LeCroy

Vehicle Bus Analyzer

OPERATOR'S MANUAL

November 2005

LeCroy Corporation
700 Chestnut Ridge Road
Chestnut Ridge, NY 10977-6499
Tel: (845) 578 6020
Fax: (845) 578 5985

Internet: www.lecroy.com

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VBA-OM-E Rev A
913671-00

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INTRODUCTION

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 ^{o}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 Instrument it is connected to in a manner other than specified may impair the protection mechanisms.

Refer to the WaveRunner 6000A *Operator's Manual* for additional safety information.

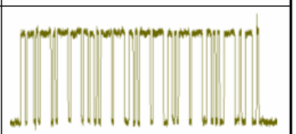
Vehicle Bus Analyzer

Overview

The Vehicle Bus Analyzer is a unique tool from LeCroy that will greatly increase your ability to debug and analyze embedded controllers that use serial data communications, or entire systems consisting of multiple embedded controllers that communicate between each other with serial data. Since the Vehicle Bus Analyzer is, at its core, an oscilloscope, you can use it for a wide variety of tasks in which a stand-alone protocol analyzer is not suitable.

Currently, the Vehicle Bus Analyzer supports Protocol (Hex) and Symbolic (Application) layer decode of CAN waveforms. The Vehicle Bus Analyzer can decode up to four serial data waveforms at one time, and is structured to allow additional options for decoding of other standards.

The Vehicle Bus Analyzer uses the CANbus TD Series hardware for triggering on CAN signals. It also uses proprietary software to decode serial data waveforms to either the Protocol (hex) or Symbolic (application layer) levels, perform automated timing and other measurements, statistically analyze and graph measurements, and extract data and plot it in a graphical format.

OSI Layer	Example
7 Application Layer	Engine Speed = 1717 rpm
2 Protocol Layer	Time: 03:43:52 ID: 7AF DATA: 06 B5
1 Physical Layer	

The advantages of using the Vehicle Bus Analyzer include the following:

- You can view all OSI levels (Physical, Protocol, and Symbolic/Application) of serial data streams on one tool
- You can decode up to four buses at one time, in a mix of modes.
- You can view additional sensor, actuator, or other embedded controller signals time coincident with your decoded serial data signals.
- You can use the long memory of the Vehicle Bus Analyzer to capture several seconds of serial data and other signals, or use Sequence Mode to capture many different, intermittent events.

- You can use automatic parameter measurements to calculate timing values. These parameter measurements can then be statistically analyzed or graphed on the Vehicle Bus Analyzer screen so that you can understand variations in the timing, or visualize trends in the data.

The Vehicle Bus Analyzer consists of a CANbus TD Series Hardware CAN Trigger kit, and specialized software that runs on a LeCroy WaveRunner class oscilloscope. The Hardware kit contains the necessary components to connect to most CAN controllers, with accessories available to customize the hardware to your specific requirements.

Probes will also be required to input the CAN signal to the Vehicle Bus Analyzer for signal viewing. The standard single-ended passive probes supplied with the Vehicle Bus Analyzer can be used; or, more appropriately, an optional differential probe can be purchased.

There are a number of public domain documents that describe CAN physical layer and protocol layer signals. These documents include:

- ISO 11519
- ISO 11898
- CAN Specification 2.0A
- CAN Specification 2.0B

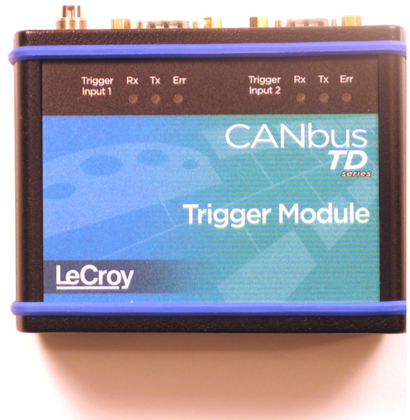
Since the Vehicle Bus Analyzer is based on a LeCroy WaveRunner class oscilloscope, the *Getting Started Manual* for the WaveRunner oscilloscope is also provided. The Vehicle Bus Analyzer *Getting Started Manual* will assume that you have a basic understanding of the operation of the WaveRunner oscilloscope, a basic understanding of CAN physical layer and protocol layer specifications, and knowledge of how CAN controllers interconnect to each other. Where practical or necessary, details on specific oscilloscope features are also 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 Vehicle Bus Analyzer display. However, functionality will be nearly identical.

The CANbus TD Series Standard Trigger 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) must 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 or Vehicle Bus Analyzer), 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 or Vehicle Bus Analyzer, 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 does the following:

    a. sets the Oscilloscope or Vehicle Bus Analyzer 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.

    b. displays the CAN trigger dialog

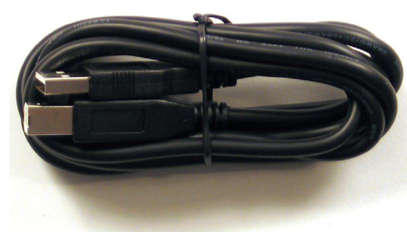
    c. applies a skew correction to all channels (to ensure that the trigger point aligns with the EOF point of the triggered CAN message.

    d. sets the horizontal settings to real-time sample mode using 4 channels.

    e. if connected to a channel, it also resets various

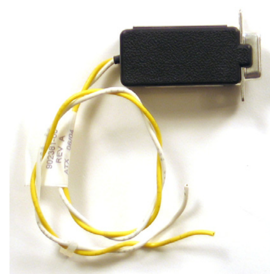
channel settings (interpolation, variable gain, scale and offset, averaging, etc.) to a default value.

- Qty. 1 **USB2.0 Cable** – Provides power to the Trigger Module. Also downloads CAN trigger conditions from the Oscilloscope or Vehicle Bus Analyzer's CAN Trigger dialog to the Trigger Module.

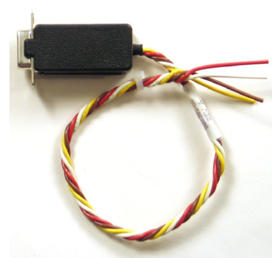


- Qty. 2 **120 Ω Terminations** – A 9-pin to 9-pin DSUB connector with an internal 120 Ω termination between pins 2 and 7 (to convert an ISO 11519 cable to an ISO 11898-2 cable).

- Qty. 1 CAN Bus Connection Cable (ISO-11898-2)



- Qty. 1 CAN Bus Connection Cable (ISO 11519 and GM-LAN/J2411 single-wire)



- Qty. 1 Quick Reference Guide (for connecting CANbus TD Series trigger hardware to your circuit and to the Oscilloscope or Vehicle Bus Analyzer)

- Qty. 1 Getting Started Manual
- Qty. 1 Carrying Case

CANbus TD Series Trigger Hardware Accessories

Various accessories are also available to use with the CANbus TD Series Trigger Module. 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:
    - 251 ISO 11898-2 (Included with Trigger Module)
    - 1050 ISO 11898-2
    - 1041 ISO 11898-2 (Wake-Up)
    - 1054 ISO 11519
    - 5790c GM-LAN/J2411 single-wire
    - B10011S Truck & Trailer

  All Trigger Couplers are optically isolated and feature optical decoupling between the CANbus TD Series 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 (V_S) 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 ISO 11519 and ISO 11898-2 CAN are available. These cable sets provide all that is needed to connect to 9-pin terminated CAN in many situations. In addition, an ISO 11519 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 CAN BUS CIRCUIT

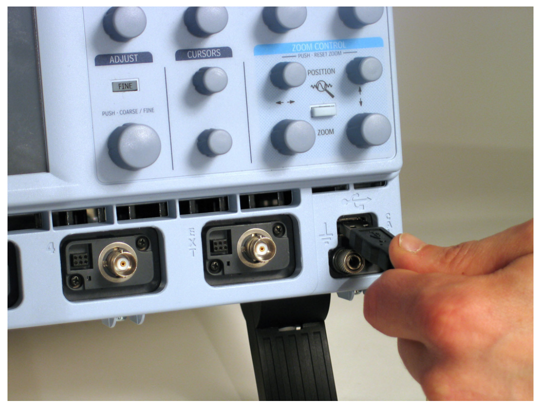
Overview

The CANbus TD Series 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 or Vehicle Bus Analyzer display, you must also probe the CANH and CANL signals with the included PP007 single-ended probes, or a differential probe (such as the LeCroy ADP305 or AP033) and input probe signals to an Oscilloscope or Vehicle Bus Analyzer channel.

Connecting the Trigger Module to the Oscilloscope or Vehicle Bus Analyzer

Connect the CANbus TD Series Trigger Module and Oscilloscope Interface Module (OIM) to the Oscilloscope or Vehicle Bus Analyzer as follows:

1. Connect the USB2.0 Cable to one of the Oscilloscope or Vehicle Bus Analyzer's PC-USB ports.



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

3. Connect the CANbus TD Series Oscilloscope Interface Module (OIM) to the EXT input of the Oscilloscope or Vehicle Bus Analyzer. Make sure that the top (OIM labeled side) is facing up. (**Note:** Then make sure that the OIM is at a right angle to the connector).

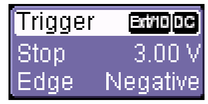
4. Connect the 3-pin plug end of the OIM to the Trigger Module.

Understanding Which Trigger Coupler is Installed in the Trigger Module

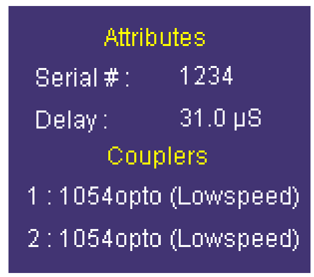
The Trigger Coupler is a CAN Transceiver. Therefore, the Trigger Coupler in the Trigger Module must match the transceiver in the CAN circuit you wish to connect to. If it does not match, the CAN trigger will not function properly.

To identify the couplers that are installed, do the following:

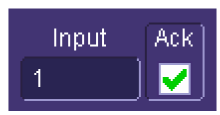
1. Open the CAN Trigger dialog by touching the Trigger descriptor box (or by pushing the front panel “Bus Analysis” pushbutton, and then selecting the CAN Trigger dialog). With the Trigger Module connected to the Oscilloscope or Vehicle Bus Analyzer, the Trigger Dialog will default to the CAN Trigger tab.



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.



3. Trigger Module Input (and hence, Trigger Coupler) used for triggering may be selected from the CAN Trigger dialog “Input” selection.



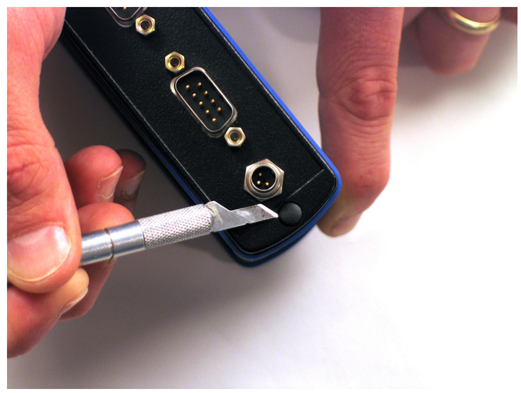
Installing or Removing a Trigger Coupler

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.

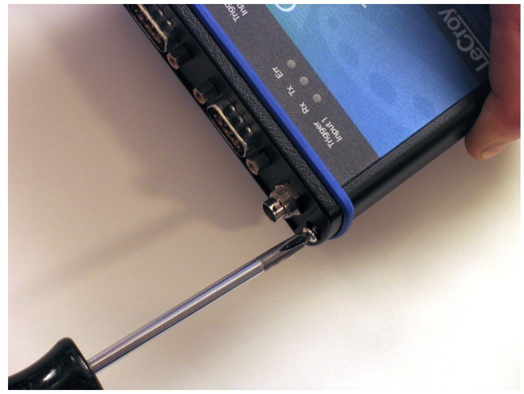
The CANbus TD Series Trigger Module housing can be opened easily. Follow the instructions below to open the Trigger Module and install or remove a Trigger Coupler.

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

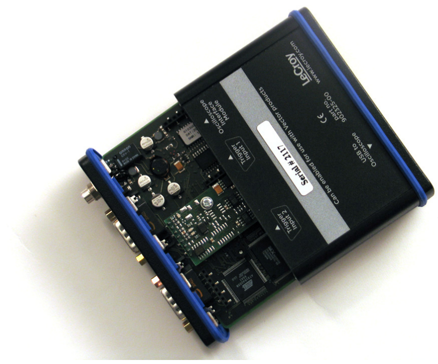
2. The housing is shipped with two of the plastic end caps (that cover the screws) uninstalled. If these have been installed by you or someone else, you will need to remove them with a small screwdriver or knife.



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

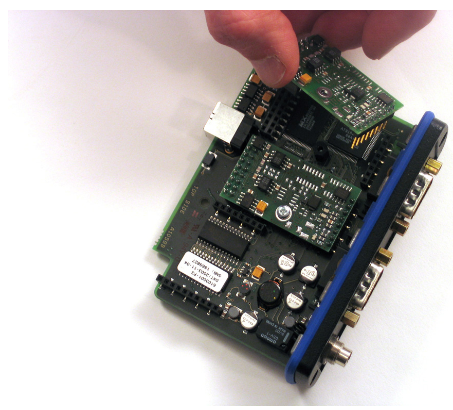


4. Slide the tray out of the housing (you may have to pull with some force if it has not been opened before).

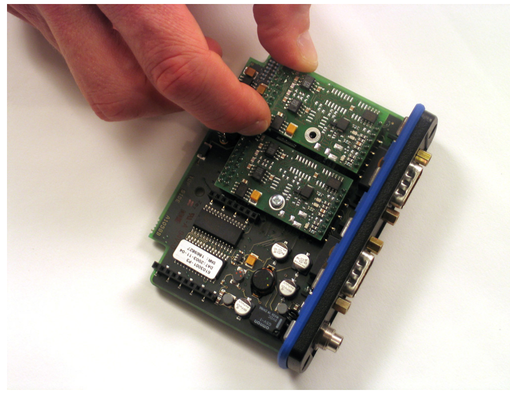


Note: Be sure to avoid touching the bottom or top of the Trigger Couplers or the Trigger Module main boards. If you are unsure, use normal static grounding techniques.

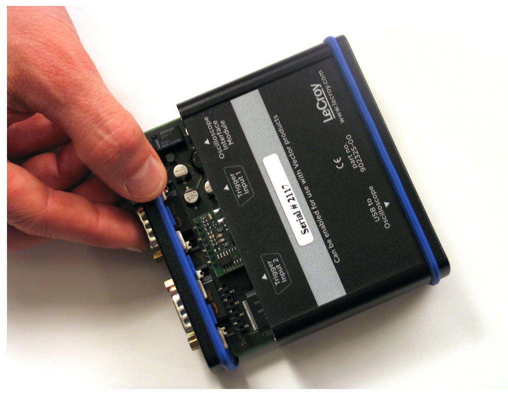
5. The Trigger Coupler is held down with a screw and locknut. Use a Philips #1 screwdriver to remove them. If necessary, carefully remove a Trigger Coupler from the main board, taking care not to touch the bottom of the Trigger Coupler. Store the Trigger Coupler in one of the static sensitive boxes (provided).



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 connections to the bus correctly, the CANbus TD Series 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 ISO 11898-2, ISO 11519, and GM-LAN, or GM-LAN/J2411 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 ISO 11519, ISO 11898-2, or GM-LAN/J2411 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 (ISO 11519) or VB- (GM-LAN/J2411 single-wire)	Brown
7	CANH	Yellow
8	VB+ or VB_{BATT}	Red
Notes	Connect Pin 3 as necessary, depending on whether it is ISO 11519 or GM-LAN/J2411 single-wire CAN	
Use for ISO 11519 (1054) or GM-LAN/J2411 single-wire (5790c) CAN		

Cable Part Number 902381-00		
DSUB (9-pin) Pin #	**Definition**	**Wire Color**
2	CANL	White
7	CANH	Yellow
Notes	A 120 Ω terminating resistor is connected across pins 2 and 7, in accordance with IS0 11898.	
Use for ISO 11898-2 (251, 1050, 1041) CAN		

Verifying Proper Trigger Module Connection to the CAN Bus

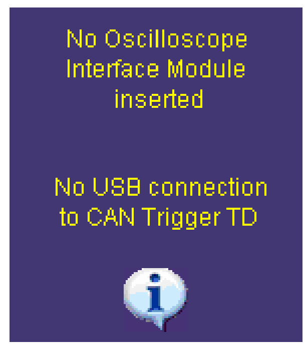
The CANbus TD Series Trigger Module has several LEDs on the front of the module. These LEDs will light to indicate CAN message direction and error frame activity. There is one set of LEDs for each input (or Trigger Coupler). The LEDs will light as follows:

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, 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, 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, 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 ISO 11898-2 and ISO 11519 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)

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 Ω 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 Ω 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 Ω terminations.
2	CAN adapter with one 9-pin DSUB plug connector and one 9-pin DSUB socket connector with all pins connected. Includes 120 Ω termination between pins 2 and 7.
Note: This cable set is ideal for ISO 11898-2 CAN.	

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 Ω 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 Ω terminations.
Note: This cable set is ideal for ISO 11519 CAN.	

Viewing the CAN Bus Signal on the Oscilloscope or Vehicle Bus Analyzer

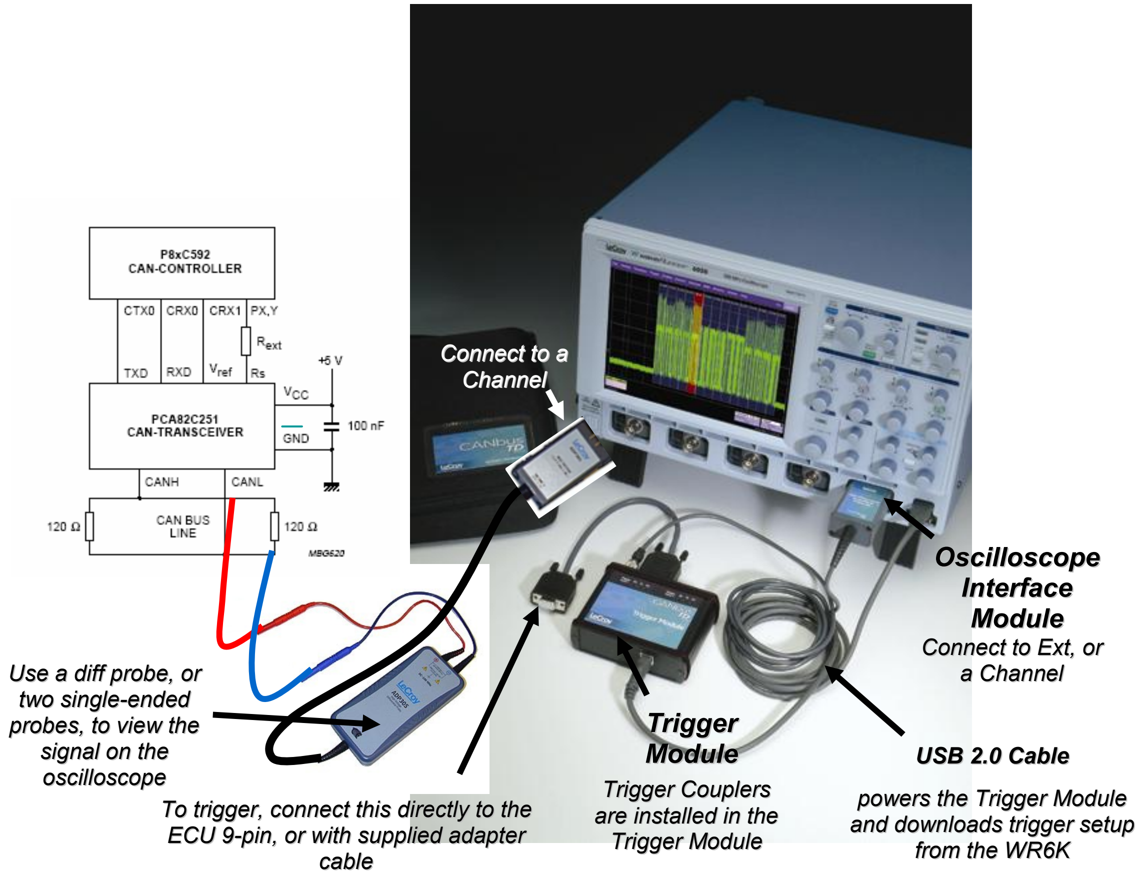
The CANbus TD Series Trigger Module input is only providing a trigger signal to the Oscilloscope or Vehicle Bus Analyzer. It doesn't "pass through" an analog CAN signal to the scope for viewing. Therefore, you must use a probe to connect to the CANH and CANL lines on the CAN Bus.

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 Oscilloscope or Vehicle Bus Analyzer, which is a benefit if you want to view the CAN signal and many other analog signals on the Oscilloscope or Vehicle Bus Analyzer.

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 following illustration:



It is usually easiest to view the raw channel input first before setting up the CAN Trace with a defined CAN Source. Reference your Oscilloscope or Vehicle Bus Analyzer's on-line Help if you have questions about displaying a signal on an oscilloscope or Vehicle Bus Analyzer channel. After the setup is verified, it is then a simple matter to turn the channel OFF and view the CAN Trace, with decoding (as desired), and any other non-CAN signals.

Basic Oscilloscope or Vehicle Bus Analyzer Operation

For information on setting up the Oscilloscope or Vehicle Bus Analyzer to view CAN (or other) signals, reference your Oscilloscope or Vehicle Bus Analyzer on-line help system.

ACCESSING THE VEHICLE BUS ANALYZER TOOLSETS

Overview

The Vehicle Bus Analyzer (VBA) combines capabilities of an oscilloscope and a protocol analyzer in one instrument. The VBA trigger and decoding tools are easily accessible in a variety of ways, with specific vehicle bus analysis tools logically grouped into a single menu structure. In addition, the VBA may also be used as a standard oscilloscope with all the normal oscilloscope functionality.

Vehicle Bus Analyzer User Interface

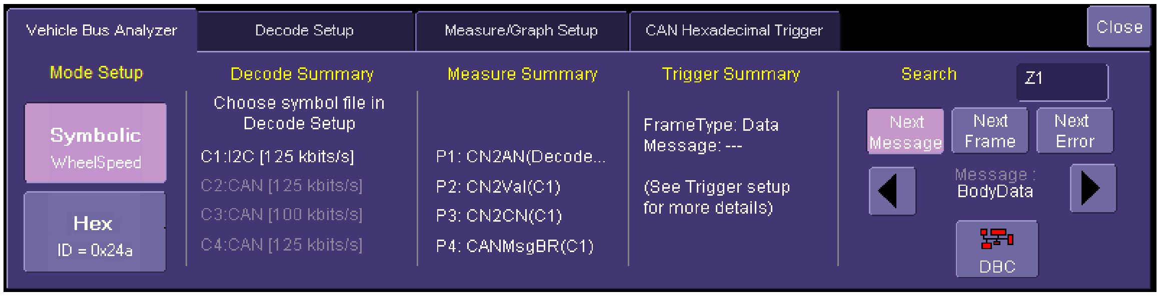
The Vehicle Bus Analyzer has a unique user interface to allow quick and easy access to all controls, and fast setup of serial triggering, decode, and measure/graph. This user interface is accessible at all times by means of the green front panel "Bus Analysis" button in the Horizontal section of the front panel.

Once selected, the user interface offers the following dialogs in an easy-to-access tab format:

- **Vehicle Bus Analyzer** – The main user interface page where the decode and display triggering mode (either Symbolic or Hexadecimal) is selected, where various summaries are provided, and where global Search capability is accessed.
- **Decode Setup** – Allows up to 4 different decodes to be defined with a selection of a protocol, bit rate, source, etc.
- **Measure/Graph Setup** – Allows quick and convenient general purpose setup for CAN related measurements that is easily accessible from the other CAN menus. In addition, shortcuts are provided to quickly view a histogram, trend, or track of any of the measurements.
- **CAN Trigger Setup** – Allows a CAN trigger condition to be set from within the Vehicle Bus Analyzer using an easy-to-understand interface. Depending on the mode selected (Hexadecimal or Symbolic), the appropriate CAN Trigger setup dialog will be displayed.

This main dialog is always shown on top. The other dialogs are shown as tabs, and may be selected by touching the display or clicking a mouse. The main dialog appears as shown below:

Vehicle Bus Analyzer



When the front panel “Bus Analysis” button is pushed, a dialog will automatically be displayed. If you don’t wish for it to be displayed, you can simply touch “Close” to close the dialog.

Vehicle Bus Analyzer Main Dialog

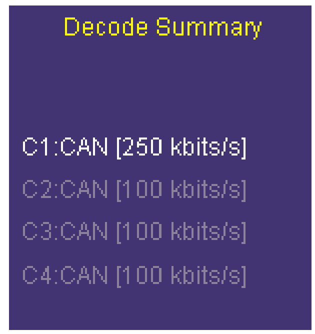
A description for each section of the Vehicle Bus Analyzer main dialog is as follows:

Mode Switch – Touch either the Symbolic or Hexadecimal buttons to choose the Mode that you wish to operate the VBA in. The mode will be consistently used throughout the VBA whenever possible. Therefore, the Vehicle Bus Analyzer main dialog will change slightly depending on which mode is selected.

> **Note:** The mode switch is not used to select the Symbolic (e.g., DBC) database file for symbolic decoding, triggering, etc. This is done in other menus.

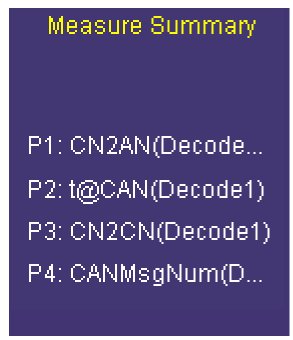
Decode Summary – This area provides an overview of what is defined in the Decode Setup dialog.

If a Decoder is turned "ON" in the Decode Setup dialog, the summary information will appear in white text. If the Decoder is turned "OFF" in the Decode Setup dialog, the summary information will appear in gray text.

