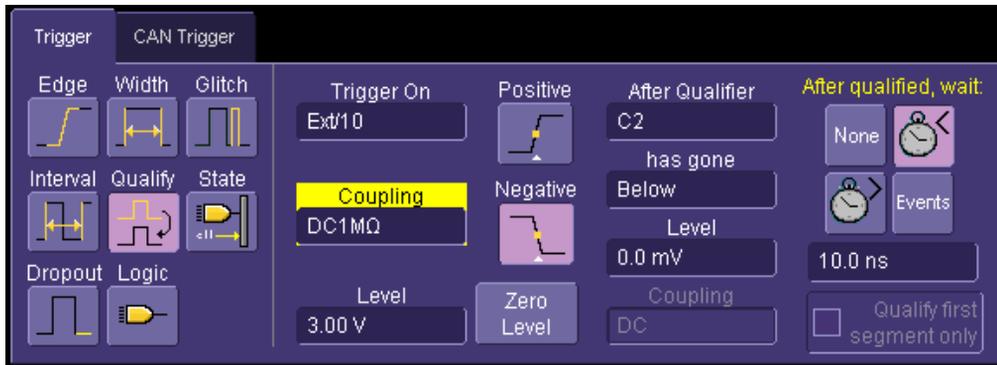
The Data Bytes are labeled D0 through D7. The far left bit in each byte is bit 7 and the far right bit is bit 0. A “1” is always a dominant bit, and a “0” is always a recessive bit. An “X” means that the bit can be either a 1 or a 0. Select a bit value by touching the existing value and choosing a value from the pop-up menu. The data bytes shown in the Binary trigger setup dialog are always in LSB (Least Significant Byte) format.

DLC value represents the number of total data bytes in the CAN message, not the number of bytes you want to trigger on. If you want to trigger on bit values in the 3rd and 4th bytes in an 8-byte CAN message, then you must select the DLC to be 8, and select “X” values in the portion of the message that you don’t care to trigger on.

Using CAN as a Trigger Qualifier

Since the external CAN Trigger module is enabled with a simple pulse output and the standard oscilloscope Edge trigger, it is possible to set up Qualified SMART Triggers using the CAN Trigger pulse and another signal.

For example, let’s assume that you wanted to trigger on the CAN signal only after a different signal (such as an analog signal) had gone above a certain threshold. You could use the LeCroy Qualified SMART Trigger to set up that trigger condition, as shown below:



The “Trigger On” condition is that of the normal pulse output from the CAN Trigger module, and the Qualifier is your analog signal.

You can also set up a Pattern (Logic) and State trigger similarly. This gives you powerful additional capability beyond simple CAN or Edge triggering.