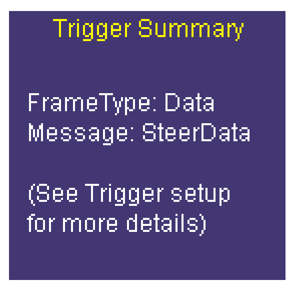


Measure Summary – This area provides a measurement overview of the measurements defined in the Measure/Graph Setup tab.

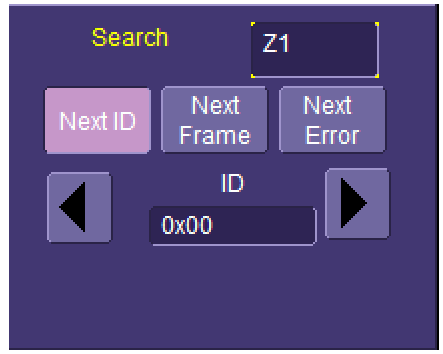
If a measurement parameter is turned "ON" in the parameter setup dialog (accessed through the top menu Measure, Measure Setup, Px tabs), the summary information will appear in white text. If the measurement parameter is turned "OFF" in the parameter setup dialog, the summary information will appear in gray text.



Trigger Summary – This area provides an overview of the Trigger Summary information at the ID (Hexadecimal) or Message (Symbolic) level. Additional information about the exact trigger condition can be found in the CAN Hexadecimal Trigger or CAN Symbolic Trigger Setup dialog box, accessed by pressing the appropriate tab.



Search – Acquire long records of CAN message data, and use Search to look through the record for a particular CAN Hex ID of Symbolic Message, for the next CAN Frame, or for the next CAN Error Message.

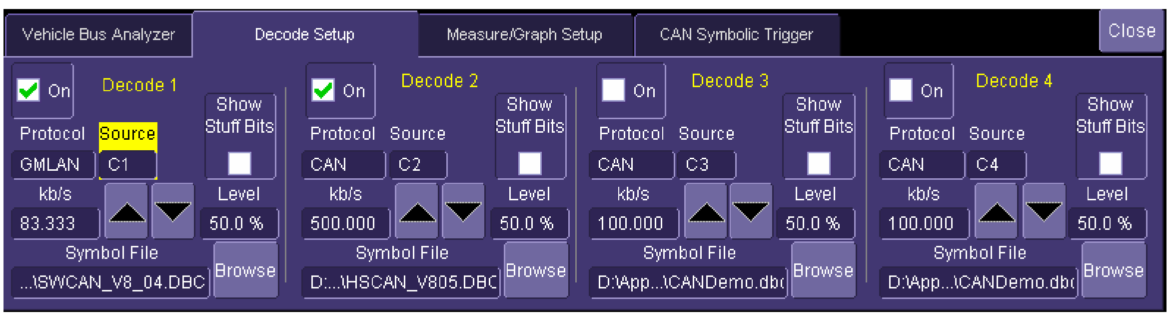


Upon finding a CAN message that meets the search criteria, the complete CAN message will be displayed with a Zoom Trace. If you are decoding with Decode 1, the Zoom 1 trace will be created and displayed to show the Search result. If you are using Decode 2, the Zoom 2 trace will be created, etc.

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.

Decode Setup Main Dialog

The Decode Setup main dialog is where the decoding requirements are defined for any source. Sources can be channels, memory (reference) traces, or math functions (i.e., C1-C2, or CANH-CANL). Up to 4 sources may be decoded at any one time. The sources are defined in a unique Decoder that applies a visual overlay of decoded information on top of the source trace. Each Decoder has a number, and this Decoder 1, Decoder 2, etc. is used as a source for CAN specific measurement parameters. The Decode Setup main dialog is shown below:



Decoding Algorithm Overview

The CANbus TD Series HW Trigger Module is not required to be connected for CAN decoding (although triggering is often done with decoding).

Any source can be decoded, including channels, memory traces (reference waveforms), and math functions. During normal acquisition, the source would be a channel. At times when you want to analyze previously acquired data, the source would be a memory trace. For analysis of sequence mode acquisitions (see the Chapter on Isolating and Analyzing Bus Activity), the source would be a function (math trace) to allow you to see the CAN decoding performed sequence by sequence.

Protocol decoding of the CAN trace is performed with a software algorithm that examines the embedded clock for each CAN message based on a default (or user set) vertical level. The algorithm is intelligent in that it applies a hysteresis to the falling edge of the CAN signal to minimize the chance that perturbations or ringing on the falling edge will affect the decoding. The default level is set to 50% and is determined from a top and base calculation of the acquisition. A different algorithm locates stuff bits in the message and performs a decoding of the CAN message into hexadecimal format after separation of the underlying data into logical groups (ID, DLC, DATA, CRC, etc.). Finally, another algorithm provides the appropriate color coding of the message, and displays the protocol message data on the screen, as desired, above the CAN Trace. Various compaction schemes are utilized to show the data during a long acquisition (many hundreds or thousands of CAN messages) or a short acquisition (one CAN acquisition). In the case of the longest acquisition, only Error Frames are highlighted. In the case of the shortest acquisition, all information is displayed (ID, DLC, DATA, and CRC, with additional highlighting of the ACK bit and the complete message frame). Stuff bits may optionally be highlighted also.

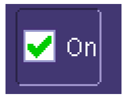
Symbolic decoding is accomplished through a lookup table that compares the hexadecimal calculated values to a symbol file (in the case of CAN, a DBC database file). Then, symbolic information is added to existing hexadecimal information on the display.

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 CAN controller sampling point-based decode. In addition, the clock extraction technique allows partial decoding of error frame messages, in many cases, whereas a CAN controller-based sampling point decode cannot. This is a significant advantage for the LeCroy software algorithm. However, there may be instances in which messages are badly corrupted or there is excessive noise on the CAN signal and the decoder may fail to decode in these instances (returning an Error Frame) signal instead. Since the physical layer is easily observable on the display, these cases will usually be very obvious.

If the sampling rate (SR) is insufficient to resolve the signal adequately, based on the bit rate (BR) setup, the protocol or symbolic decoding will be turned OFF in order to avoid 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 CAN analog signal.

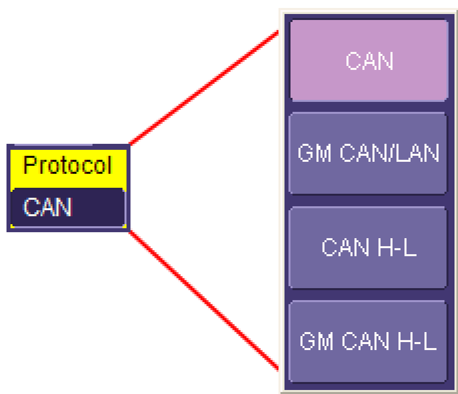
Decode Setup Dialog Description

Decoder ON Checkbox – Check this box if you want decoding turned ON. Decoding ON will provide a highlight of each CAN message frame, with color coded highlighting on the source or zoom waveforms of the ID, DLC, DATA, CRC, and ACK bits, and decoding of the ID, DLC, DATA, and CRC data. Note that for very long acquisitions with hundreds or thousands of CAN messages, decoding of the entire acquisition will take longer.



> **Note:** If you are acquiring large records in AUTO or NORMAL mode and notice a significant reduction in update rate, you may want to uncheck the Decoder ON checkbox, acquire your records, then recheck the checkbox.

Protocol Selection – Touch this area to select a protocol to use for decoding. Currently, the VBA supports CAN, CANH-L, GM-CAN/LAN, and GM CANH-L.



If you are using two single-ended probes on a differential CAN signal, use a Math function to perform a waveform subtraction of your two channels, then use that function as a source for the decoding (i.e., F1 = C1-C2, Source=F1).

If you are using a GM version of CAN with Parameter ID, Priority ID, and Source ID, use the GM format protocols for proper symbolic decoding.

Source – Touch inside the Source field area and choose a source to use for the CAN Trace.

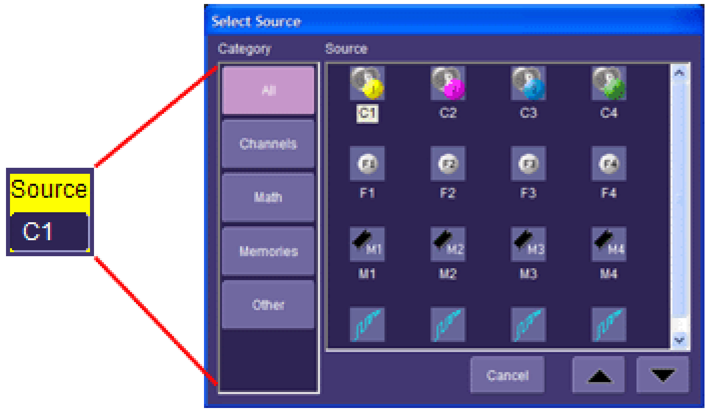
This source can be either a Channel (C1–C4), a Memory Trace (M1–M4), or a Math Function (F1–F4).

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 VBA's on-line Help for information about how to Store and Recall Waveforms.

A Math Function would be used to view a differential signal with two single-ended probes. In this case, define a Math trace (e.g. F1 = C1-C2), and then define that Math trace as the source (i.e. Source = F1).

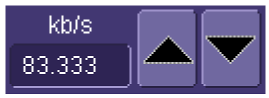
A Math function could also be used to view decoded data on Sequence mode acquisitions. Sequence Mode is a unique capability whereby you can utilize oscilloscope memory to capture events widely spaced in time, and view them sequentially. Reference the chapter on Isolating and Analyzing CAN Bus Activity for more information on setting the oscilloscope up in this mode.



Note: If you use a Memory or Math Function as a Source for the CAN Trace, the Zoom Ratio and Position of this source is controlled by the underlying Source Zoom and Position controls in the Memory or Math Function dialog. The front panel zoom controls may also be used to control the zoom ratio and position.

Note: If you choose to use two single-ended probes to probe your CAN signal, the probes should be identical, and should be set to the same coupling, gain, etc. The probes must also be identically grounded. In addition, since the Vehicle Bus Analyzer math function has to subtract the digitized values for the two probes before performing decode, using two single-ended probes will result in a speed penalty of approximately 2x compared to using a differential probe. For best results, a differential probe, which requires no grounding, is recommended unless you wish to look at CANH and CANL independently as part of your analysis.

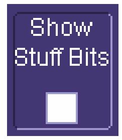
Bit Rate Selection – Touch this area to increase or decrease the bit rate. Adjust the bit rate value here to match the bit rate on the bus you are connected to. Use the scroll arrows to move through standard bit rates (10, 25, 33.333, 50, 83.333, 100, 125, 250, 500, and 1000 kb/s) and make a selection.



When you use the scroll arrows, the bit rate will increment in coarse steps through the common bit rates (10, 25, 33.333, 50, 83.333, 100, 125, 250, 500, 1000 kb/s).

If you need a different bit rate, touch inside the numeric entry box and open the keypad. Then, simply type in any bit rate desired. Unlike CANbus TD and TDM (where the decode bit rate is the same as the trigger bit rate), the VBA decode bit rate can be any value.

Show Stuff Bits – During decoding, the decoded values are written over the waveform on the VBA display. If you wish to highlight CAN Stuff Bits, simply check this box.



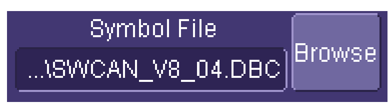
Note: The DBC Message Selector button is specific to the Search function only – it does not choose the Symbol File for decoding. That is performed in Decode Setup.

Decode Level Setup – The message decoding algorithm setup level is performed here. The level is 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 Vertical Level appears as a dotted horizontal line across the oscilloscope grid.

If your initial message decoding indicates that there are a number of error frames, and your bit rate is set correctly, make sure that the level is set to a reasonable value. The default value is 50.

Symbol File Selection – Touch inside this field to select the Symbolic file to be used for Symbolic Decoding. If you have not already defined the Mode as "Symbolic" on the Vehicle Bus Analyzer Main Dialog.



Measure/Graph Setup Main Dialog

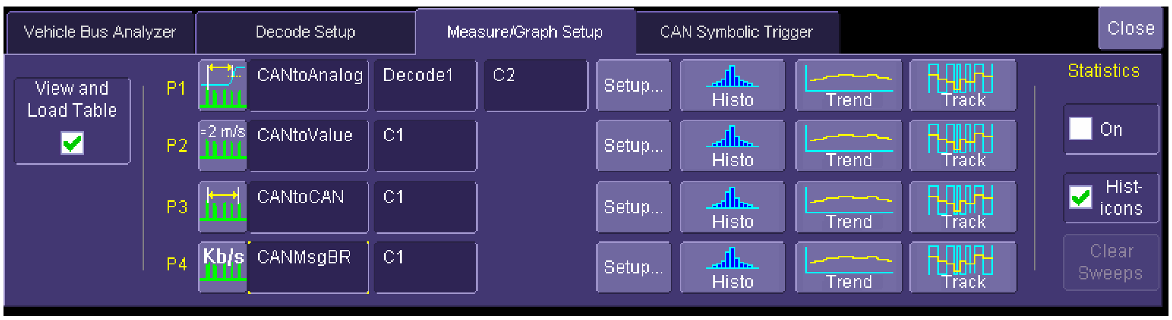
This dialog provides the ability to set up the VBA for measurements, statistical analysis, and graphing of any measurement parameter, including serial data (i.e., CAN) measurement parameters.

CAN measurement parameters consist of timing, bus load, bit rate, and data value parameters specific to CAN testing, and also standard LeCroy measurement parameters that you may want to use for measurement of CAN physical layer (such as rise time, fall time, amplitude, etc.).

General information is provided below. Detailed information on setup of Measurements and Graphing can be found in the sections on “Measurement of CAN Bus System Performance” and “Statistical Evaluation of Parameter Measurements.”

Note: The Measure/Graph Setup dialog is a convenience dialog. It is easily accessed when you are already in the Vehicle Bus Analyzer dialogs. However, there is not direct access to it from the standard Measure dialog, or from the top toolbar. The Measure/Graph Setup dialog has a simplified user interface compared to the standard Measure dialog.

The Measure/Graph Setup Main Dialog is shown below:



Measure/Graph Setup Dialog Description

View and Load Table Checkbox – The VBA Measure/Graph Setup dialog exists separately from the main Measure dialog. Check this box to “upload” the measurements from this dialog to the main Measure dialog, and simultaneously turn on and display measurement results.

Measurement Parameter and Source Selection – Any parameter can be selected from this menu. Parameters are identified as P1-P4 in this menu (P5 and P6 can only be set up in the main Measure dialog).

Touch the measurement icon to select a measurement. The two entry boxes at the far right are the sources for the measurement. Touch these to select the appropriate sources for the measurement.

> **Note:** Any trace that is decoded must use one of the Decode sources as a measurement source *if* it is a serial data (i.e., CAN or other) parameter. Thus, if you want to use a CAN parameter to measure something on Channel 1 that is decoded with Decode1, you would select Decode 1 as the source and not C1 (Channel 1).

Setup Button – Touch this button to go to the parameter detailed setup dialog, located within the main Measure setup dialog.

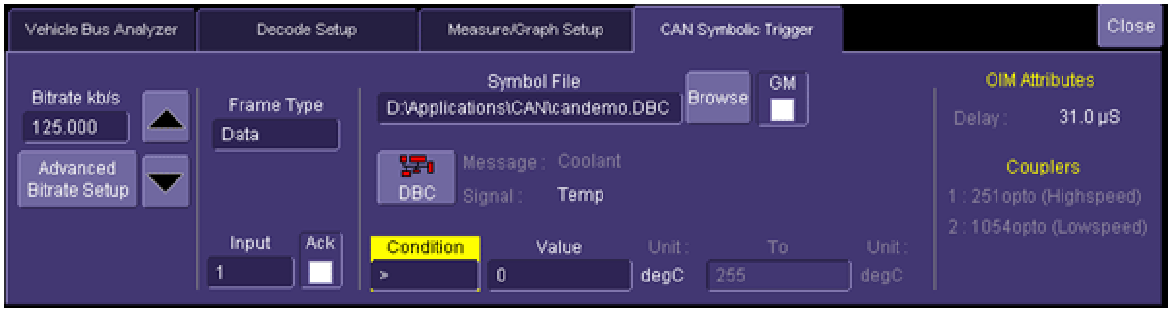
Graphing and Plotting Setup Buttons – The VBA provides the ability to statistically analyze and display a Histogram of a measurement parameter, or to plot a Trend or Track of a measurement parameter. Simply touch the appropriate icon, and a math function will be created to display the Histogram, Trend, or Track. For more information on this capability, reference the sections on "Measurement of CAN Bus System Performance" and "Statistical Evaluation of Parameter Measurements."

Statistics Setup – Small histograms (Histicons) and Clear Sweeps are used to statistically evaluate many measurement results. Reference the section on "Statistical Evaluation of Parameter Measurements" for more information.

CAN Symbolic Trigger Setup Main Dialog

This dialog is present when the VBA is set to operate in Symbolic Mode. It provides the ability to set up the VBA's CAN Trigger symbolically by choosing Messages and Signals, and Signal conditions. You must supply the applicable DBC database file for this feature to work correctly.

The CAN Symbolic Trigger Setup Main Dialog is shown below:

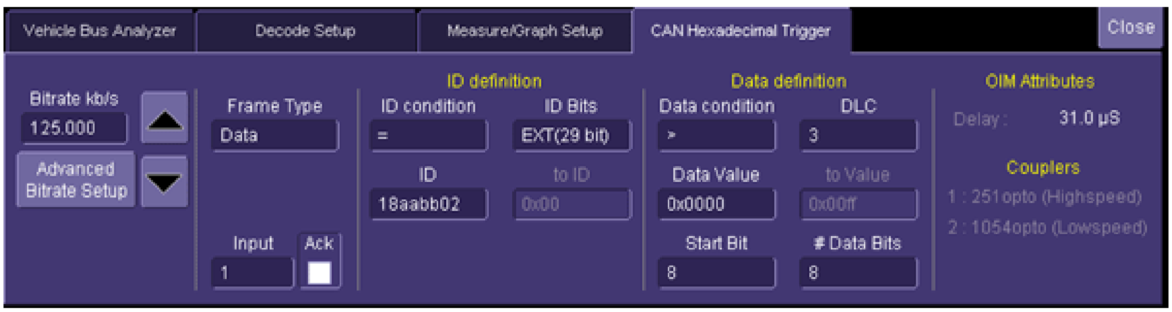


Information on how to set up a Symbolic CAN Trigger is provided in the "CAN Trigger Setup" section.

CAN Hexadecimal & Binary Trigger Setup Main Dialog

This dialog is present when the VBA is set to operate in Hexadecimal Mode. It provides the ability to set up the VBA's CAN Trigger hexadecimally by manually entering ID and DATA information, and entering DATA conditions.

The CAN Hexadecimal & Binary Trigger Setup Main Dialog is shown below:



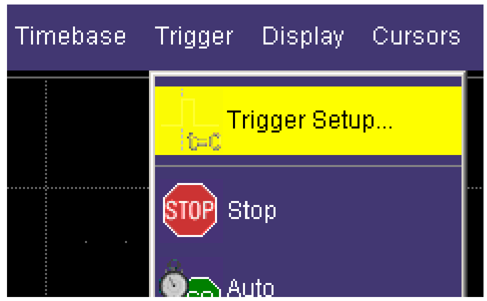
Information on how to set up a Hexadecimal or Binary CAN Trigger is provided in the "CAN Trigger Setup" section.

Alternate Ways to Access CAN Trigger Dialogs

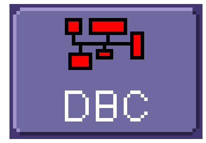
Other ways to access the CAN Trigger dialogs are listed below:

1. Touch the **Trigger** descriptor button. If the CANbus TD Trigger Module is connected to the oscilloscope, the dialog will default to the CAN Trigger tab. If it is not connected, touch the CAN Trigger tab to select it.

2. Touch **Trigger** in the menu bar, and select **Trigger Setup…**. Then select the CAN Trigger tab (as necessary).

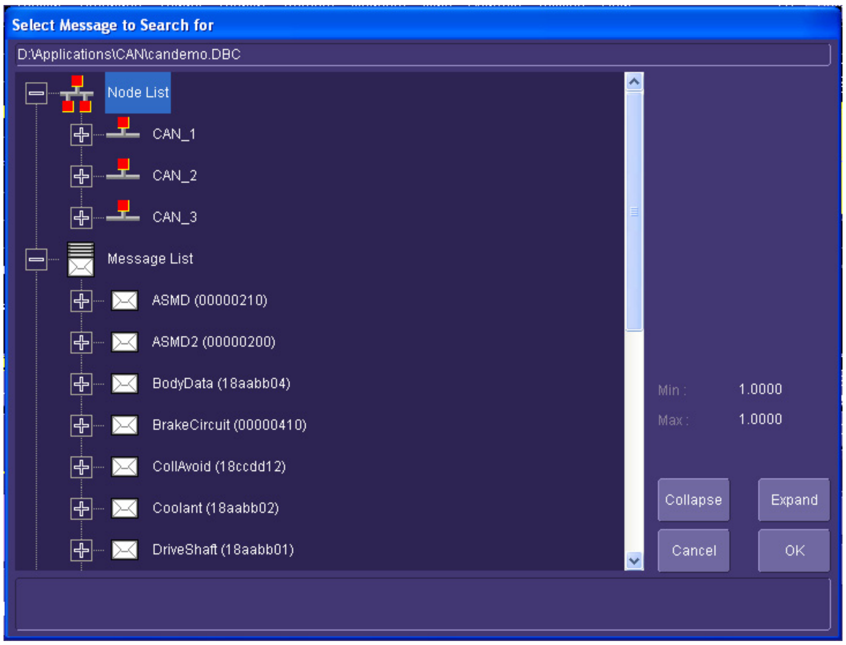


Using the DBC Symbolic Message/Signal Selector

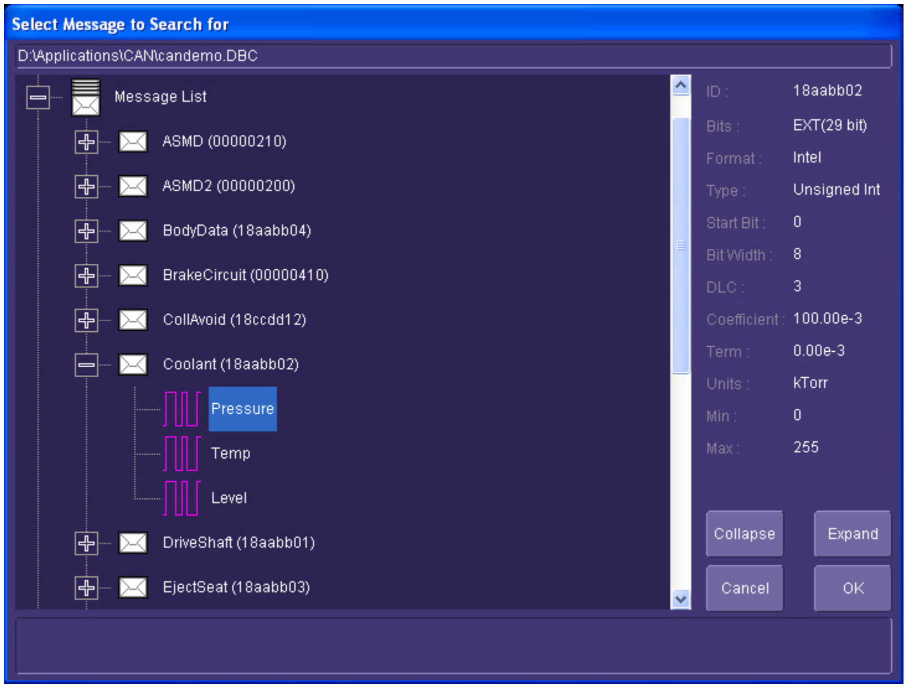


When the VBA is in Symbolic Mode, there are a number of places (CAN Symbolic Trigger setup, CAN Search, and some CAN parameters, i.e. CAN to Value) where a Message or a Signal must be selected. There is a pop-up dialog that is used to make this selection, and it is accessed by the button shown to the right.

When this button is touched, it opens a pop-up dialog, as shown below:



There is a Node List, a Message List, and a Signal List. Each of the items can be opened further (signaled by the + sign), or collapsed (signaled by the – sign). Thus, you could collapse all the items and just show a list of Nodes, Messages, and Signals, or open a particular Message and Signal, as shown below:



Thus, if you wanted to select the Pressure Signal in the Coolant Message, you could open the message list, open the Coolant Message, and double click on the Pressure Signal to make the values carry over into the column on the right, and, if the OK button is pressed, into the Trigger, Search, or Parameter setup dialog. Similar selections could be made by Node or by Signal.

- Within the Message List, Signals are listed in byte order left to right as they appear on the Vehicle Bus Analyzer display.
- Within the Signal List, Signals are listed in alphabetical order.
- Within the Node List, Messages are grouped by Tx and Rx.

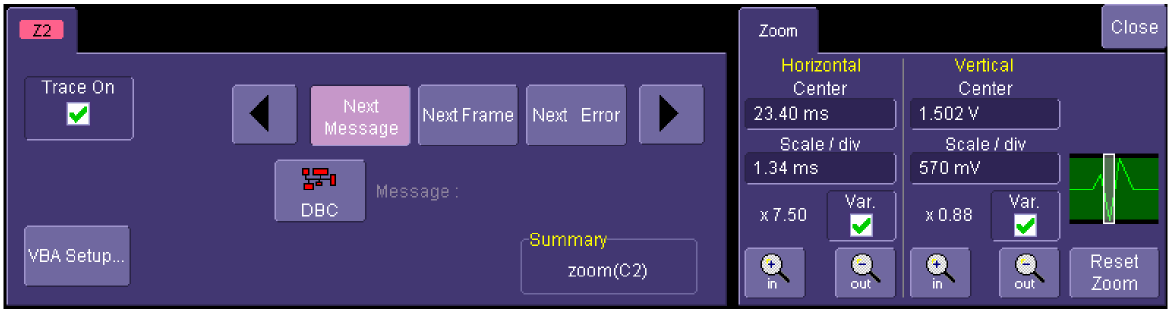
Zooming on Decoded Channels

It is possible to “zoom for detail” on a decoded channel and get decoded zoom traces.

To do this, use the mouse to “draw a box” around the trace that you want to zoom. A new trace will the be created. The name of the trace will be Z1, Z2, Z3, or Z4, with the number corresponding to the Decode number in the Decode Setup dialog.

Note the color highlighting in the original trace.

To access the Zoom trace setup dialog, touch the **Zoom** descriptor label (Z2 in the figure above). The setup dialog then appears as follows:



The search feature may be used just as searching is used on the VBA Main dialog. Front Panel zoom controls can be used to adjust the zoom position and scale, or it can be adjusted from within the dialog.

The CAN Zoom trace (light magenta) and the CAN Trace (green) are both displayed. In this case, the CAN Zoom trace is zoomed by a factor of 7.50 (Channel 2 has a horizontal scale of 10 ms/div and the Z2 Zoom Trace has a horizontal scale of 1.33 ms/div). You can see the light magenta highlight on the C2 Trace showing the position of the Z2 Zoom Trace.

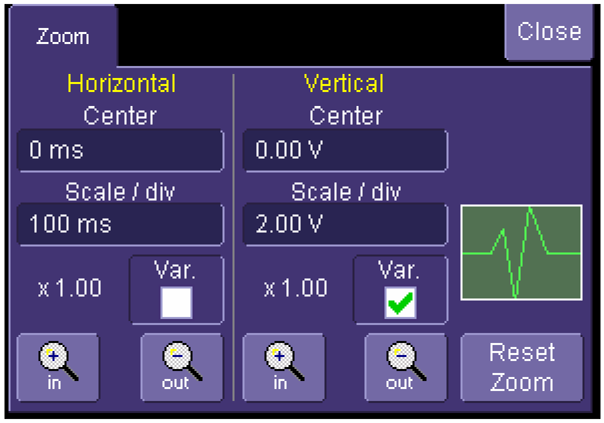
The various selections in this dialog are described below:

Trace ON – Touch this box to turn the Zoom ON or OFF, as desired.

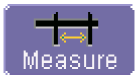
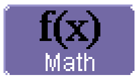
Search – Acquire long records of CAN message data, and use Search to look through the record for a particular CAN ID, for the next CAN Message Frame, or for the next CAN Error Message. Upon finding a CAN message that meets the search criteria, the complete CAN message will be displayed with the Zoom Trace. Touch the arrow buttons to advance to the next message, or revert to the previous message.

> **Note:** This is the same functionality that is in the VBA Main dialog. It is repeated here for operator convenience.

Zoom Controls – Use the zoom controls in the dialog to adjust the horizontal and vertical position and scale of the Zoom trace. Alternatively, use the front panel zoom controls.



Toolbar – The toolbar at the bottom of the dialog is the same as that for the channel dialog, except that there is no Zoom selection. These toolbar shortcuts can be used to perform specific actions for the CAN Zoom. For more information on Measure, Zoom, Math, and Memories (reference waveforms), see the oscilloscope's on-line Help.

	Opens a Measurement selection pop-up menu. You can then select parameters (measurements) for the active channel from this menu without leaving the CAN Zoom dialog. The parameters automatically appear below the grid.
	Opens a Math selection pop-up menu. You can then select a math function for the CAN Zoom from this menu without leaving the CAN Zoom dialog.
	Copies the CAN Zoom into a corresponding Memory (reference waveform) location. CAN Zoom is always loaded into M1.
	Opens a Labeling pop-up menu that allows you to tie labels bearing your own text to the waveform.

CAN TRIGGER SETUP

Overview

The Oscilloscope or Vehicle Bus Analyzer 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 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 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 Oscilloscope or Vehicle Bus Analyzer, 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

As previously stated, 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 Oscilloscope or Vehicle Bus Analyzer to the Trigger Module.

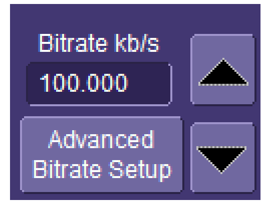
The Oscilloscope Interface Module (OIM) contains intelligence to identify the Trigger Module to the Oscilloscope or Vehicle Bus Analyzer, and transmits the trigger edge to the Oscilloscope or Vehicle Bus Analyzer input. As part of its “identification” function, the OIM does the following when it is plugged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

- Automatically sets the Oscilloscope or Vehicle Bus Analyzer 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 Oscilloscope or Vehicle Bus Analyzer 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 Oscilloscope or Vehicle Bus Analyzer 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 Oscilloscope or Vehicle Bus Analyzer display, you must also probe the CANH and CANL signals with the included PP007 single-ended probes, or a differential probe (such as the LeCroy ADP305 or AP033) and input the probe signals to a Oscilloscope or Vehicle Bus Analyzer channel.

General CAN Trigger Setup (Symbolic and Hexadecimal)

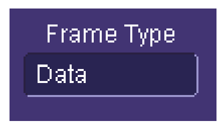
For both Symbolic and Hexadecimal modes, various selections must be made for Bit Rate, Frame Type, and Trigger Input (on the CANbus TD Series Trigger Module). These selections are described in detail below:



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 (or use a mouse) to open a pop-up keypad and enter the value directly.

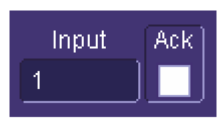
> **Note:** If you select a value that is higher than that supported by the installed Trigger Coupler, you will not be able to trigger, and will create error frames on your bus.

Non-standard bit rates (such as 102.4 kb/s) can be entered by touching the Advanced Bitrate Setup button, or selecting the Advanced Bitrate tab. From within that dialog, there is complete control over selection of all aspects of bit rate and sampling point setup. 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. Reference Appendix E for the complete list of bit rates that are supported.



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 Signal/Data condition to set up, and Error Frames don't have a Message/ID or Signal/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 signal for the other node. The default setup is to not acknowledge. If you wish for it to acknowledge, check the **Ack** box.

Creating a Symbolic Trigger Condition

Creating a CAN Symbolic trigger condition is very easy. Simply load a DBC database file onto the VBA, select the DBC file name in the CAN Symbolic Trigger dialog, and choose a Message/Signal and Signal condition. Once you have used this method, you will probably not want to use the Hexadecimal setup very often.

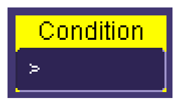
> **Note:** If a Symbolic trigger condition is selected, and then the VBA mode is changed to Hexadecimal, the Symbolic Trigger condition will also be converted to Hexadecimal format in case you want to view it in Hex format or to double check the setup.

Symbolic Mode Trigger Setup Detail

Symbol File Selection – Touch browse to locate the file on your VBA's hard drive, and then select the particular file that you wish to use for triggering.

Message/Signal Selection – Touch the DBC icon to access the DBC Message/Signal selector. Then, choose a specific message or signal. Only one Message/Signal can be chosen at a time.

Condition Selection – This selection only appears if you chose to trigger on a Signal.



Touch the condition entry box and choose a <=, <, =, >, >=,≠, In Range, Out of Range, or Don't Care condition for your Signal. You may also choose a Binary condition, which will create an additional Trig Binary tab to use for Binary data setup.

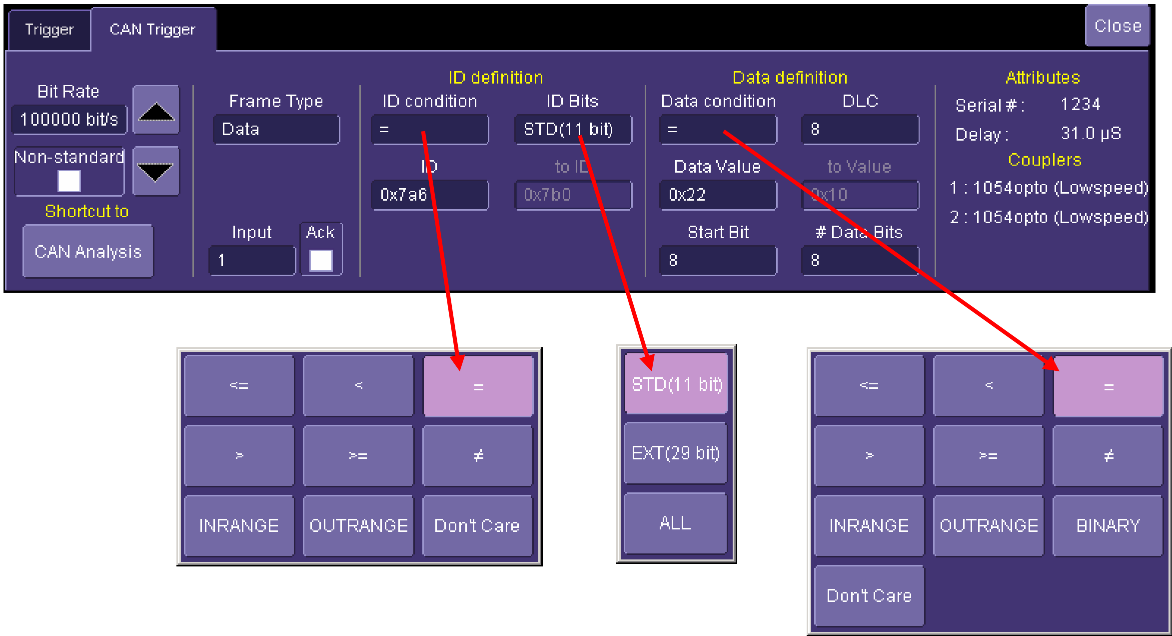
Value Selection – Touch the Value entry box to use a numeric entry keypad to make a selection for the data value. This data value will be made in decimal format in whatever units are defined for that signal in your symbol file.

Value To Selection – If you have selected an In Range or Out of Range condition, you will also need to select a second value selection, as per above.

Once your trigger setup is complete, use the standard Oscilloscope or Vehicle Bus Analyzer/Oscilloscope trigger controls to begin triggering on the desired Message/Signal.

Creating a Hexadecimal Trigger Condition

The CAN Hexadecimal 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. Appendix B contains a flowchart of possible trigger setups so that you can understand the capability of the Hexadecimal CAN Trigger.

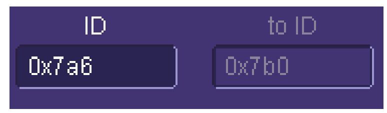
To select a value for any of the conditions, touch the existing value (or use a mouse) to open the pop-up dialog box with a list of choices, and select one of the choices.

Hexadecimal Mode Trigger Setup Detail

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

The ID condition can be set to <=, <, =, >, >=, ≠, in range, out of 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 OUTRANGE, you will enter two ID values.

Data Condition – The Data Condition can be set to many different operators. The Data condition can be set to <=, <, =, >, >=, ≠, in range, out of 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 that 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

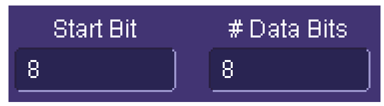
INRANGE or OUTRANGE, you will enter two Data Values.

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

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 7^{th} bit in the byte appearing at the far left of the byte; and the 0^{th} 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.

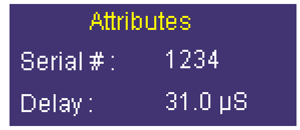


Start Bit and # Bits – The CANbus TD Series trigger allows you to trigger on up to 24 contiguous data bits (3 data bytes). This maximum 24-bit string can start at any location in the CAN message data field — it is not limited to the start of a full byte or a nibble.

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 1^{st} data byte is bits 0-7, the 2^{nd} 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 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).

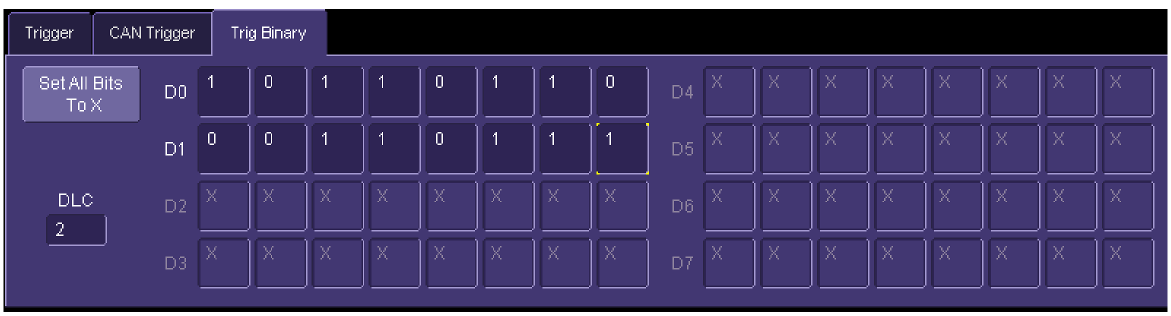
Trigger Couplers – When the Trigger Module is correctly connected to the oscilloscope, the Trigger Input (1 or 2) and the Trigger Coupler type are identified. This makes it easy to understand which Trigger Couplers are installed, and which trigger input to use when connected to the bus.

Setting a Trigger Condition in Binary

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:



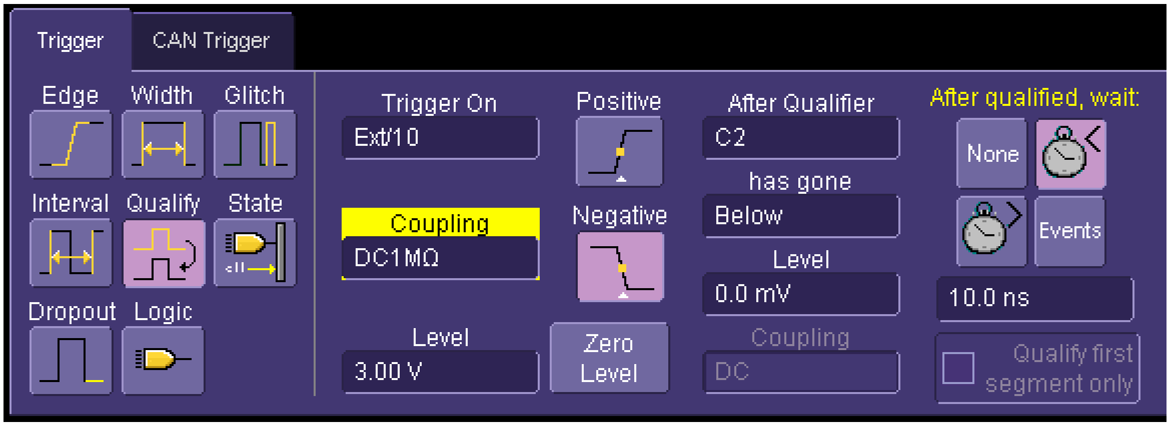
The Data Bytes are labeled D0 through D7. The far left bit in each byte is bit 7 and the far right bit is bit 0. A "1" is always a dominant bit, and a "0" is always a recessive bit. An "X" means that the bit can be either a 1 or a 0. Select a bit value by touching the existing value and choosing a value 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, 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 Qualifier in a Trigger (Symbolic or Hexadecimal Mode)

Since the CAN Trigger 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.

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

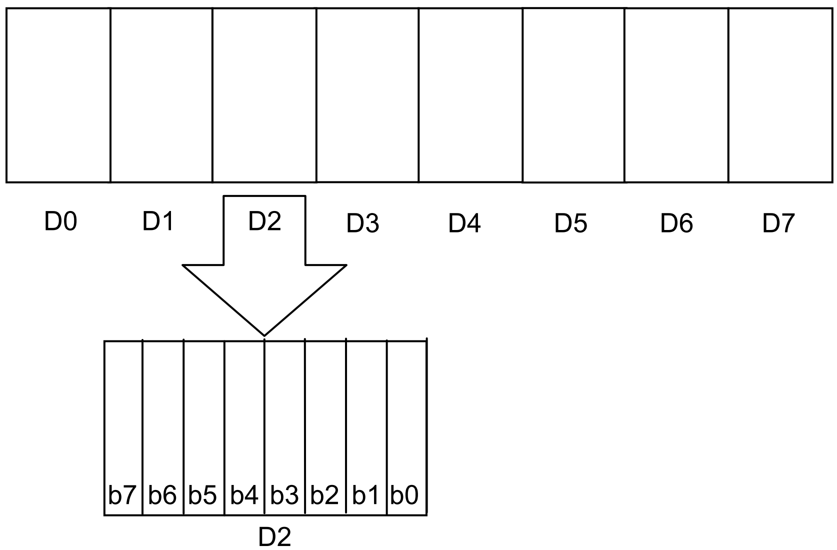
Hexadecimal Mode Trigger Setup Examples

Note: These examples were taken using a WaveRunner 6000A oscilloscope with CANbus TDM. Some of the screen images may appear slightly different from the Oscilloscope or Vehicle Bus Analyzer, but the overall setup operation for the trigger is the same.

Note: Using Symbolic triggering for complicated ID and DATA triggering, like the examples shown below, is much simpler than using Hexadecimal triggering for these same examples.

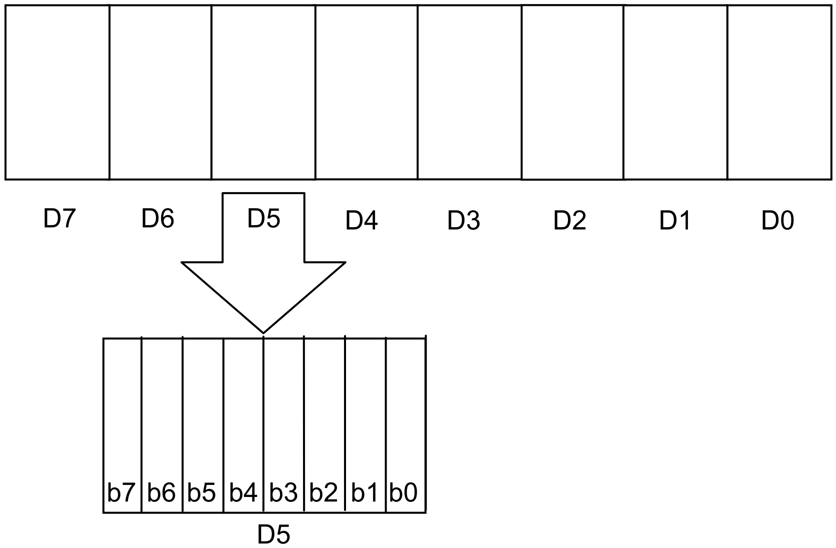
When setting up the CAN trigger for a data value that is longer than one byte, is a partial byte, or is spread between bytes, it is helpful to know the underlying format of the trigger module so that you can set up the trigger correctly.

CAN data is decoded and displayed on the oscilloscope screen in an LSB (Least Significant Byte) and lsb (least significant bit, bitwise to the left) format. This is shown in the image that follows:



where Dx represents the Data Byte number and bx represents the bit number within the byte.

The CANbus TD Series Trigger Module uses a CAN controller that is MSB (Most Significant Byte) and lsb (least significant bit, bitwise to the left). This is shown below:



Thus, the format for the displayed decoded data and the CAN trigger Data Value field is different. If you are only triggering on one data byte value, there is no impact to setup, since reversing the byte order of a one-data-byte message has no effect. If you are triggering on more than one data byte, you must reverse the values in the Data Value field in order for triggering to work correctly.

Multiple Data Bytes – DLC Matches Number of Triggered Data Bytes

If you are only triggering on one data byte value, there is no impact to setup, since reversing the byte order of a one-data-byte message has no effect.

If you have more than one data byte, the Data Values must be reversed. For example, let's assume the following:

- You want to trigger on a 3-byte message.
- The data is contained in 3 full bytes, and is not spread across bytes.
- The DLC for the message is 3.

This is, obviously, a very simple case, but it is a good example to start with.

When this message is captured and decoded, it will be decoded in LSB format. However, the trigger must be set up in reverse order. If the message is decoded as 1d a1 07 (D0 D1 D2), the Data Value field for triggering must be set to 07 a1 1d (D2 D1 D0). Of course, your DLC (3), Start Bit (0), and # Data Bits (24) must also be correctly set. This example is shown in the image that follows:

If you are triggering on 2 full data bytes, the process is the same (just make sure that you change the DLC, Start Bit, and # Data Bits value as appropriate.

Multiple Data Bytes – DLC Does Not Match Number of Triggered Data Bytes

If the DLC does not match the number of triggered data bytes, you must specify the correct Start Bit and the # Data Bits within the message that you wish to trigger on.

For example, let's assume the following:

- You want to trigger on a 3-byte message.
- The data of interest is contained in 2 full bytes (bytes D3 and D4), and is not spread across bytes.
- The DLC for the message is 5.

When this message is captured and decoded, it will be decoded in LSB format. However, the trigger must be set up in reverse order. If the message is decoded as 00 80 96 98 00 (D0 D1 D2 D3 D4), the trigger should be set up as follows:

- Data Value must be set to 00 98 (D4 D3)

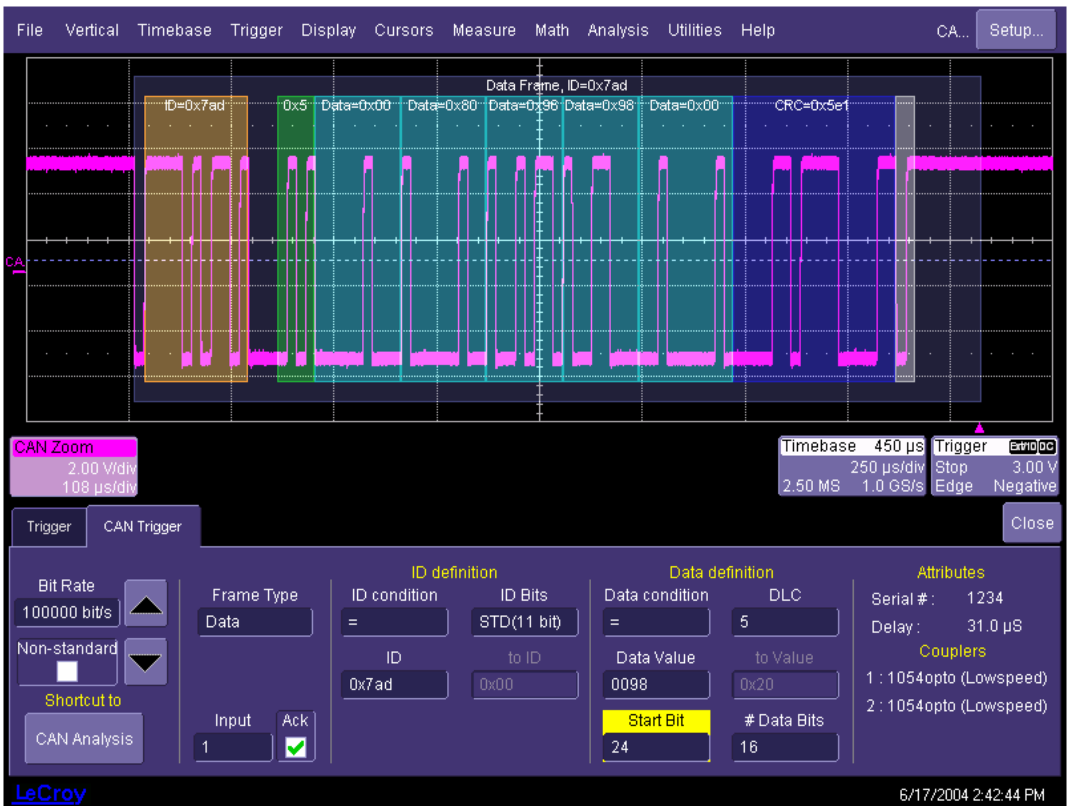
- Data Condition can be anything (in this example, we set it up as "=", but it could be any of the data conditions.
- DLC = 5
- Start Bit = 24 (the start bit for the 4th byte)
- # Data Bits = 16

Note: While the Data Value is MSB, the Start Bit value is not. In a 5-byte message, the bit pattern is as follows:

7 6 5 4 3 2 1 0 ‖ 15 14 13 12 11 10 9 8 ‖ 23 22 21 20 19 18 17 16 ‖ 31 30 29 28 27 26 25 24 ‖ 39 38 37 36 35 34 33 32

The first bit (counting from right to left) of the 4th data byte (D3) is 24. Therefore, this is defined as the Start Bit.

This example is shown below:



Multiple Data Bytes – Data is Spread Across Bytes

With CANbus TD, you need not confine your triggering to full bytes or even full nibbles. You can set up the CAN trigger to trigger across data bytes. For example, if your data was a 5-byte signal with values as follows:

00 1f a1 07 00 (for D0 D1 D2 D3 D4)

you could set up the CAN trigger to trigger on the 14 bits that are spread from the 6th bit in D1 (this is the 13th bit in the 5-byte message) to the 3rd bit in D3 (this is the 26th bit in the 5-byte message). In order to set this CAN trigger up correctly, it is probably helpful to divide the data in nibbles and then into bits as necessary. This is done below, with the bits of interest in red, bold text:

Data Byte	**Hexadecimal Value**	**Nibble Value**	**Binary Value**	**Bit Values**
D0	00	0 0	0000 0000	7 6 5 4 3 2 1 0
D1	1f	1 f	**000**1 1111	**15 14 13** 12 11 10 9 8
D2	a1	a 1	**1010** **0001**	**23 22 21 20** **19 18 17 16**
D3	07	0 7	0000 0**111**	31 30 29 28 27 **26 25 24**
D4	00	0 0	0000 0000	39 38 37 36 35 34 33 32

If the data were rearranged into a table from msb to lsb (remember that our hexadecimal Data Value field in the CAN trigger dialog is in MSB format) it would look like this:

Bit	26	25	24	23	22	21	20	19	18	17	16	15	14	13
Value	1	1	1	1	0	1	0	0	0	0	1	0	0	0

If this data was then divided into nibbles, and recoded into hexadecimal format, it would look like this:

Bit	26	25	24	23	22	21	20	19	18	17	16	15	14	13
Value	1	1	1	1	0	1	0	0	0	0	1	0	0	0
Nibble	3		d				0				8			

Using the above table, you can now enter values into the CAN Trigger as follows

- DLC = 5
- Data Condition can be anything (in this example, we set it up as "=", but it could be any of the data conditions.
- Data Value = 3d08
- Start Bit = 13 (the 5th bit in the 2nd (D1) data byte)
- # Data Bits = 14

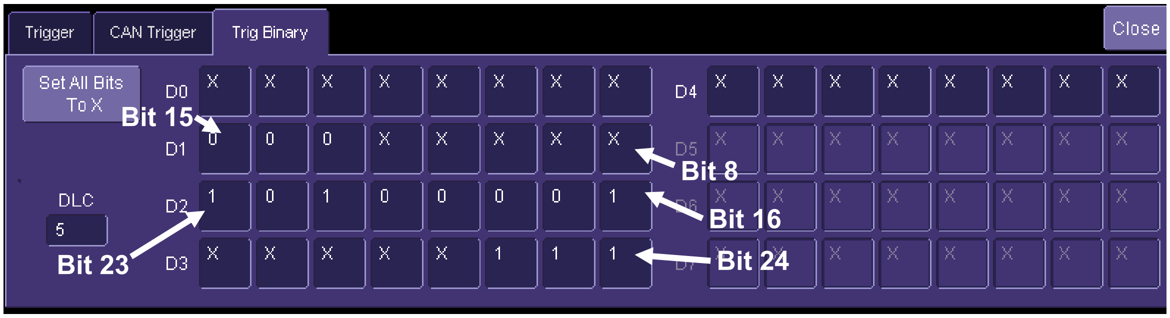
The resultant trigger capture is shown below:

Note: Since the data values are spread across bytes in values that do not equal a full nibble or a full byte, there will not be correlation between the Data Value and the decoded data on the oscilloscope display.

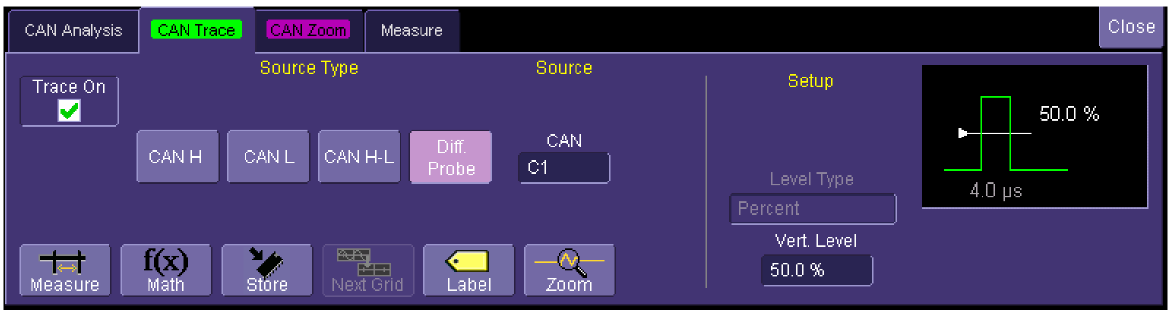
You can also use the binary trigger setup to trigger on this same condition. Recall that our condition was as follows:

Bit	26	25	24	23	22	21	20	19	18	17	16	15	14	13
Value	1	1	1	1	0	1	0	0	0	0	1	0	0	0

You would then set up the binary trigger dialog as follows:



Note: Binary setup can be much easier to achieve when you need to trigger on data spread across bytes; however, you lose the capability to set a data condition other than "=". In the hexadecimal setup described above, your data condition can be <, <=, =, >, >=, ≠, In Range, and Out of Range.



The various selections in this dialog are described below:

Trace ON – Touch this box to turn the CAN Trace ON or OFF, as desired.

Source Type – Choose one of the sources to be defined as your CAN Trace. The currently selected CAN source type will be highlighted in light purple. "Diff. Probe" is an abbreviation for Differential Probe.

If you select CAN H, CAN L, or Diff. Probe, you will only define one source. If you select CAN H-L, you will need to define two sources (such as two single-ended probes).

Note: If you choose to use two single-ended probes to probe your CAN signal, the probes should be identical, and should be set to the same coupling, gain, etc. The probes must also be identically grounded. In addition, since the CANbus TD program has to subtract the digitized values for the two probes before performing decoding, using two single-ended probes will result in a speed penalty of approximately 2.5x compared to using a differential probe. For best results, a differential probe, which requires no grounding, is recommended unless you wish to look at CANH and CANL independently as part of your analysis.

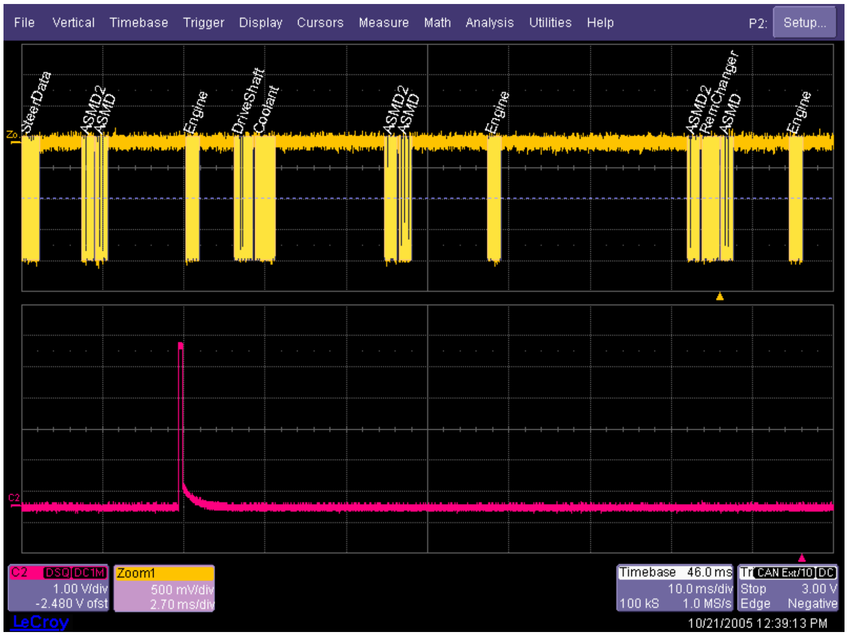
CHARACTERIZING AND VALIDATING SYSTEM PERFORMANCE

Overview

Your oscilloscope or Vehicle Bus Analyzer contains a number of built-in tools, such as cursors, measurement parameters, and statistical analysis. These can be used to characterize performance on CAN systems 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 CAN physical signal.

The oscilloscope and Vehicle Bus Analyzer provides basic tools to characterize CAN Bus system performance. These tools can be used on any decoded source (channel, memory, math function) just like they are used on any non-decoded source. 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.

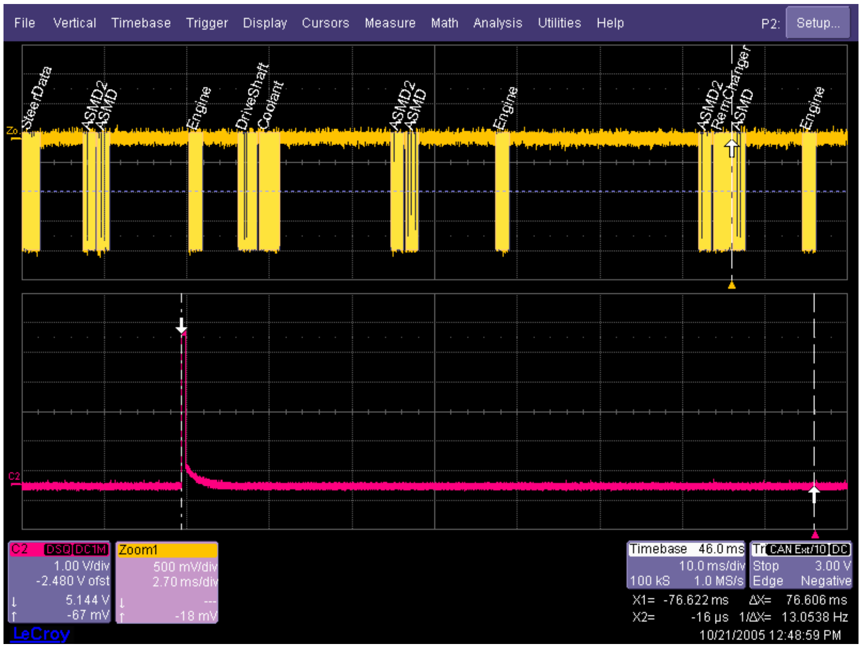
For instance, take the example below of an analog signal preceding a particular CAN message (note: this example is showing symbolic decode using a Vehicle Bus Analyzer):



This data was acquired over a 100 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

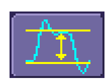
Use horizontal cursors to mark locations on the waveform where the time measurement should be done, then read the cursor values to establish the measurement. As necessary, adjust the timebase or create zooms of the channels (as shown in the image below) and/or analog signal so as to be able to view the signal with enough detail. This is a good method for single-shot or single measurements. For information on how to use automated timing parameters to perform the same function on multiple shots, reference the section "Measuring CAN Bus System Performance."



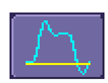
Using Measurement Parameters

Measurement parameters can be used 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 (Reference the chapter on Isolating and Analyzing CAN Bus Activity for more information on Sequence mode).

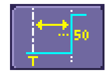
Amplitude – Noise and overshoot resistant measurement of the amplitude of the signal (measurement of amplitude from Top to Base).



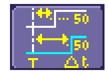
Base – Value of the lowermost state in a bi-modal waveform, such as a CAN Message.



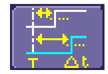
Delay – Time from the trigger to the first transition at the 50% amplitude crossing.



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

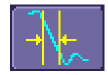


Delta Time @ Level – Time between selectable levels of two waveforms.

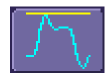


Delta Trig Time – The time from last trigger to this trigger (usually used in Sequence mode).

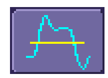
Fall (90-10), Fall (80-20), Fall@Level – Transition time on the falling edge. Three selections are available to determine at which vertical level the measurement is made.



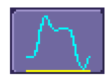
Maximum – Highest value in the input waveform.



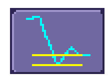
Mean – Average of all data values.



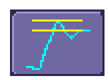
Minimum – Lowest value in the input waveform.



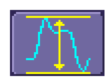
Overshoot Negative – Overshoot following a falling edge.



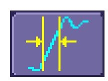
Overshoot Positive – Overshoot following a rising edge.



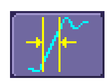
Peak to Peak – Difference between the Maximum and Minimum data values.



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



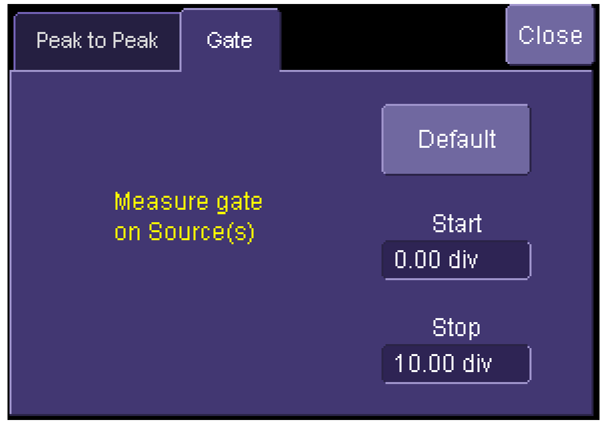
Top – Value of the uppermost state in a bi-modal waveform, such as a CAN Message.



Measurement Gating

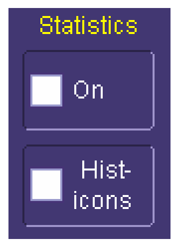
Gating is available on each standard parameter to allow you to set a measurement window that the parameter should be active in. This allows you to eliminate unwanted portions of the acquisition from your measurement. Gating is not available with the CAN specific measurement parameters.

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

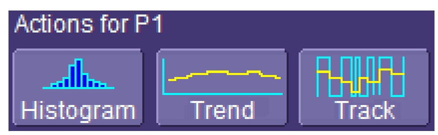


Using Statistics and Graphing

Statistics and Histicons are included with 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. Simply touch the appropriate box to checkmark it and turn it ON, or touch it again to turn it OFF.

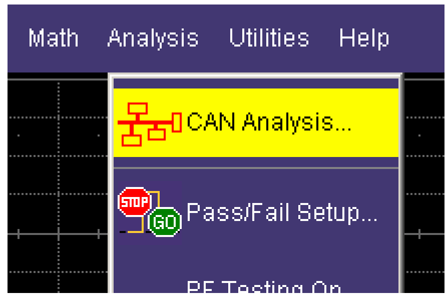


In addition, the CANbus TDM option or Vehicle Bus Analyzer provides capability to produce larger histograms, trends, and tracks of your measurement parameters. You can access this capability through the Measurement Parameter setup dialog (the Px tab), or through the Measure/Graph tab in the CANbus TDM or Vehicle Bus Analyzer dialogs.

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 failure, or send an email in the event of a failure.

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.



MEASURING CAN BUS PERFORMANCE

Overview

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:

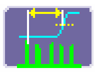
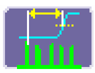
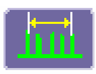
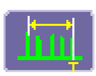
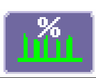
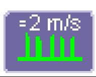
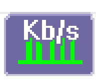
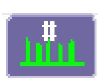
- **Measure Timing Δ Between CAN and Analog Signals & Accumulate Statistics** – Measure the time difference between an analog signal and CAN signal generated in response to it (or vice-a-versa). View the mean, minimum, and maximum timing values, the number of samples, and the standard deviation of the measurements.
- **Measure Timing Δ Between Two CAN Messages & Accumulate Statistics** – Same as above, but with two CAN signals.
- **Measure Timing Δ From the Trigger Point to a CAN Message –** Same as above, 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.
- **Measure Bit Rate of a CAN bus traffic, Graph/Plot change in bit rate** – Measure the average and worst case bit rates in a CAN bus acquisition. Graphically view the change in bit rate in a time-correlated way to understand which messages have deviating bit rates.
- **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.

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.

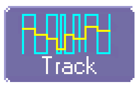
CANbus TDM and the Vehicle Bus Analyzer contain specific CAN measurement parameters that allow you to quickly and easily accumulate statistical information on a wide variety of events, and graphical display tools to visualize the data on your oscilloscope screen. These sophisticated measurement and graphical display tools are the “missing link” between standard oscilloscope and protocol analyzer capability. The CANbus TDM or Vehicle Bus Analyzer 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 or Vehicle Bus Analyzer 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.

Both CANbus TDM or the Vehicle Bus Analyzer contain CAN specific measurement, graphing, and statistical analysis capability as follows:

Measurement 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 (**t@CAN**)
	CAN Bus Message Load Percentage (**CANLoad**)
	Extract CAN Message Data to a Decimal Value (**CANtoValue**)
	CAN Bus Message Bit Rate calculation (**CANMsgBR)**
	CAN Bus Message Number calculation (**CANMsgNum**)

CANbus TDM Graphing & Statistical Analysis

	**Histogram** – Selecting *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 to observe changes in timing. *Track* is typically used for a single-shot acquisition. A long acquisition with many parameter measurements analyzed with *Track* can provide information about the modulation of the parameter.

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

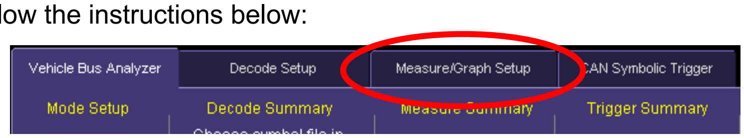
The above measurement parameters are available in the "Statistics" category in the measurement selection pop-up dialog.

General Setup of CAN Measurement Parameters

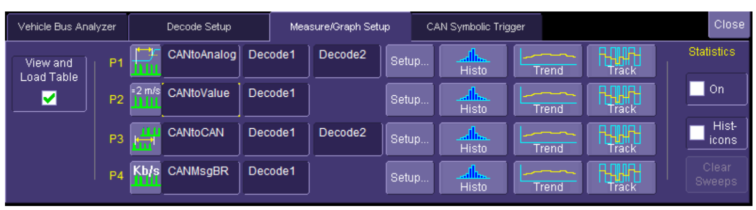
There are two different ways to set up CAN related measurements. The easiest way is to use the Measure/Graph Setup tab in the CANbus TDM or Vehicle Bus Analyzer dialogs to access the Measure/Graph setup dialog. This dialog is specifically tailored to meet the needs of an engineer who is debugging CAN embedded controller based systems. It contains different categories of CAN, pulse, statistical, etc. measurement parameters that are commonly used to measure CAN system performance.

To access and use this dialog, follow the instructions below:

1. Touch the **Measure/Graph Setup** tab in the CANbus TDM or Vehicle Bus Analyzer dialog.

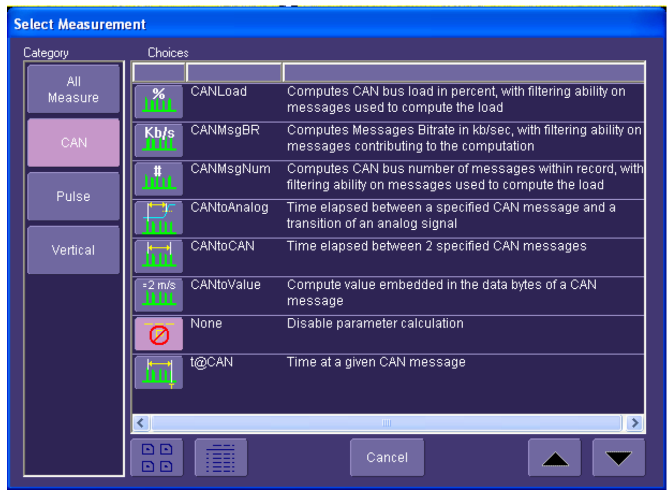


2. There are four parameter measurements displayed (P1 through P4).



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

4. In the CAN Select Measurement pop-up dialog, choose a parameter. (This dialog does not list all parameters, only a subset of them that are commonly used for CAN testing). Touch an icon to select the measurement.

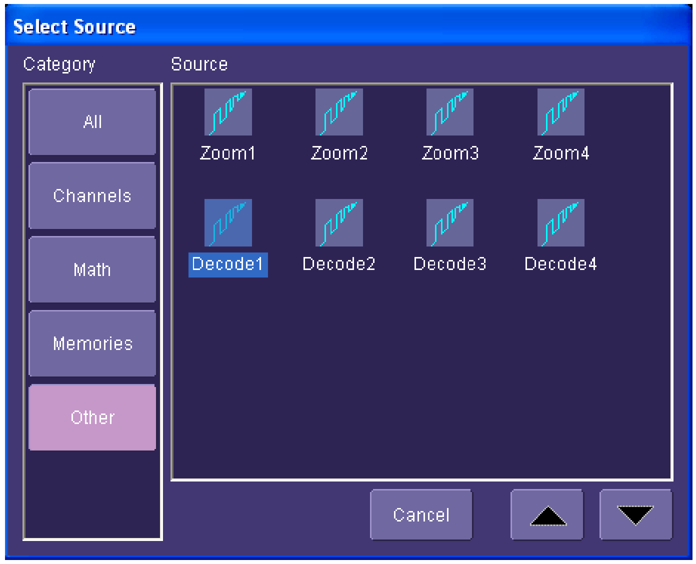


5. Touch the source field(s) to open the Select Source pop-up dialog.

Note: For the Vehicle Bus Analyzer, if the CAN signal is your source, you need to use the **Decode1, Decode2, Decode3,** or **Decode4** selection (that corresponds to the setup in the Decode Setup dialog. These are located in the "Other" category in the Select Source pop-up dialog. Channel, math, memory, etc. For CANbus TDM, you need to use the CAN Decode source. Sources are selected by just picking the appropriate channel, math, memory, etc.

6. Select a category to display the available sources, then select the appropriate source.

> **Note:** If the CAN signal is your source, use the corresponding **Decode** selection and not the Channel (if you are using a differential probe) or Math (if you are using two single-ended probes and subtracting CANH-CANL in Math) sources. Other sources are selected by just picking the appropriate channel, math, memory, etc.
>
> **For CANbus TDM –** use the CAN Decode source.



7. The View and Load Table checkbox is checked automatically when you select your parameters. You may uncheck it to turn measurements OFF.

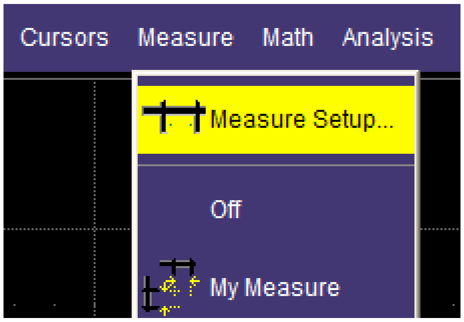
> **Note:** Measurement parameter and source selections that are set up in the Measure/Graph Setup dialog are uploaded to the oscilloscope or Vehicle Bus Analyzer standard Measure menu.

8. 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, simply touch the **Setup** button at top-right of the scope display. This will take you to a different setup dialog. You can return to the Measure/Graph Setup dialog by re-accessing the

CANbus TDM or Vehicle Bus Analyzer dialog and following Step 1 above.

Measurement parameters may also be set up in the oscilloscope or Vehicle Bus Analyzer standard Measure menu available from the menu bar. This may be accessed as follows:

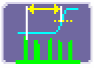
1. Touch **Measure** in the menu bar, and select **Measure Setup…**. Then select the appropriate CAN or other parameter just like you would any other parameter (reference your oscilloscope or Vehicle Bus Analyzer on-line Help or Getting Started Manual for more information).



Note: All CAN measurement parameters (with the exception of CAN Load % and CANMsgNum) 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 % and CANMsgNum returns only one value during each acquisition since it is evaluating the load % or the number of messages (respectively) for the entire acquisition time.

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



CAN Message to Analog Signal timing (**CANtoAnalog**)

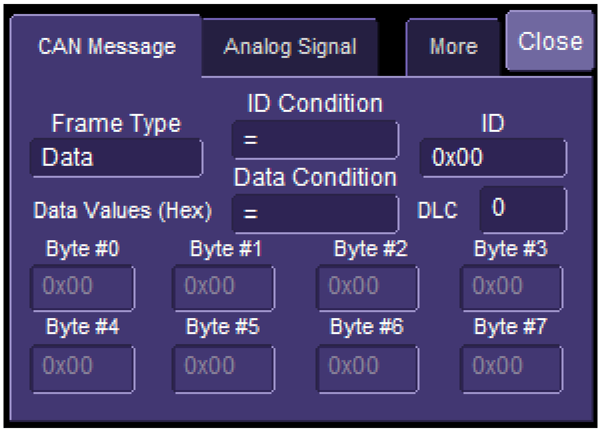
This measurement parameter is used to measure timing from either a CAN Message to an Analog Signal, or from an Analog Signal to a CAN Message. The Frame Type, ID, DATA, etc. conditions for the CAN message can be fully defined, as can the slope, level, etc. conditions for the analog signal transition.

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 (the leftmost source) should always be defined as the **Decode**d waveform 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.

CANtoAnalog Measurement Parameter Setup Detail

To access the setup dialog, touch Setup for that particular parameter in the Measure/Graph Setup dialog. This will take you to the Px Parameter dialog box. On the right-hand 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 box:



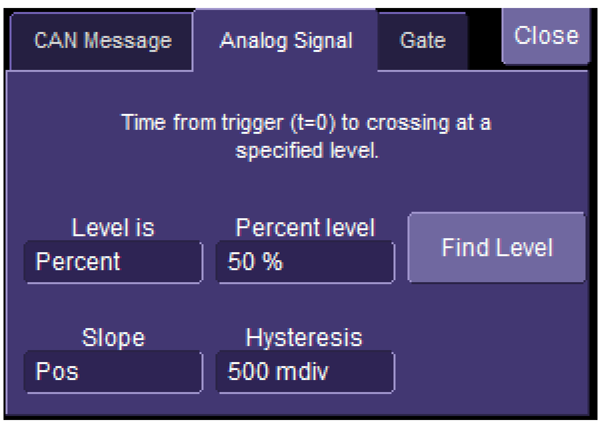
The **CAN Message** dialog defines the CAN Message Setup.

The **Analog Signal** dialog 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.

Setup of the CAN Message is nearly identical to that of the CAN message in the CAN Trigger dialog, so details will not be repeated here.

The **Analog Signal** setup dialog is shown below:



Simply select the measurement level as Percent or Absolute, and adjust the value. Then select the slope of the edge you wish to measure to. 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:

1. Hysteresis must be larger than the maximum noise spike you want to ignore.
2. The largest value of hysteresis usable is less than the distance from the level to the closest extreme value of the waveform.
3. 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.

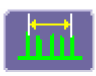
In all cases, the cause of the condition can be viewed on the message line by clicking on the yellow icon , below the measurement parameter value(s).

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 tab is encountered in the whole record processed by the algorithm. In this case the error message will be "Can not 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

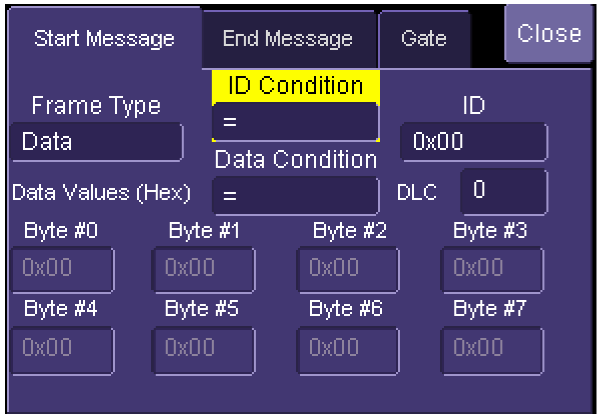


CAN Message-to-CAN Message timing (**CANtoCAN**)

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. In addition, this parameter can be used to measure the time for a CAN message to cross a gateway by selecting two different sources (i.e., the decoded low-speed CAN Bus and the decoded high-speed CAN Bus). The timing is always measured from the End of Frame (EOF) of the first CAN message to the Start of Frame (SOF) of the second CAN message.

CANtoCAN Measurement Parameter Setup Detail

To access the setup dialog, touch **Setup** for that particular parameter in the **Measure/Graph Setup** dialog. This will take you to the Px Parameter dialog box. On the right-hand side of this dialog there is another setup dialog:



- The **Start Message** dialog defines the first CAN Message Setup.
- The **End Message** dialog defines the second CAN Message Setup.
- 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 value 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 will 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 value(s).

The simplest, and most common, reason for non-computation of the CAN timing parameters is that none of the Start or End conditions defined in the right-hand dialog tab is encountered in the whole record processed by the algorithm. In this case the error message will be "Can not 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 setup tab 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".

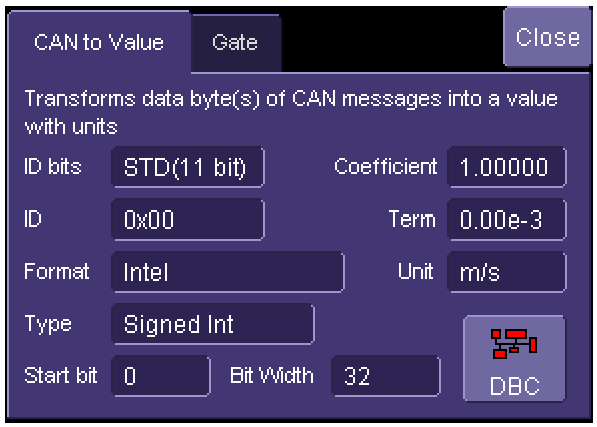
Extract CAN Message Data to a Decimal Value

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 conversion of a bit field embedded in a CAN message into a value with user-definable units

CANtoValue Measurement Parameter Setup Detail

To access the setup dialog, touch **Setup** for that particular parameter in the **Measure/Graph Setup** dialog. This will take you to the Px Parameter dialog. On the right-hand side of this dialog there is another setup dialog:



Symbolic Setup (Vehicle Bus Analyzer only)

The easiest way to populate the various entries is to simply touch the **DBC** button and pick a Signal within a specific CAN Message. The program will then automatically populate the values, including Format, Type, data bit location, and scaling coefficients and units.

Using this measurement parameter, it is possible to graph data using the Trend or Track function.

Hexadecimal Setup

Alternatively, you may specify the ID length, ID Value, etc. 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 of 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.

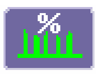
Finally, the last stage of the conversion process transforms the raw value into a physical value with units, using a linear transformation of the type: Parameter Value = Coefficient * Raw Value + Term. Units can be specified as well, provided they belong to the list provided in "Rescaling and Assigning Units." The unit specified here will propagate throughout the system to the parameter value, subsequent Tracks and Trends, and cursor readout on any derived function. (Reference the oscilloscope on-line Help for a complete list of allowable units.)

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, it is possible to graph data using the Trend or Track function.

CAN Bus Message Load % Measurement Parameter

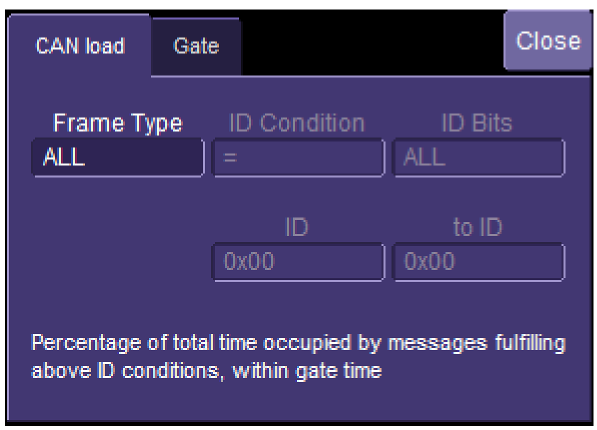


CAN Bus Message Load Percentage (**CANLoad**)

This measurement parameter is used to measure total bus load 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.

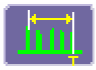
CANLoad Measurement Parameter Setup Detail

To access the setup dialog, touch Setup for that particular parameter in the Measure/Graph Setup dialog. This will take you to the Px Parameter dialog box. On the right hand side of this dialog there is another setup 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.

Time from Trigger Point to CAN Message Measurement Parameter

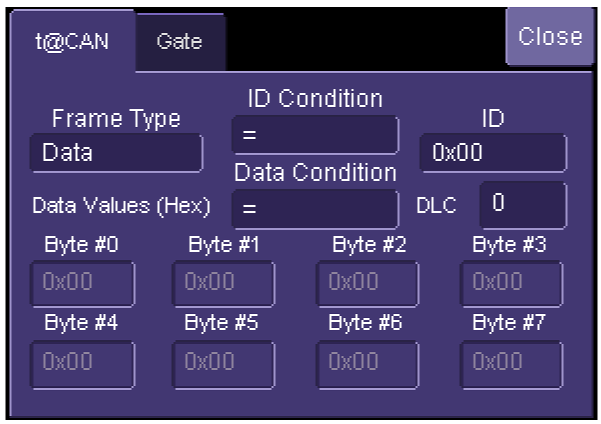


Time from Trigger Point to CAN Message (**t@CAN**)

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.

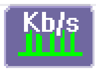
t@CAN Measurement Parameter Setup Detail

To access the setup dialog, touch **Setup** for that particular parameter in the **Measure/Graph Setup** dialog. This will take you to the Px Parameter dialog. On the right-hand side of this dialog there is another setup dialog:



The setup of this dialog is straightforward and has been described before in descriptions of other CAN parameters.

CAN Bus Message Bit Rate Parameter

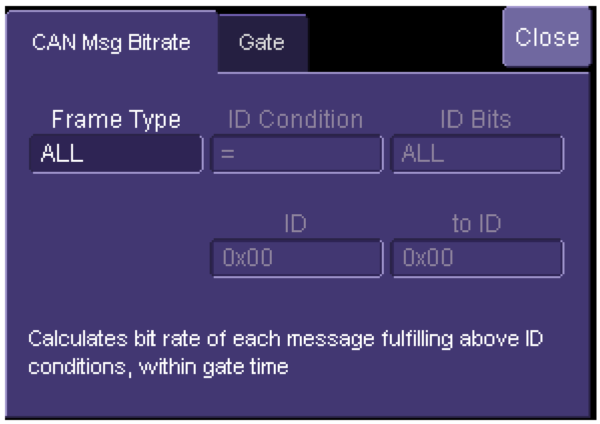


Calculation of Average Bit Rate of a CAN Message (**CANMsgBR**)

This measurement parameter is used to calculate the average bit rate of a CAN message or a series of CAN messages, with qualifiers set for frame type and ID. If there are N CAN messages in an acquisition, it will return N values for bit rate. Combined with the Track function, this parameter is very helpful for locating a particular node/ID that has an abnormally set bit rate.

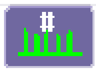
CANMsgBR Measurement Parameter Setup Detail

To access the setup dialog, touch **Setup** for that particular parameter in the **Measure/Graph Setup** dialog. This will take you to the Px Parameter dialog. On the right-hand side of this dialog there is another setup dialog:



The setup of this dialog is straightforward and has been described before in descriptions of other CAN parameters.

CAN Bus Number of Messages Parameter

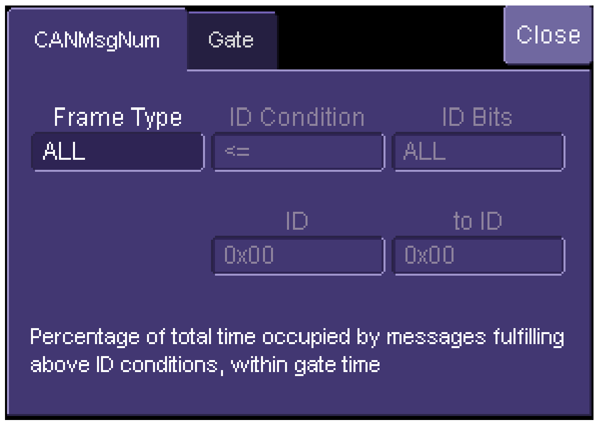


Calculation of Number of Messages in a CAN Acquisition (**CANMsgNum**)

This measurement parameter is used to calculate the number of CAN messages in a specific CAN acquisition, with qualifiers set for frame type and ID. If there are N CAN messages in an acquisition that meet the condition, it will return N values for the number of messages that meet the condition.

CANMsgNum Measurement Parameter Setup Detail

To access the setup dialog, touch Setup for that particular parameter in the Measure/Graph Setup dialog. This will take you to the Px Parameter dialog box. On the right-hand side of this dialog there is another setup dialog:



The setup of this dialog is straightforward and has been described before in descriptions of other CAN parameters.

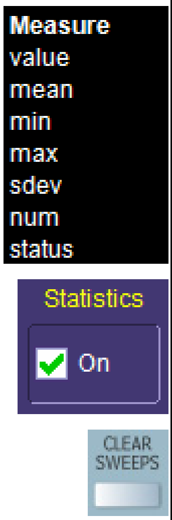
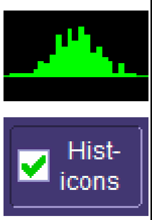
STATISTICAL EVALUATION OF PARAMETER MEASUREMENTS

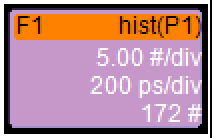
Overview

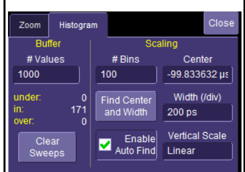
Parameter measurements are powerful tools to understand CAN system behavior. However, there are additional tools that allow you to understand statistical variation of these measurements so that worst case values, mean values, standard deviation of the measurement set, and modality can be understood, and root causes of timing or other irregularities debugged.

Statistical Evaluation Tools

The various tools for statistical evaluation are described below:

	**Statistics** – Allows you to view statistics of any measurement. Statistics can be turned on by touching the **Statistics** checkbox in the **Measure/Graph Setup** menu. Values reported are as follows: • (last) Value measured • Mean of all Values • Minimum of all Values • Maximum of all Values • Standard Deviation of all Values • Number of Values in the measurement set (values will accumulate over multiple acquisitions unless **CLEAR SWEEPS** is pressed). • Status of measurement (reference your Vehicle Bus Analyzer on-line Help or Oscilloscope's Getting Started Manual for information on what the various status icons indicate, or touch or click on the status icon to review a status message) Press the front panel **CLEAR SWEEPS** button to reset the accumulation of statistics for all of your parameter measurements.
	**Histicons** – Histicons are **Hist**ogram **Icons**. They are small versions of Histograms (see below) that can be quickly applied to all of your measurement parameters. Histicons can be turned on by touching the **Histicons** checkbox in the **Measure/Graph Setup** menu. They will accumulate for many measurements, but there is no ability to change the default settings to see more detail, and cursors and statistical measurements can't be used on Histicons.
	**Histogram** – The Histogram displays a statistical distribution of a measurement parameter. Histograms are helpful to understand the modality of a measurement parameter, and to debug the root cause of excessive variation. Histograms are just like any other trace: cursors can be used to make measurements; additional parameter





measurements can be applied to the Histogram trace; and the Histogram view can be modified to show the level of detail that you want.

Histograms are created in a math (Fx) trace using a parameter measurement (Px) as a source. Touching the Histogram icon nearly completely automates the setup of a Histogram: you only have to select which Fx trace to create the histogram in.

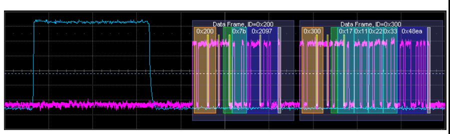
To adjust the Histogram setup/view, touch the Histogram descriptor label twice. This will bring up a setup dialog for the selected Fx trace that defines the Histogram.

Then touch the Histogram tab in the right-hand dialog. All histogram adjustments are conveniently located here.

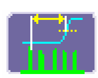
Note: The default number of measurements for the histogram is 1000. You can change this in this dialog, and will need to if you want to see more than 1000 values. Up to 2 billion values can be histogrammed.

Setting Up Histograms

There are five steps to analyzing data with histograms:

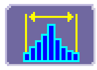


1. Set up a trigger condition to acquire the signals you want to make a measurement of (in this case, a CAN message and an Analog signal). Begin acquisition.

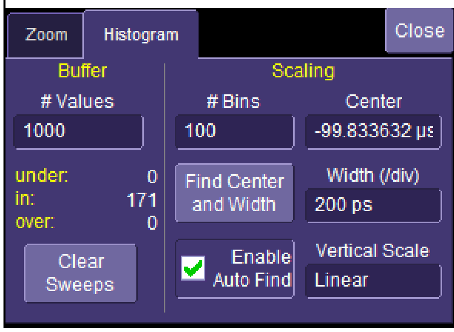


2. Set up a parameter (in this case, a CANtoAnalog timing parameter)

3. Create a histogram of the parameter by touching the Histogram button for that parameter in the **Measure/Graph Setup** dialog, and following the on-screen directions.



4. Apply additional Statistical parameters to your histogram, as necessary or desired. In this case, the Range parameter is applied to the histogram to understand the maximum range of measurements.



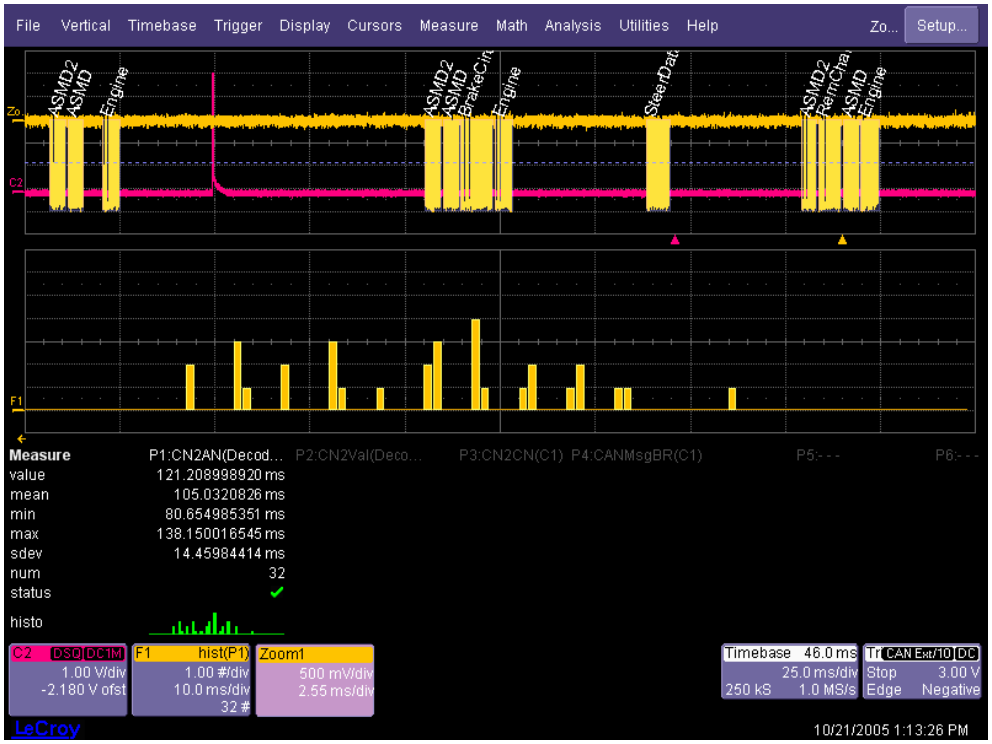
5. In the Histogram setup right-hand dialog (accessed through the descriptor label for the Histogram, you can make adjustments for the **#Values** in the “Buffer” and the **#Bins**. You can also use the other controls to position and scale the Histogram on the display. The most convenient selection is to simply check the **Enable AutoFind** checkbox (the default condition).

Note: Since a Histogram is a math function, you can use the front panel zoom control knobs to change the vertical and horizontal position and scale of the Histogram.

Histogram Example

Below is a screen image of a CANtoAnalog signal measurement. The CAN trigger is set to symbolically trigger on Message=RemChanger. There is an analog signal that correlates with this message, and there is a need to measure how long the Analog signal precedes the CAN signal. More than one measurement must be made, and statistical data must be accumulated to ensure that there are no infrequent events that would not meet specifications.

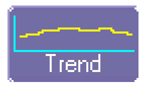
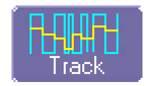
The CANtoAnalog parameter is set up in Parameter 1 (P1). It is used to measure the time between the Message=RemChanger CAN message and the Analog signal (the magenta Channel 2 signal). In the Measure table, the last CANtoAnalog value measured in the last acquisition is reported to be 121.2 ms. However, there has been more than one measurement event. These measurement events have been captured and stored in the Vehicle Bus Analyzer. The Histogram (shown as Trace F1, on the bottom) displays the distribution of the different measurements. It is clear that there is a wide range of different measurements. We have also displayed measurement Statistics and found the min, max, mean, and standard deviation of the complete measurement set. But the Histogram display gives us a clear indication that the distribution is not Gaussian, whereas the measurement statistics alone do not. This could help us understand cause and effect, and enable better debugging. It will also help us to understand the expected worst case events, especially if 10,000, 100,000, or more events were captured, measured, and displayed.



GRAPHING AND PLOTTING OF MEASUREMENT DATA

Overview

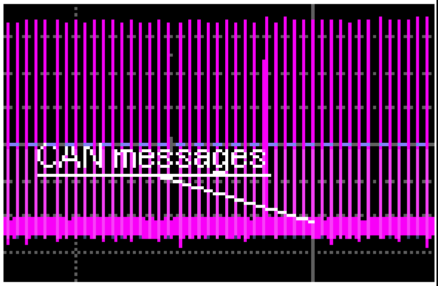
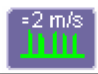
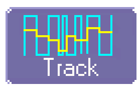
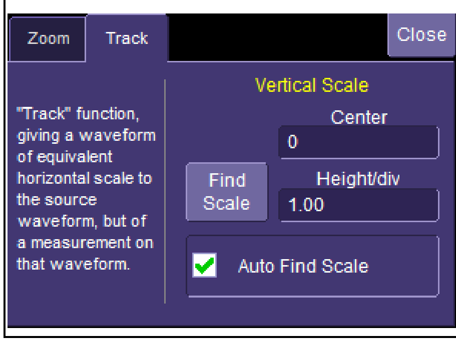
Both Track and Trend are tools that can be used to plot measurement data and observe variations with respect to time. Differences between Track and Trend are summarized in the table below:

Characteristic		
Representation	Parameter value vs. events	Parameter value vs. time
Behavior	Cumulative over several acquisitions up to 1 million events	Non-cumulative (resets after every acquisition). Unlimited number of events
Time-Correlation to Other Data	No	Yes
Monitor an Evolution in the Frequency Domain	No. Trend points are not evenly spaced in time and therefore cannot be used for an FFT.	Yes
Monitor the Evolution of a Measurement Parameter over Several Acquisitions	Yes	No. Track resets after every acquisition.
Ensures no Lost Measurement Data	No. Since data can be accumulated over many acquisitions, and since the Oscilloscope or Vehicle Bus Analyzer takes time to calculate measurement values and display data before trigger is re-armed, data may be missed.	Yes. Maximum time period that can be captured is limited by acquisition memory and sampling rate.

In general, Track will be the tool to use if you want to capture a continuous stream of data that is spaced closely together. Trend can be used if your data is spaced widely apart and longer than the “dead-time” of the Oscilloscope or Vehicle Bus Analyzer between acquisitions.

Setting Up Tracks and Trends

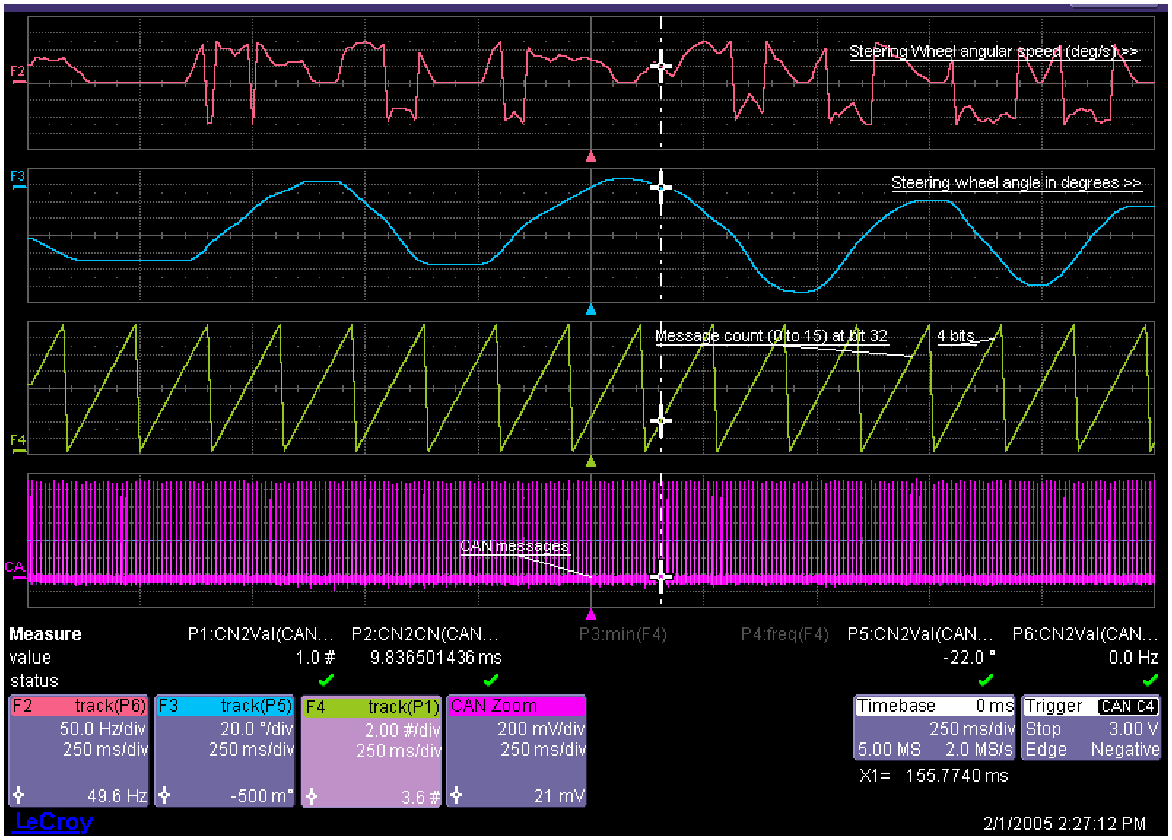
There are four steps to analyzing data with Tracks and Trends:

	1. Set up a trigger condition to acquire the signals you want to make a measurement of (in this case, a CAN message). If you wanted to compare it to an Analog signal, you would want to acquire that also. Begin acquisition.
	2. Set up a parameter (in this case, a CANtoValue parameter)
	3. Create a Track (or Trend) of the parameter by touching the **Track** (or **Trend**) button for that parameter in the **Measure/Graph Setup** dialog, and following the on-screen directions.
	4. In the Track setup right-hand dialog (accessed through the descriptor label for the Track) you can make adjustments to the Scale (Horizontal center and Vertical height). The most convenient selection is to simply check the Auto Find Scale checkbox (the default condition). 5. Setup of Trend is very similar, except that you must adjust the number of points in the Trend. A Trend will accumulate over many acquisitions while a Track will not.

Track Example – Extract Data from CAN Messages and Plot

Note: This example was taken using a WaveRunner 6000A oscilloscope with CANbus TDM. Some of the screen images may appear slightly differently from the Vehicle Bus Analyzer, but the overall setup operation for the Measure and Track is the same.

Below is a screen image of an acquisition of many CAN messages that represent the CAN data for a steering angle sensor. Three CANtoValue measurement parameters were used to extract data in decimal format for the steering angle sensor ID. There were three different pieces of data in the same message, at different bit position – Angular Speed in degrees/second (parameter P6, Tracked with function F2), Angle in degrees (parameter P5, tracked with function F3), and message count in events from 1 to 15 (parameter P1, Tracked with function F4). The CANtoValue parameter data was rescaled to present the data in the appropriate units. Next, a Track function was applied to each CANtoValue measurement parameter. It is now easy to see how the data is varying with time, and how it corresponds to the original CAN signal (which in CANbus TDM is called CANTrace, but on the VBA is simply your source name), time aligned vertically. This data could also be compared to other analog signals. Here the CANtoCAN parameter in P2 is used to verify the message spacing between identical messages, as explained under CANtoCAN.



HISTOGRAM AND TREND CALCULATION

Overview

With the instrument configured for Histograms or Trends, the timing measurement parameter values are calculated and the Histogram or Trend function is performed on each measurement parameter following the acquisition. The Histogram or Trend values themselves are calculated immediately after each acquisition.

The result is a waveform of data points that can be used the same way as any other waveform. Other parameters can be calculated on it, it can be zoomed, serve as the **x** or **y** trace in an **XY** plot, or used in cursor measurements.

Acquisition Sequence

The sequence of events for acquiring Histogram or Trend data is:

1. Trigger
2. Waveform Acquisition
3. Parameter Calculations
4. Histogram Update
5. Trigger Re-arm

If the timebase is set in non-segmented mode, a single acquisition occurs prior to parameter calculations.

However, in segment mode an acquisition for each segment occurs prior to parameter calculations. If the source of the Histogram or Trend data is a memory, storing new data to memory effectively acts as a trigger and acquisition. Because updating the screen can take significant processing time, it occurs only once a second, minimizing trigger dead-time. (Under remote control, the display can be turned off to maximize measurement speed.)

Parameter Buffer

The instrument maintains a circular parameter buffer of the last 20,000 measurements, including values that fall outside the set histogram range. If the maximum number of events to be used in a histogram or trend is a number **N** less than 20,000, the histogram will be continuously updated with the last **N** events as new acquisitions occur. If the maximum number is greater than 20,000, the histogram or trend will be updated until the number of events equals **N**. Then, if the number of bins or the histogram or trend range is modified, the instrument will use the parameter buffer values to redraw the histogram with either the last **N** or 20,000 values acquired, whichever is the lesser. The parameter buffer thereby allows histograms or trends to be redisplayed using an acquired set of values and settings that produce a distribution shape with the most useful information.

In many cases the optimal range is not readily apparent, so the instrument has a powerful range finding function. If required, it will examine the values in the parameter buffer to calculate an optimal range and redisplay the histogram or trend using it. The instrument will also give a running count of the number of parameter values that fall within, below, and above the range. If any fall below or above the range, the range finder can then recalculate using these parameter values, while they are still within the buffer.

Parameter Events Capture

The number of events captured per waveform acquisition or display sweep depends on the type of parameter. Acquisitions are initiated by the occurrence of a trigger event. Sweeps are equivalent to the waveform captured and displayed on an input channel.

For non-segmented waveforms, an acquisition is identical to a sweep, but for segmented waveforms an acquisition occurs for each segment and a sweep is equivalent to acquisitions for all segments. Only the section of a waveform between the measurement parameter gates is used in the calculation of parameter values and corresponding histogram events.

For most timing measurements (such as CANtoAnalog, CANtoCAN), the Histogram or Trend data is composed of every measurement event in the acquisition or portion of the acquisition defined by the parameter gates (there could be many measurement events in one acquisition). For others (such as CANload), there is a single measurement for a single acquisition or portion of the acquisition defined by the parameter gates. For non-CAN parameters, reference the on-line Help or Getting Started Manual for more information.

Zoom Traces and Segmented Waveforms

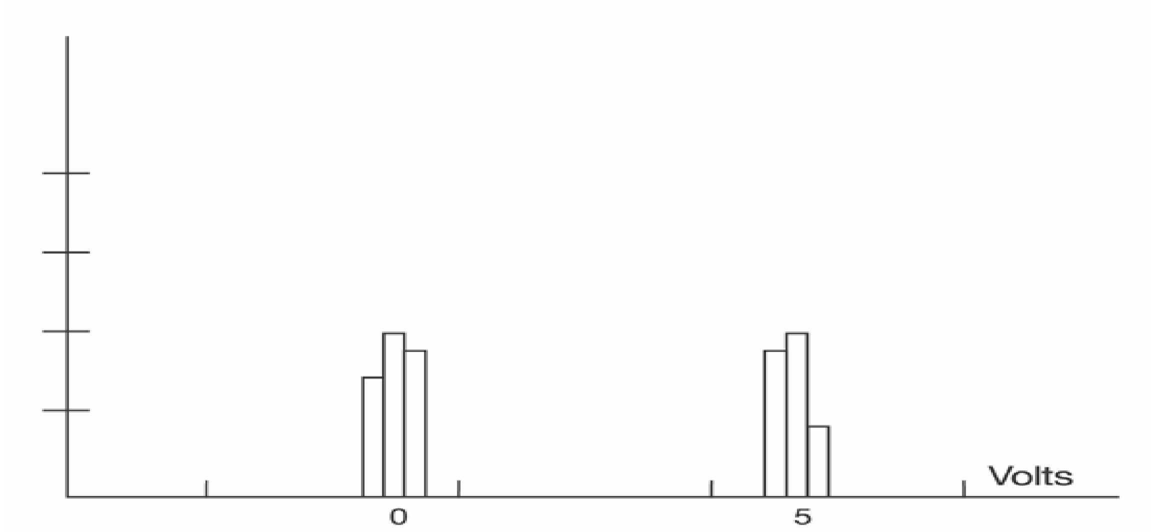
Histograms and Trends of zoom traces display all events for the displayed portion of a waveform between the parameter gates. When dealing with segmented waveforms, and when a single segment is selected, the histogram or trend will be recalculated for all events in the displayed portion of this segment between the parameter gates.

Histogram Peaks

Because the shape of histogram distributions is particularly interesting, additional parameter measurements are available for analyzing these distributions. They are generally centered on one of several peak value bins, known (with its associated bins) as a histogram peak.

Example

A histogram of the voltage value of a five-volt amplitude square wave is centered on two peak value bins: **0 V** and **5 *V*** (see figure). The adjacent bins signify variation due to noise. The graph of the centered bins shows both as peaks.



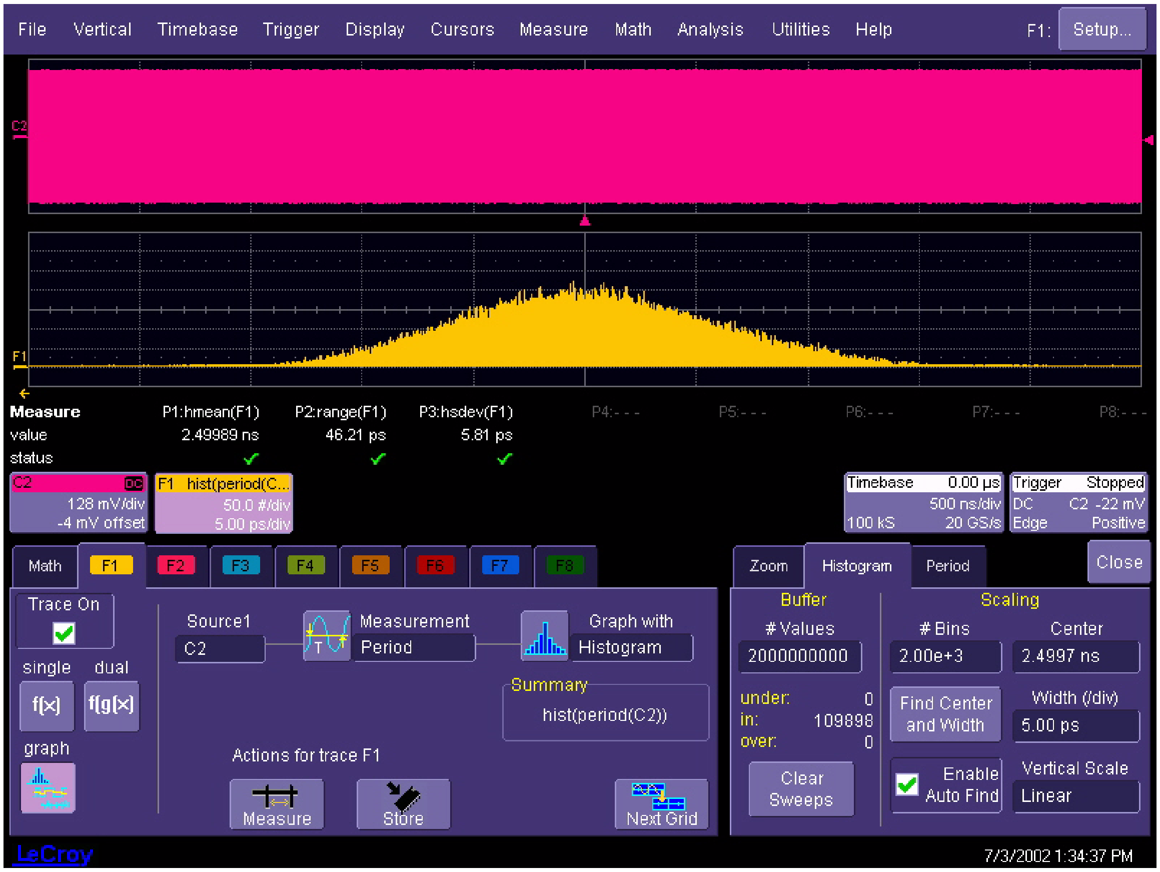
Determining such peaks is very useful because they indicate dominant values of a signal. However, signal noise and the use of a high number of bins relative to the number of parameter values acquired can give a jagged and spiky histogram, making meaningful peaks hard to distinguish. The instrument analyzes histogram data to identify peaks from background noise and histogram definition artifacts such as small gaps, which are due to very narrow bins.

Binning and Measurement Accuracy

Histogram bins represent a sub-range of waveform parameter values, or events. The events represented by a bin may have a value anywhere within its sub-range. However, parameter measurements of the histogram itself, such as **average**, assume that all events in a bin have a single value. The instrument uses the center value of each bin's sub-range in all its calculations. The greater the number of bins used to subdivide a histogram's range, the less the potential deviation between actual event values and those values assumed in histogram parameter calculations.

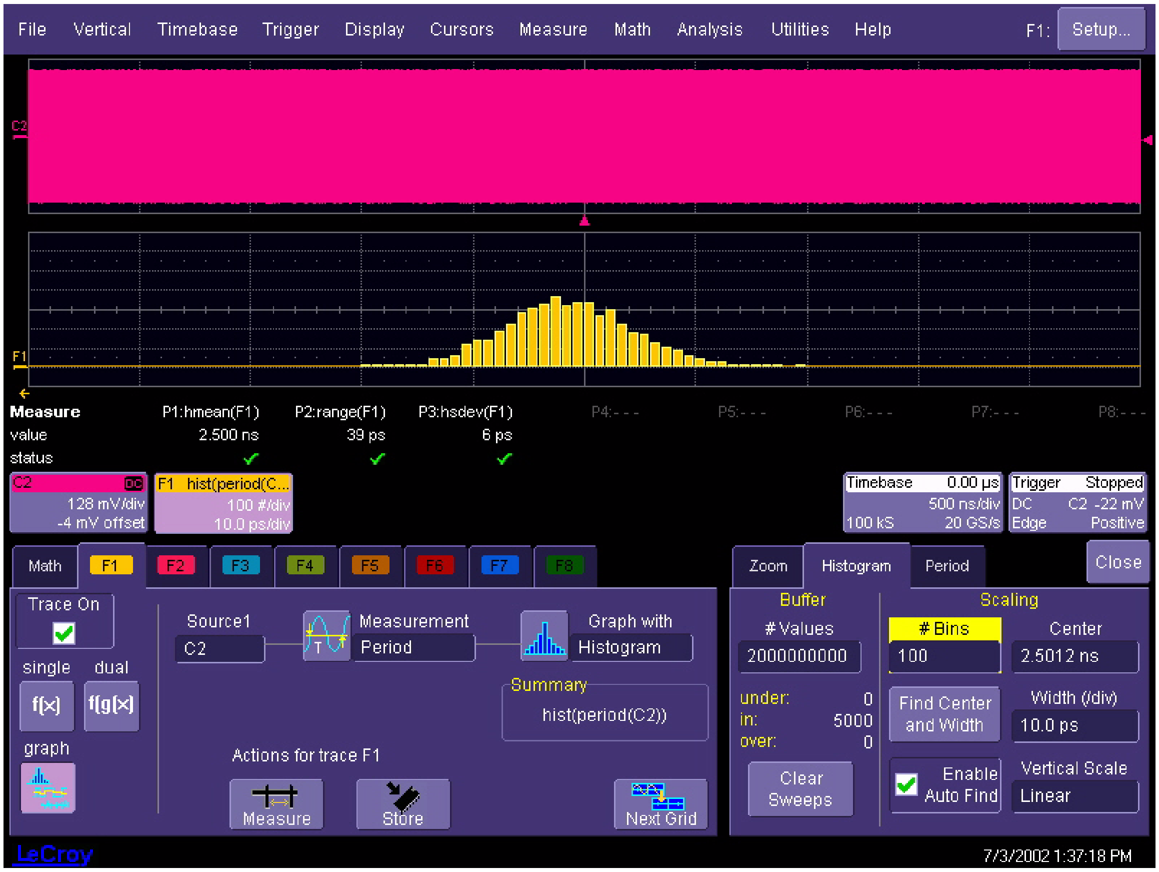
Nevertheless, using more bins may require a greater number of waveform parameter measurements to populate the bins sufficiently for the identification of a characteristic histogram distribution.

The next figure shows a histogram display of 17,999 parameter measurements divided or classified into 2000 bins. The standard deviation of the histogram sigma is 6.750 ps.



The instrument’s parameter buffer is very effective for determining the optimal number of bins to be used. An optimal bin number is one where the change in parameter values is insignificant, and the histogram distribution does not have a jagged appearance. With this buffer, a histogram can be dynamically redisplayed as the number of bins is modified by the user. In addition, depending on the number of bins selected, the change in waveform parameter values can be seen.

In the next figure, the histogram shown in the previous figure has been recalculated with 100 bins. Note how it has become far less jagged, while the real peaks are more apparent. Also, the change in sigma is minimal (6.750 ps compared with 6.8 ps).



File
Vertical
Timebase
Trigger
Display
Cursors
Measure
Math
Analysis
Utilities
Help
F1:
Setup...
C2
F1
Measure
value
status
P1:hmean(F1)
2.500 ns
P2:range(F1)
39 ps
P3:hsdev(F1)
6 ps
P4:- - -
P5:- - -
P6:- - -
P7:- - -
P8:- - -
C2
DC
128 mV/div
-4 mV offset
F1 hist(period(C...
100 #/div
10.0 ps/div
Timebase 0.00 µs
500 ns/div
100 kS 20 GS/s
Trigger Stopped
DC C2 -22 mV
Edge Positive
Math
F1
F2
F3
F4
F5
F6
F7
F8
Zoom
Histogram
Period
Close
Trace On
single
dual
f(x)
f(g(x)
graph
Source1
C2
Measurement
Period
Graph with
Histogram
Summary
hist(period(C2))
Actions for trace F1
Measure
Store
Next Grid
Buffer
Values
2000000000
under: 0
in: 5000
over: 0
Clear Sweeps
Scaling
Bins
100
Center
2.5012 ns
Find Center and Width
Width (/div)
10.0 ps
Enable Auto Find
Vertical Scale
Linear
LeCroy
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ISOLATE AND ANALYZE CAN BUS ACTIVITY

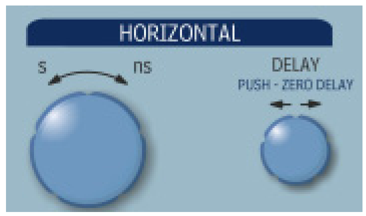
The combination of Symbolic CAN Bus Triggering, Symbolic Decoding, and normal oscilloscope features is a powerful combination of tools that can make it very easy to find latent CAN Bus hardware or software problems in your circuit. No longer is the oscilloscope a tool just for the hardware engineer. Now the software engineer can also easily visualize the CAN Bus signals and relate it to programming code and operation. The Vehicle Bus Analyzer can enable the hardware Engineer and software Engineer to “speak the same language” when it comes to system debugging and performance checking.

Some common CAN Bus analysis needs and methods are discussed below:

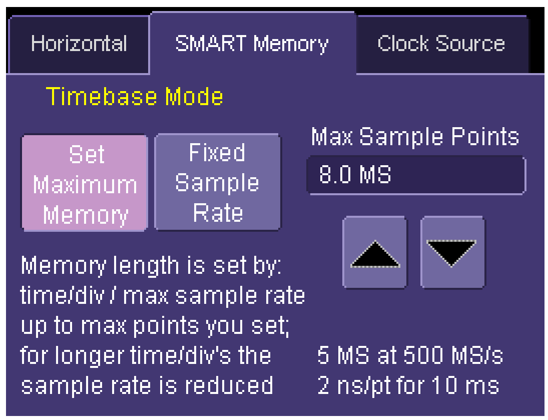
Capture Long Pre-Trigger Time

LeCroy Vehicle Bus Analyzers are available with optional very long acquisition memory. For instance, the Vehicle Bus Analyzers can capture up to 12 Mpts on 4 channels, or 24 Mpts on 2 channels. If your CAN Bus signal is 83.333 kb/s, and you sample at the minimum required and available sample rate (500 kS/s), you would be able to capture 48 seconds of CAN Bus 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 Vehicle Bus Analyzer’s front panel.

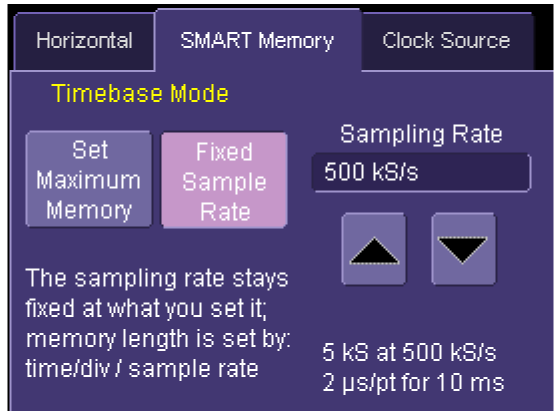


2. Optimize your Sample Rate or Memory Length by accessing the Horizontal Dialog in your Vehicle Bus Analyzer and selecting either **Set Max Memory** mode or **Fixed Sample Rate** mode.



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 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 a too low 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 CAN message (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 CAN and analog signals (at least 2x the frequency of any expected transients, preferably 10x).



Reference your Vehicle Bus Analyzer'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 Vehicle Bus Analyzer 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 CAN (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 Vehicle Bus Analyzer for later analysis.

Even though the LeCroy Vehicle Bus Analyzer 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 Vehicle Bus Analyzer'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 < 6 microseconds. This is ideal for finding repetitive causes of Error Frames on your CAN Bus.

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 Vehicle Bus Analyzer. For instance, for a VBA6050A 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 Vehicle Bus Analyzer'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 Vehicle Bus Analyzer screen.

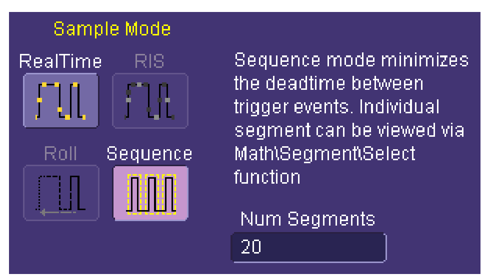
Acquisition dead time is kept to a minimum because there are no operations performed during the acquisition. All data for each triggered event is written only into high-speed acquisition memory. Until the entire sequence is completed, there is no updating of the Vehicle Bus Analyzer display, or other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

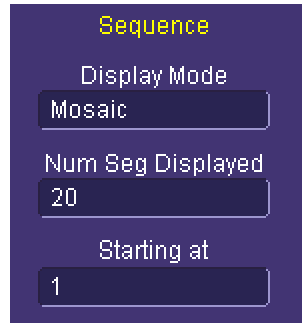
Note: You must use a differential probe if you want to capture the complete differential CAN signal. If you use single-ended probes, you will only be able to capture either CANH or CANL signals since you cannot perform a math subtraction as part of a sequence mode acquisition.

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.

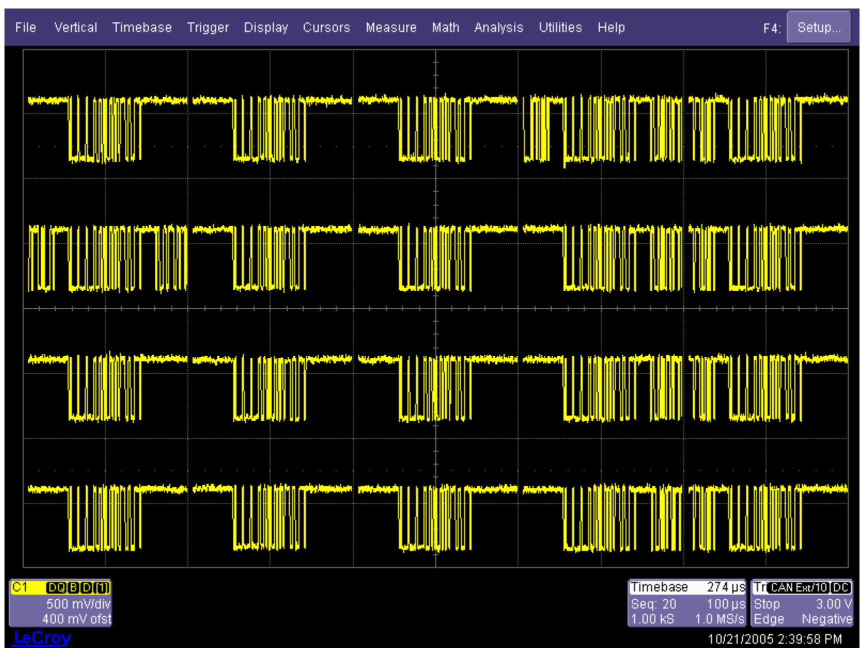
1. Touch the **Timebase** descriptor label to open the Timebase dialog.

2. In the Sample Mode area, select Sequence Mode. Also select the number of Segments that you wish to capture (in this example, we selected 20). The minimum number of segments is 2. The maximum number is determined by your Vehicle Bus Analyzer's acquisition memory.

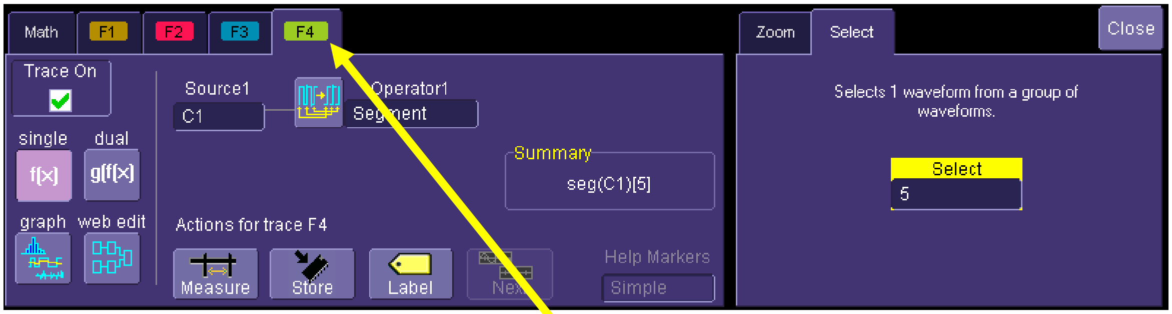




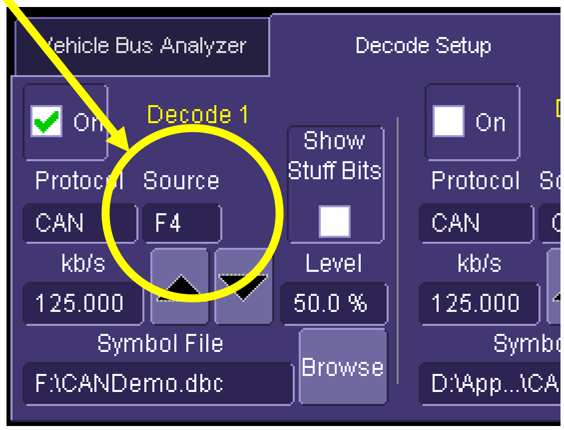
3. From the menu bar, choose **Display**, **Display Setup…** to view the Display Dialog. At the far right of this dialog choose the Display Mode, Number of Segments Displayed, and the Starting Segment. Adjacent or Mosaic Display Modes are probably most helpful for CAN Analysis (Mosaic Mode is shown through the rest of this example).
4. The Number of Segments Displayed is limited to either 80, or the total number of segments you selected in the Timebase dialog (whichever is smaller).
5. If you have acquired more segments than you can display at one time, you can choose the segment to begin the display at.
6. As described in a previous chapter, set up the CAN Trigger to capture the event you desire. For instance, you might want to trigger on Error frames, and capture long pre-trigger time to determine the cause of the error frames. In this example, we've used a simple CAN trigger with Message=Engine. 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 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 20 segment acquisition in Mosaic display mode).



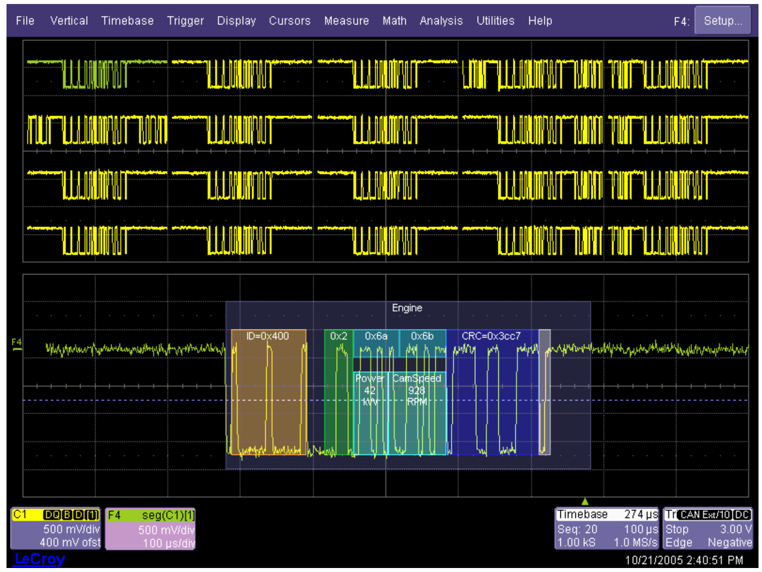
7. To display an individual segment separately from the main channel display, select **Math**, **Math Setup…** from the menu bar, and choose a math trace to define as a Segment (in this case, we chose to define F1 as a Segment). As a source, use the channel that your CAN data was acquired on (in this case Channel 1). 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.



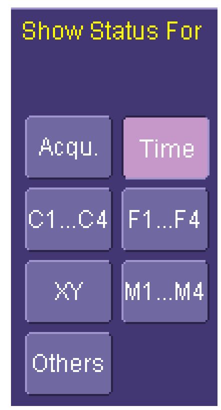
8. To view decoded data on the individual segment, set up the CAN Trace using the Math trace as the source (in this case F4 is the source). If you wish to change the segment that is decoded, just select a new segment from the Math trace dialog (as shown in the preceding step).



9. The complete display with the original Channel sequence acquisition in mosaic display mode, the Math trace showing the individual segment, and the decoded CAN Trace of the individual segment is shown to the right.



10. 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:



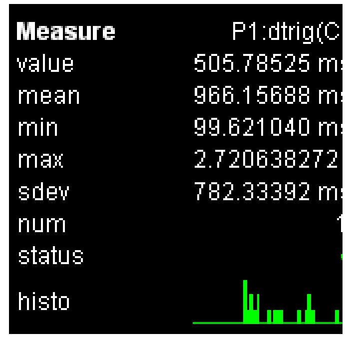
Time

Seg	Time	since Segment 1	between Segm
1)	16-June-2004 11:53:35		
2)	16-June-2004 11:53:37	1.617166812 s	1.61716681
3)	16-June-2004 11:53:37	1.718687863 s	101.521050
4)	16-June-2004 11:53:37	1.919879959 s	201.192096
5)	16-June-2004 11:53:37	2.423745193 s	503.865234
6)	16-June-2004 11:53:38	3.333904655 s	910.159462
7)	16-June-2004 11:53:40	5.247904552 s	1.91399989
8)	16-June-2004 11:53:40	5.347525592 s	99.621040
9)	16-June-2004 11:53:42	7.263465499 s	1.91593990
10)	16-June-2004 11:53:43	7.566198649 s	302.733150

11. 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.

12. Use the **dtrig** parameter with statistics ON to measure the mean, min, max, sdev, and number of times between triggers. Turn on histicons to view the distribution of times.

13. Histogramming and Trending can provide further measurement analysis.



EXPORTING CAN BUS DECODED DATA

Overview

CAN Bus data decoded in CANbus TD, TDM, and the Vehicle Bus Analyzer can be exported by GPIB Remote Command or Automation command languages. GPIB remote commands are the familiar, abbreviated commands that have typically been used to send commands and receive data through an IEEE-488 port. Automation commands are a Microsoft Windows language command set that is native to the LeCroy X-Stream system architecture.

In addition, the Vehicle Bus Analyzer contains a file named ExportDecodedTable2ASCII.vbs in the D:/Applications/CAN folder on the Vehicle Bus Analyzer hard drive. If you have loaded Excel on your VBA, this program, when run (by double clicking on it) will automatically export the decoded data to an Excel spreadsheet on your VBA.

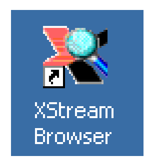
Any LeCroy GPIB Remote Command that existed before development of LeCroy X-Stream oscilloscopes (on which theVehicle Bus Analyzer is based) is still supported in the X-Stream oscilloscopes. However, new features or capabilities developed since the release of the first X-Stream oscilloscopes in early 2002 are only supported in Automation language (i.e., there are no GPIB commands for new capabilities). The CANbus TD features, therefore, are available only through Automation language. However, there are provisions for using an Automation Language command in a GPIB command program.

This chapter is not meant to provide a complete description of using these command languages. The following separate manuals more fully describe this capability:

- **GPIB Commands** - *LeCroy X-Stream Oscilloscopes Remote Control Manual*
- **Automation Commands** - *LeCroy Automation Manual*

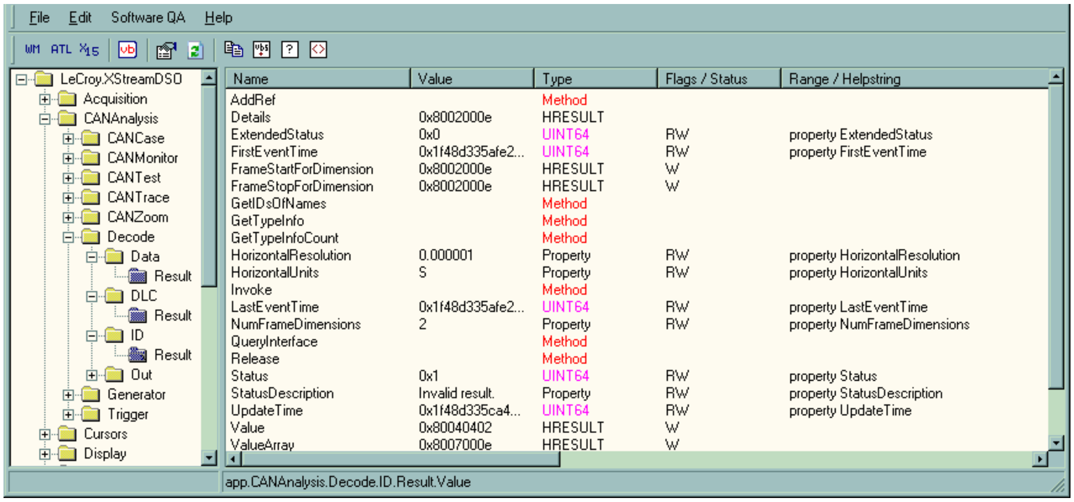
Both of these manuals can be downloaded for free from the LeCroy website.

The X-Stream Browser (located on your Vehicle Bus Analyzer Windows desktop) is also a way to access a list of Automation commands. Double click the **X-Stream Browser** icon; a pop-up dialog opens. From that pop-up dialog, select **File**, **Connect to Local Instrument**. Then, in the file structure, open the VBA folder for a complete list of the CANbus TD specific Automation commands.

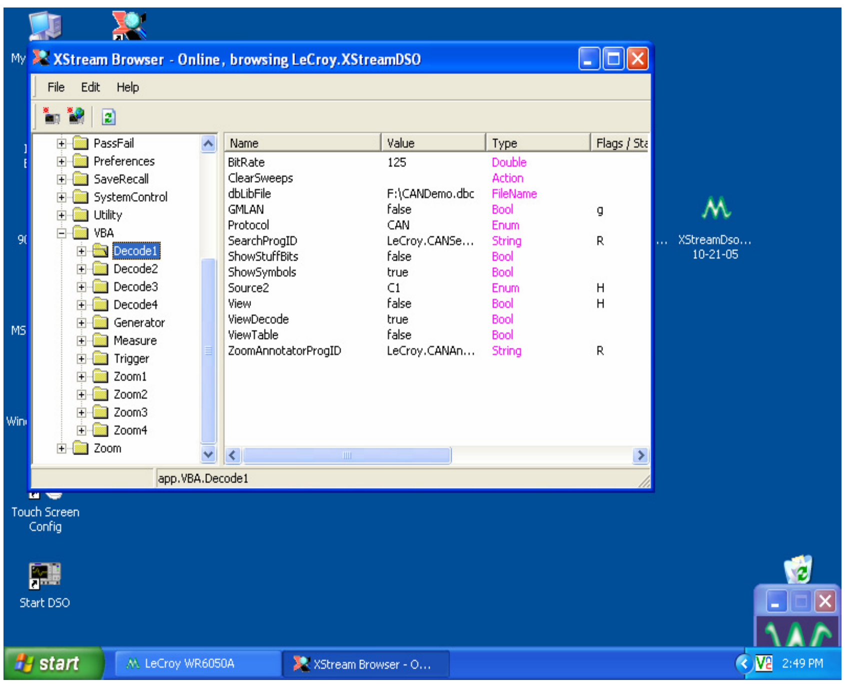


Vehicle Bus Analyzer

The file structure for CANbus TD and TDM is shown below:



The file structure for VBA is shown below:



Exporting Decoded Data

The protocol data is best thought of as a table. Each row of the table corresponds to a complete CAN message emitted on the bus. Each column of the table corresponds to an element of the message. In the case of CAN, the elements of the message are ID, DLC, Data, etc.

In a CAN TD, there is only one Decoder, therefore, only one table. In a VBA there are 4 Decoders, therefore, 4 tables.

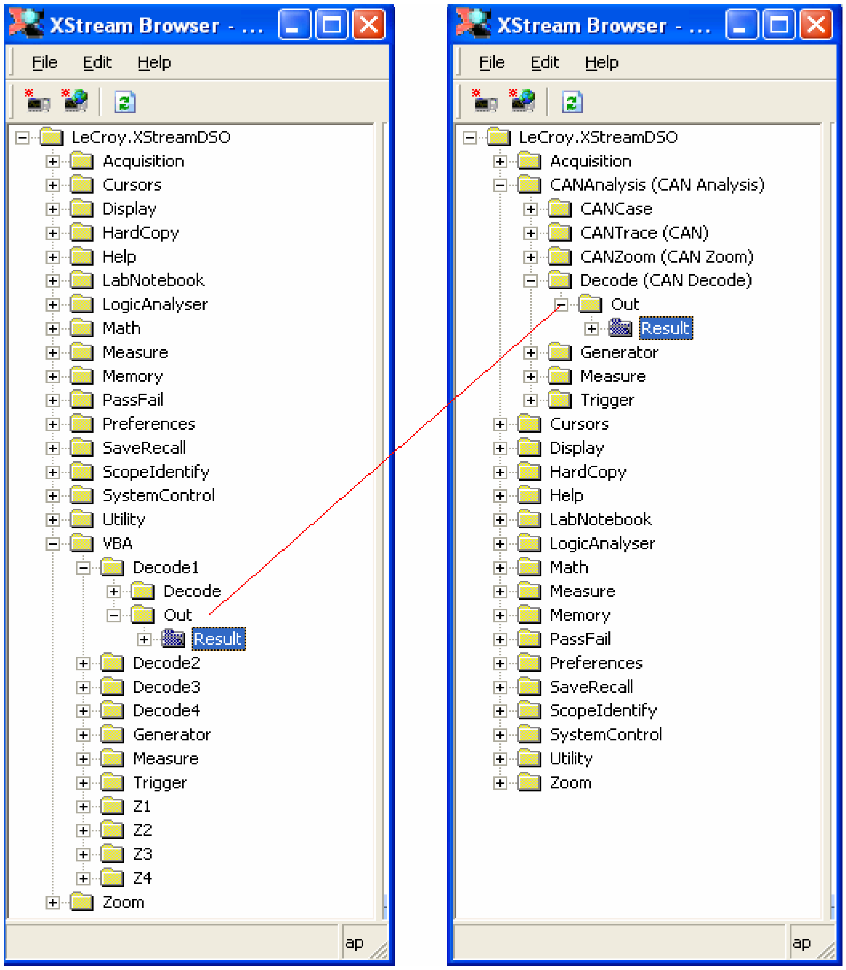
From the remote computer, you can query the Vehicle Bus Analyzer to send you data once, or just continuously query for data. In either case, the data that will be sent is whatever is displayed on theVehicle Bus Analyzer. If you only want a single CAN message, make sure that only one CAN message is displayed.

Model for accessing Decoded Data table in LeCroy oscilloscopes

As outlined above, the data in the table is accessed through the automation path tree. The path varies slightly depending on the unit used:

- On **CAN TD** units, the path is app.CANAnalysis.Decode.Out.Result.CellValue
- On **VBA** units, the path is app.VBA.Decode2.Out.Result.CellValue

Both command hierarchies are shown below. Beginning at the Out level, commands are identical for all models since the Decoder component is the same:



Model for accessing Cell Values in table

Each Decoded table consists of cells. A cell resides at the intersection of a row and a columns, exactly as in a spreadsheet.

The cell is accessed via a path: **Out.Result.CellValue(Row,Column)**. The cell contains several pieces of information that you can use. **CellValue(Row,Column).Value** contains the value (i.e., ID, data). **CellValue(Row,Column).Status** contains the statuses.

Row zero contains the column headers in string form: Idx, Time, ID, DLC, Data, CRC, ACK, Bit,Rate/Msg, Message, StuffBits, Status, Symbols, Sig, ID, Length, Attributes. These column headers determine the zero-based column index for fetching results from the table. For example the ID is found in column 2, the DLC in column 3, etc.

Subsequent rows contain the message data; each complete message occupies one row. The first decoded message, therefore, is contained in row 1. If there are 15 decoded messages, on screen the table will contain 16 rows, accounting for one header row.

You have several options to read out the decoded results from the table.

The first approach is to read out the entire decoded data table into a file, using a command script. The script is named **ExportDecodedTable2ASCII.vbs** in the D:/Applications/CAN folder on the Vehicle Bus Analyzer hard drive. When invoked, it reads out the decoded data from Decoder1 on a VBA into a file called C:\LeCroy\XStream\Waveforms\CANdecodedTable.csv. This file lends itself to viewing with Excel. You can change which Decoder is read out and to which file the results are being written. The script will automatically read out the entire results set into the table. The table length depends on the number of messages decoded. This method does not require any programming, other then minor modifications to the script, if desired.

The second approach would be to write a program that reads out specific locations in the decoded data table, and processes them in the desired way. This method involves programming. Refer to the *LeCroy Automation Manual* for complete information on defining the application and writing Automation commands.

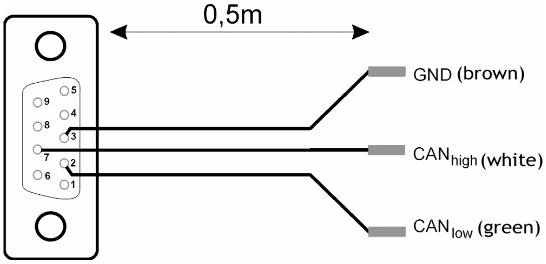
Embedding an Automation Command in a GPIB Command Program

LeCroy has created a VBS command for the LeCroy GPIB Remote Command language. This command is documented in both the *LeCroy Automation Manual* and *LeCroy X-Stream Remote Control Manual*. Essentially, it allows you to embed an Automation language command into a GPIB Command Language program. Thus, if you have already written a remote control program for an older LeCroy oscilloscope, you don't have to re-write the program in a new language to take advantage of the new CANbus TD capabilities.

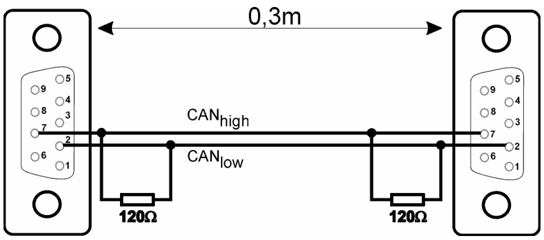
Refer to the chapter "Linking With Automation" in the *LeCroy Automation Manual* for more information.

APPENDIX A – SCHEMATICS OF OPTIONAL CABLES

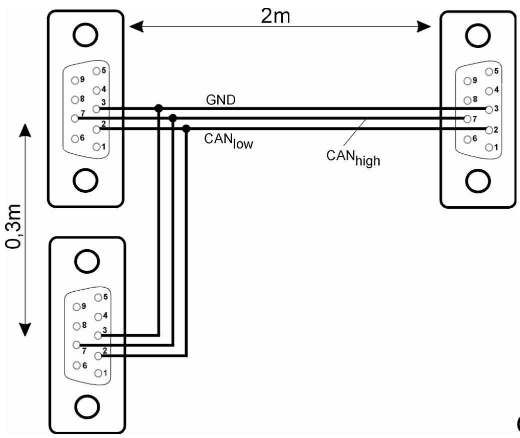
902329-00 CAN Bus ISO 11898-2 Cable Set



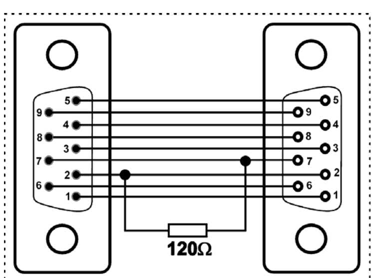
Quantity 1



Quantity 1

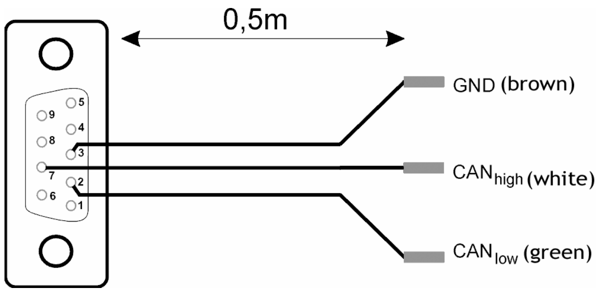


Quantity 1

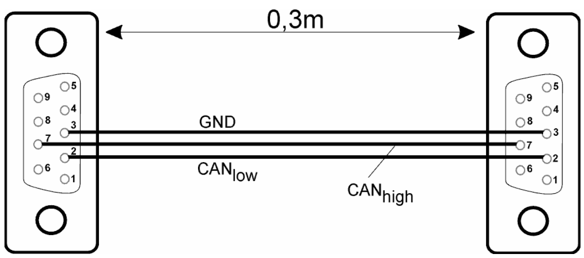


Quantity 2

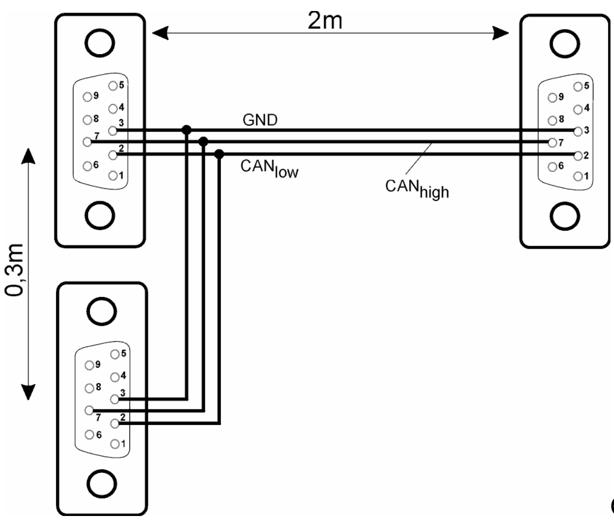
902330-00 CAN Bus ISO 11519 Cable Set



Quantity 1

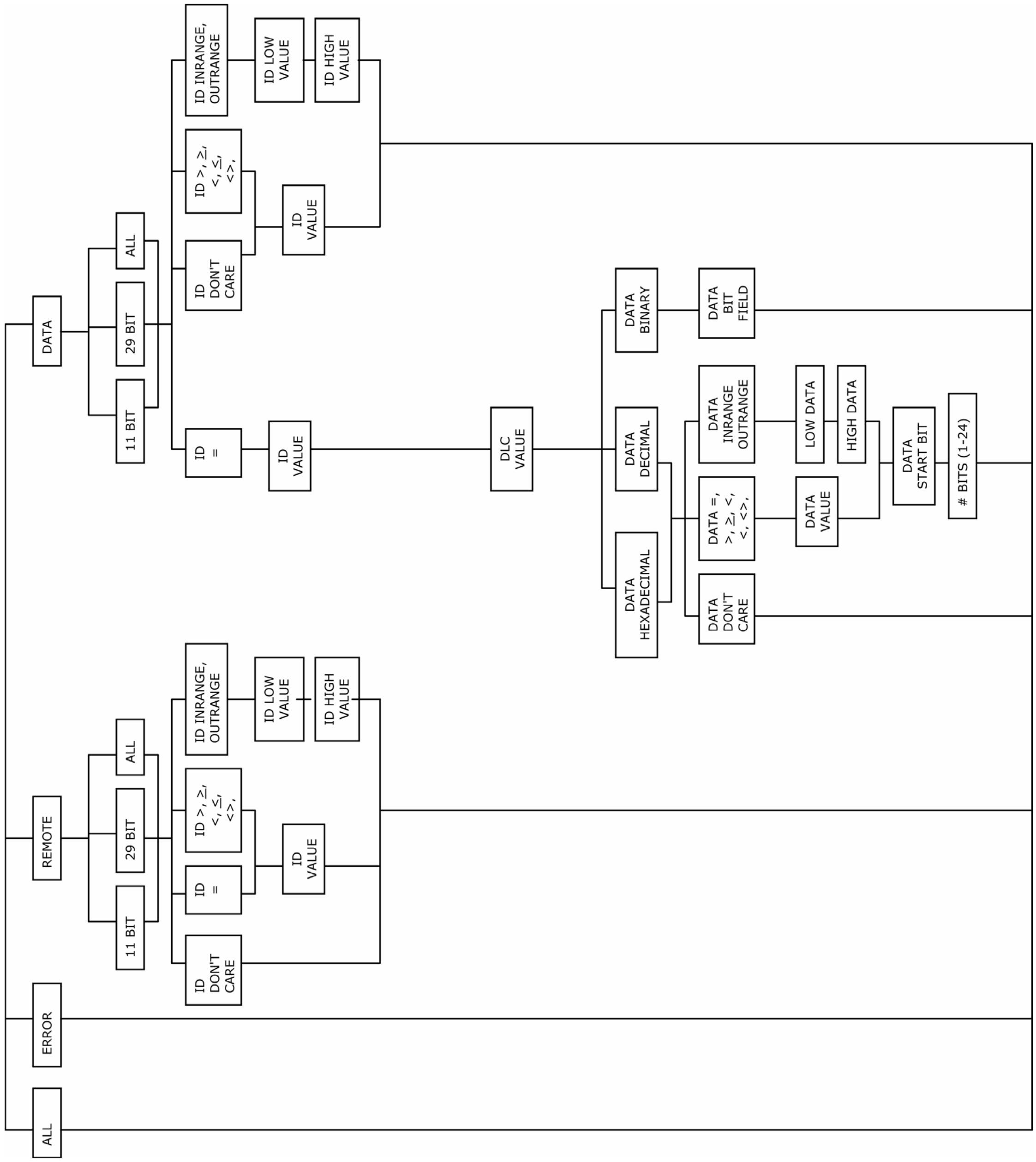


Quantity 1



Quantity 1

APPENDIX B – CAN HEXADECIMAL TRIGGER FLOWCHART



APPENDIX C – SPECIFICATIONS

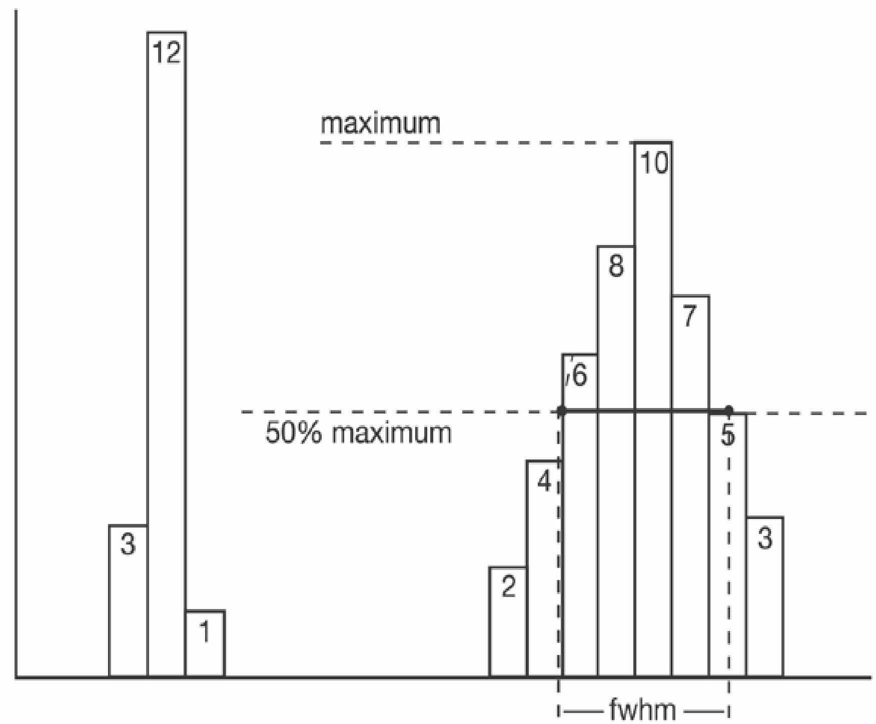
	Vehicle Bus Analyzer
Decode Capability	**Decode Capability**
Format	**Symbolic** (Message and Signal level) or **Hexadecimal**. Symbolic decode performed on waveform grid using user-provided DBC database file.
# of Decoded Waveforms	**Up to 4 souces** may be decoded at one time. Sources can be Channels, Memory (Reference) Waveforms, or Math Traces (i.e. CANH-CANL). In addition, up to 4 Zooms of these traces can be displayed (with decoded information).
Location	Above Waveform, on Grid, Next to defined source.
Visual Aid	Color Coding for FRAME, ID, DLC, DATA, CRC, ACK, Stuff Bits. **Includes textual Message name and physical Signal value with units.**
Error Frame Decoding	Decode Uncorrupted Portions, Identify Type
Stuff Bit Display	Yes, Circled on Oscilloscope Display
Symbolic Trigger Capability	
DATA Frame Setup	Yes
Message Condition Setup	Specify a Message to trigger on using customer supplied **DBC** database file. Choose from list sorted by Node, Message, or Signal.
GM CAN Compatibility	GM CAN compatible (Priority ID, Parameter ID, Source ID). Defaults to Message setup with all GM ID fields as "don't care" with operator able to change, as desired.
Mixed Message Systems Capability	Supports triggering when both 11-bit and 29-bit IDs are on the bus

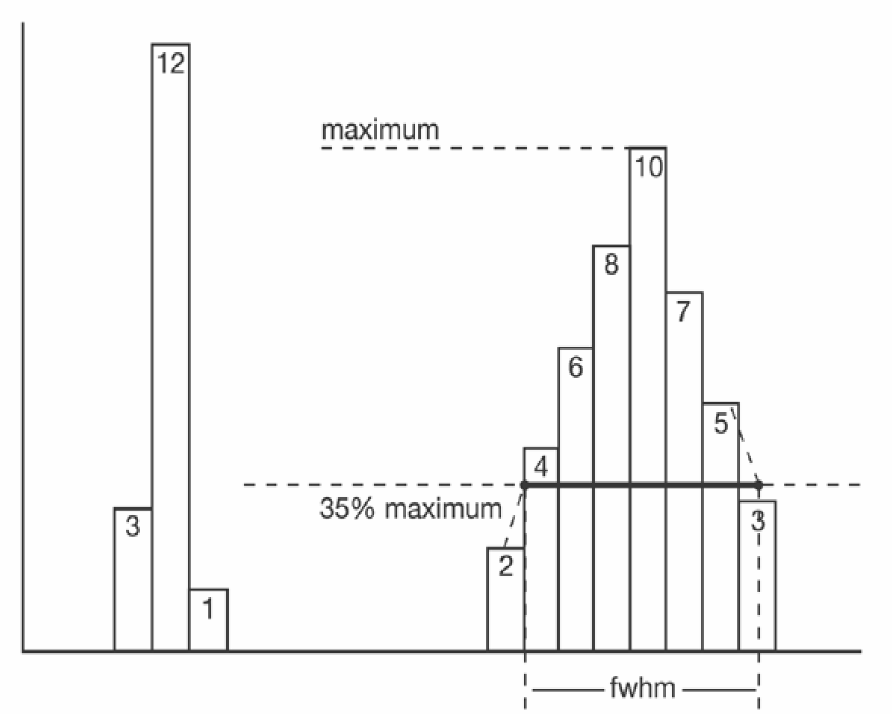
Signal Condition Setup	**Message+Signal** with Signal data value condition of <=, <, =, >, >=, ≠, in range, out of range, don't care. Signal value set in scaled units as defined in customer supplied DBC database file.
Error Frame Setup	Yes, all Active Errors
Remote Frame Setup	Yes, with Message = condition.
All Frames Setup	Yes, will trigger on any CAN Data, Remote, or Error Frame (no conditions settable)
End of Frame (EOF) Trigger	Yes (by using ALL frame triggering)
Hexadecimal Trigger Capability	
DATA Frame Setup	Yes
ID Condition Setup	Specify One ID, then <=, <, =, >, >=, ≠, in range, out of range, don't care
Mixed ID Systems Capability	Supports triggering when both 11-bit and 29-bit IDs are on the bus
DATA Condition Setup	<=, <, =, >, >=, ≠, in range, out of range, don't care. Trigger on LSB or MSB data in any condition. Possible with ID= condition only.
DATA Setup	Hexadecimal: DLC from 0-8. In full bytes, data pattern can be set to any value. In partial bytes, data pattern can be set to any Start bit, with a 24 bit data length. Binary: Any combination of 0,1, or X for 1-64 bits
Error Frame Setup	Yes, all Active Errors
Remote Frame Setup	Yes, with any ID condition (<=, <, =, >, >=, ≠, in range, out of range, don't care)
All Frames Setup	Yes, will trigger on any CAN Data, Remote, or Error Frame (no conditions settable)
Start of Frame (SOF) Trigger	Yes (by using ALL frame triggering)
Logical AND	Yes, but only between ID and DATA.
Trigger Setup	
Format	ID - **Symbolic**, Hexadecimal, Binary, DATA - **Symbolic**, Hexadecimal or Binary
ID Types	STD (11-bit), EXT (29-bit)
Bit Rates	Any of 414 bit rates, ranging from 10.0 kb/s to 1 Mb/s

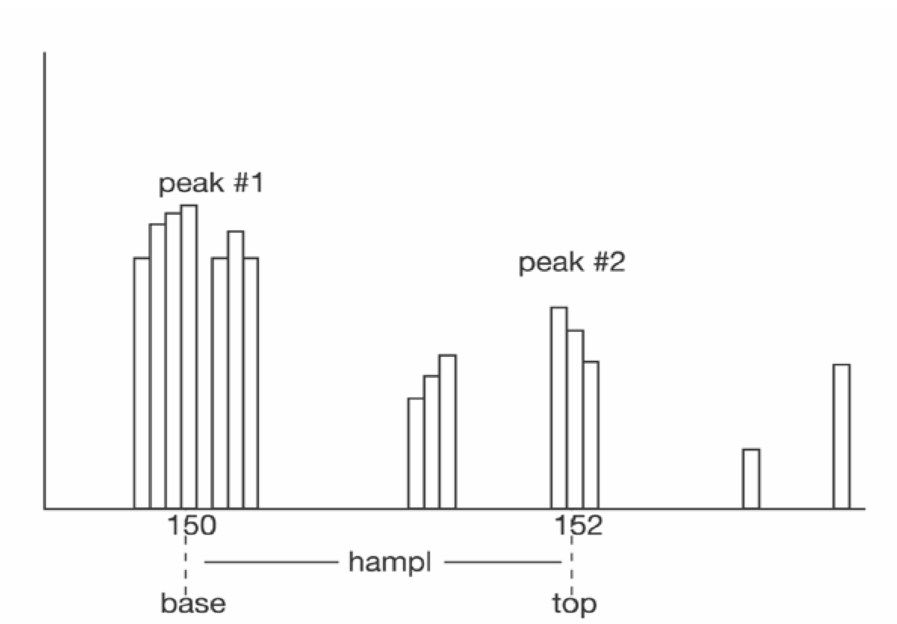
Data Spread	In **Symbolic**, can select any Signal up to 24 bits long. In Hexadecimal, can set any value, spread across nibbles or bytes, up to 24 bits long. In Binary, can set any value, spread across nibbles or bytes, up to 64 bits long.
Adjustable Sample Point	Fully adjustable
Trigger Input	Any CH or EXT
Trigger (Other)	
Trigger Design	External CAN controller using filtration (triggering on protocol message)
Will Trigger Provide ACKnowledge on Bus?	User selectable, defaults to No ACK
CAN Transceiver Support	5790c, 251, 1050, 1054, 1041, B10011S Interchangeable
Measurements & Graphing	
CAN Measurements	CAN Message to Analog Signal Timing, Analog Signal to CAN Message Timing, CAN Message to CAN Message Timing, CAN Bus Load %, CAN Message Bit Rate, CAN Message Number, CAN Message Data to Decimal Value Extraction
Statistical Analysis	Histograms (up to 2 billion events)
Statistical Parameters	fwhm, fwxx, hist ampl, hist base, hist max, hist mean, hist median, hist min, hist rms, hist sdev, hist top, max populate, mode, percentile, peaks
Graphical Analysis	Track (1 point per measurement) Trend (1 million points max)
Analysis Capability	
Maximum Record Length	24Mpt/ch (Interleaved). This equals 48 s of 100 kb/s CAN traffic, or 24,000 CAN messages
Stuff Bit Display	Yes
Sequence Mode	Yes. View decoded data on individual segments.
Pattern Search	In **Symbolic** or Hexadecimal, Search for next frame, next defined frame with a certain Message/ID, or next error frame
Other Features	

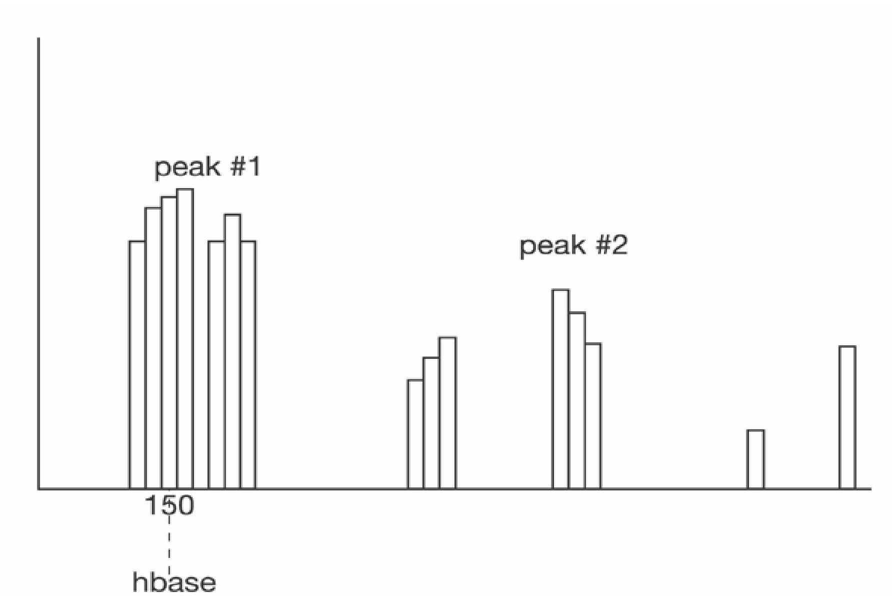
CAN Input to View	Single-ended (CANH or CANL), Single-ended (CANH-L), or Differential Probe
Differential Probe Required?	No, but helpful to save analog channels and to perform sequence mode acquisition. ADP-305 recommended.
Method of Viewing CAN Signal & Triggering On It	Trigger with CANbus TD Series Trigger Module. Separately Probe to View
Forward Compatibility	External Trigger Module Allows System to Adapt
User Interface	Graphical, Windows-based
Compatible With	Stand-Alone complete CAN oscilloscope system based on WaveRunner 6000A

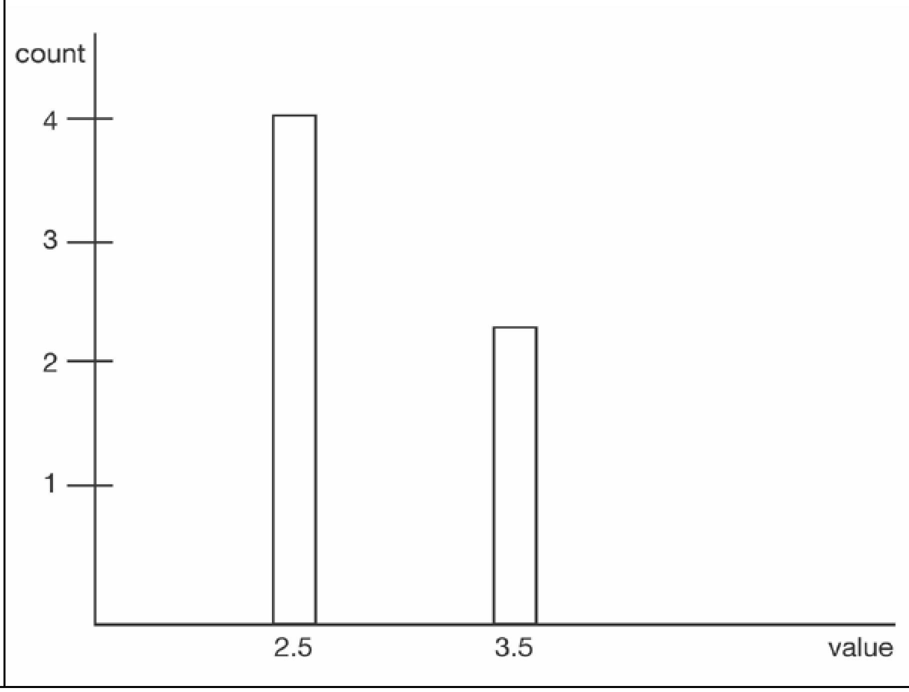
APPENDIX D – HISTOGRAM PARAMETERSHISTOGRAM PARAMETERS

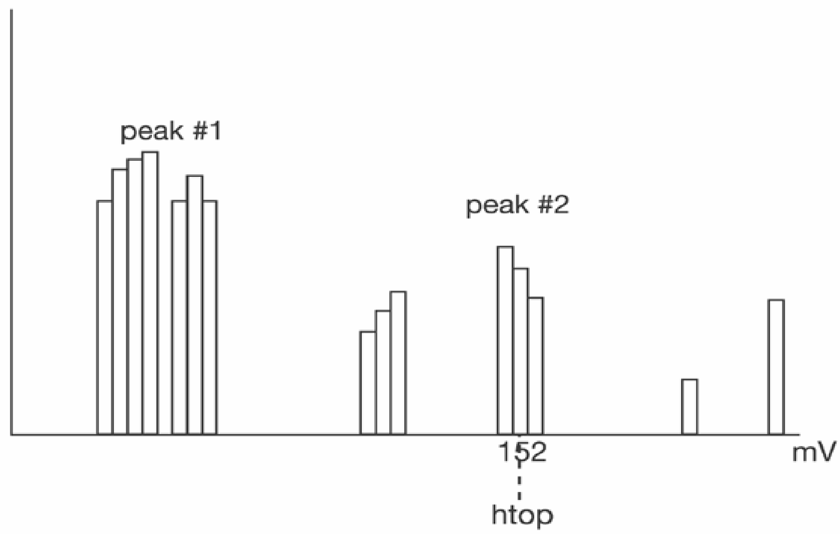
fwhm	Full Width at Half Maximum
Definition:	Determines the width of the largest area peak, measured between bins on either side of the highest bin in the peak that have a population of half the highest's population. If several peaks have an area equal to the maximum population, the leftmost peak is used in the computation.
Description:	First, the highest population peak is identified and the height of its highest bin (population) determined (for a discussion on how peaks are determined see the pks parameter Description:). Next, the populations of bins to the right and left are found, until a bin on each side is found to have a population of less than 50% of that of the highest bin's. A line is calculated on each side, from the center point of the first bin below the 50% population to that of the adjacent bin, towards the highest bin. The intersection points of these lines with the 50% height value is then determined. The length of a line connecting the intersection points is the value for fwhm.
Example:	

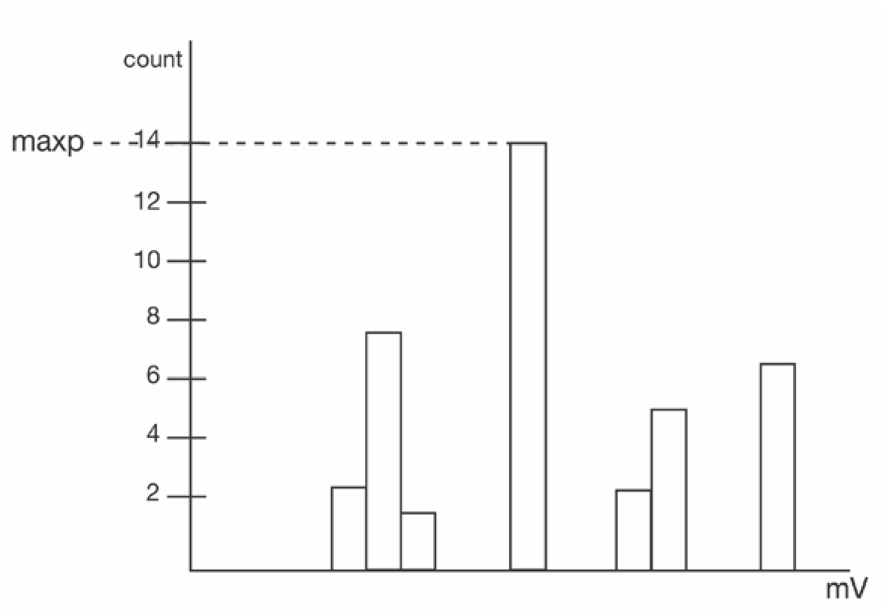
fwxx	**Full Width at xx% Maximum**
Definition:	Determines the width of the largest area peak, measured between bins on either side of the highest bin in the peak that have a population of xx% of the highest's population. If several peaks have an area equal to the maximum population, the leftmost peak is used in the computation.
Description:	First, the highest population peak is identified and the height of its highest bin (population) determined (see the pks description). Next, the bin populations to the right and left are found until a bin on each side is found to have a population of less than xx% of that of the highest bin. A line is calculated on each side, from the center point of the first bin below the 50% population to that of the adjacent bin, towards the highest bin. The intersection points of these lines with the xx% height value is then determined. The length of a line connecting the intersection points is the value for fwxx.
Example:	fwxx with threshold set to 35%:
	

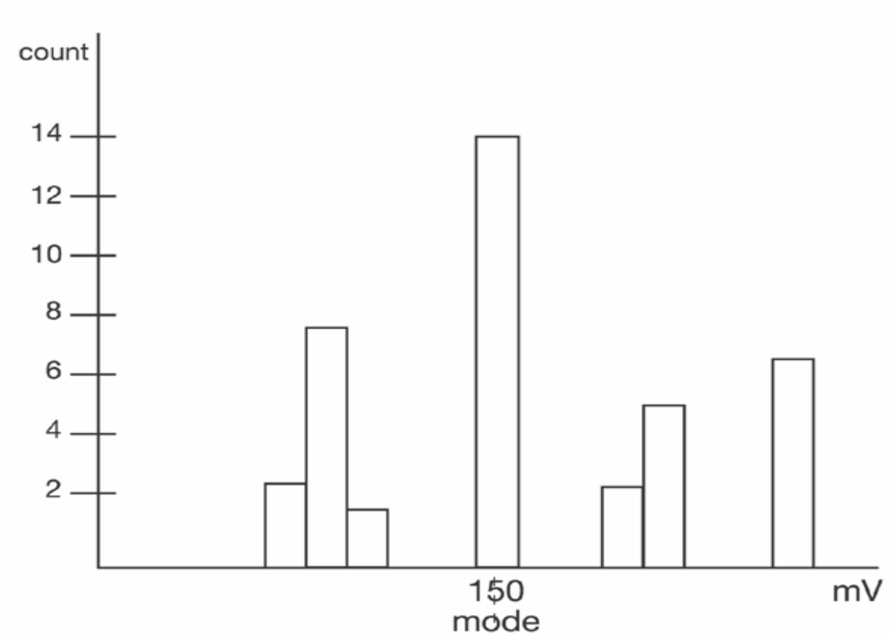
hist ampl	Histogram Amplitude
Definition:	The difference in value of the two most populated peaks in a histogram. This parameter is useful for waveforms with two primary parameter values, such as TTL voltages, where hampl would indicate the difference between the binary `1' and `0' voltage values.
Description:	The values at the center (line dividing the population of peak in half) of the two highest peaks are determined (see pks parameter description:). The value of the leftmost of the two peaks is the histogram base (see hbase). While that of the rightmost is the histogram top (see htop). The parameter is then calculated as:
	hampl = htop hbase
Example:	
	In this histogram, hampl is 152 mV 150 mV = 2 mV.

hbase	Histogram Base
Definition:	The value of the leftmost of the two most populated peaks in a histogram. This parameter is primarily useful for waveforms with two primary parameter values such as TTL voltages where hbase would indicate the binary `0' voltage value.
Description:	The two highest histogram peaks are determined. If several peaks are of equal height the leftmost peak among these is used (see pks). Then the leftmost of the two identified peaks is selected. This peak's center value (the line that divides the population of the peak in half) is the hbase.
Example:	

hist rms	**Histogram Root Mean Square**
Definition:	The rms value of the values in a histogram.
Description:	The center value of each populated bin is squared and multiplied by the population (height) of the bin. All results are summed and the total is divided by the population of all the bins. The square root of the result is returned as hrms.
Example:	Using the histogram shown here, the value for hrms is:
	hrms = $\sqrt{(3.5^2 * 2 + 2.5^2 * 4)/6}$ = 2.87
	

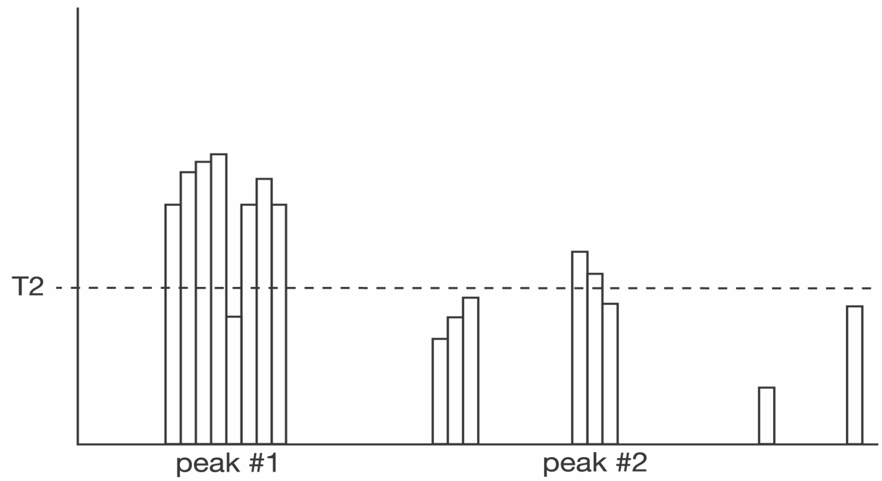
hist top	Histogram Top
Definition:	The value of the rightmost of the two most populated peaks in a histogram. This parameter is useful for waveforms with two primary parameter values, such as TTL voltages, where htop would indicate the binary `1' voltage value.
Description:	The two highest histogram peaks are determined. The rightmost of the two identified peaks is then selected. The center of that peak is htop (center is the horizontal point where the population to the left is equal to the area to the right).
Example:	

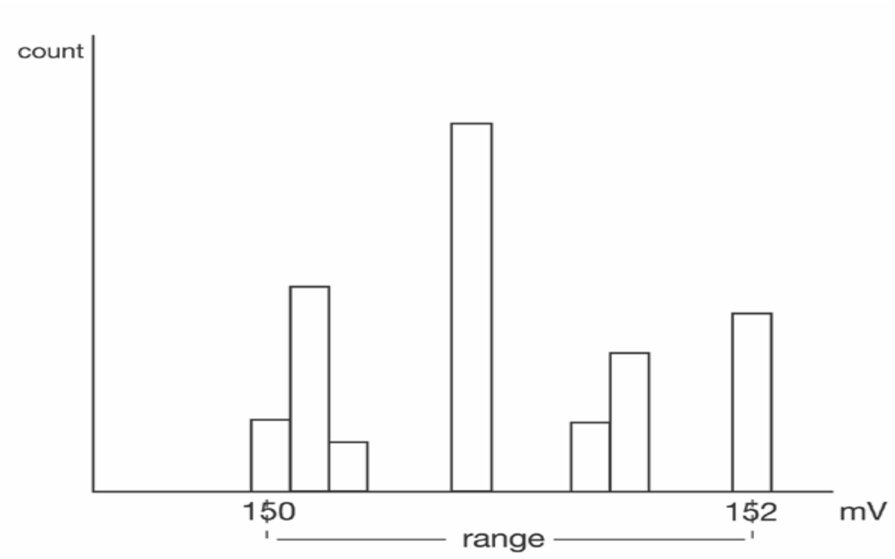
maxp	Maximum Population
Definition:	The count (vertical value) of the highest population bin in a histogram.
Description:	Each bin between the parameter cursors is examined for its count. The highest count is returned as maxp.
Example:	
	Here, maxp is 14.

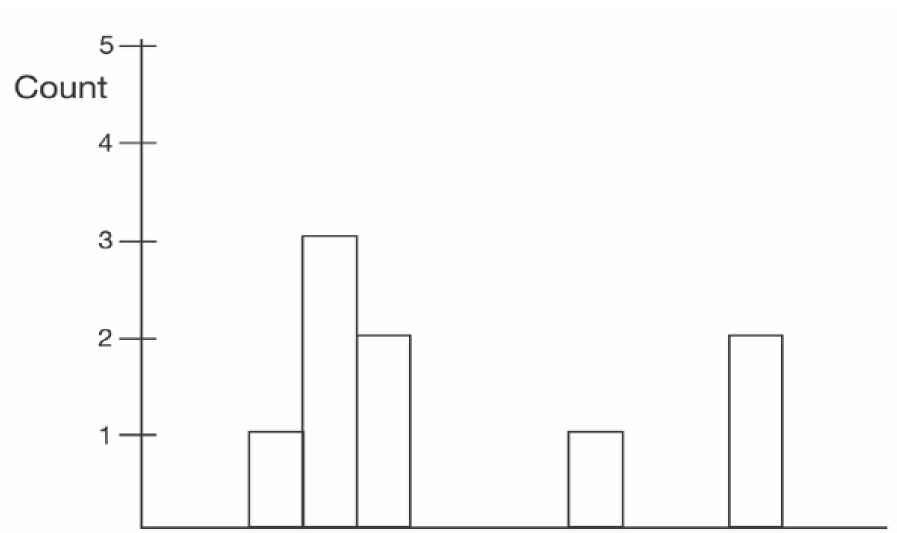
mode	Mode
Definition:	The value of the highest population bin in a histogram.
Description:	Each bin between the parameter cursors is examined for its population count. The leftmost bin with the highest count found is selected. Its center value is returned as mode.
Example:	
	Here, mode is 150 mV.

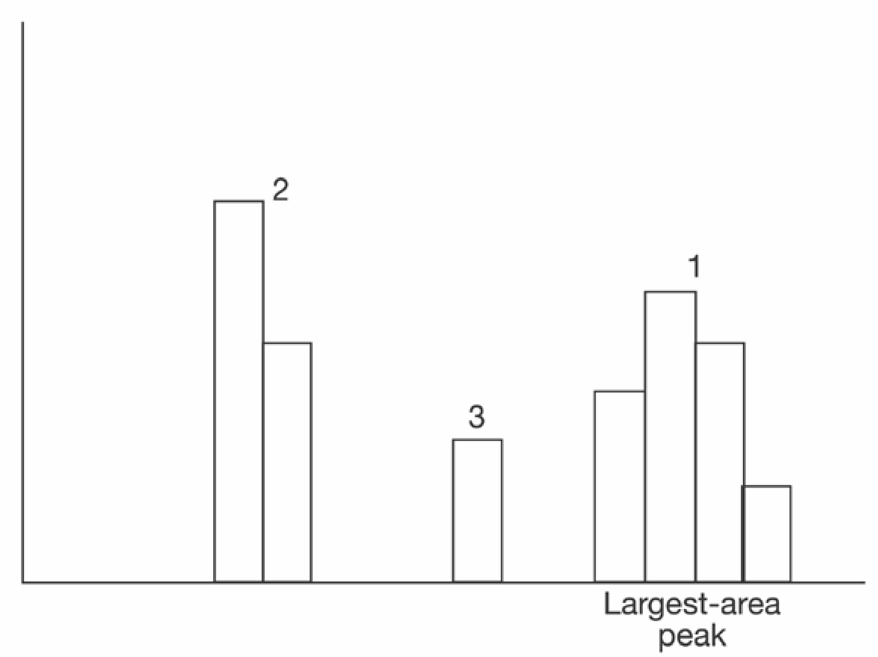
pctl	Percentile
Definition:	Computes the horizontal data value that separates the data in a histogram such that the population on the left is a specified percentage `xx' of the total population. When the threshold is set to 50%, pctl is the same as hmedian.
Description:	The total population of the histogram is determined. Scanning from left to right, the population of each bin is summed until a bin that causes the sum to equal or exceed `xx'% of the population value is encountered. A ratio of the number of counts needed for `xx'% population/total bin population is then determined for the bin. The horizontal value of the bin at that ratio point of its range is found, and returned as pctl.
Example:	The total population of a histogram is 100. The histogram range is divided into 20 bins and `xx' is set to 25%. The population sum at the sixth bin from the left is 22. The population of the seventh is 9 and its sub-range is 6.1 to 6.4 V. The ratio of counts needed for 25% population to total bin population is:
	3 counts needed / 9 counts = 1/3.
	The value for pctl is:
	6.1 volts + .33 * (6.4 6.1) volts = 6.2 volts.

pks	Peaks
Definition:	The number of peaks in a histogram.
Description:	The instrument analyzes histogram data to identify peaks from background noise and histogram binning artifacts such as small gaps.
	Peak identification is a 3-step process:
	1. The mean height of the histogram is calculated for all populated bins. A threshold (T1) is calculated from this mean, where: T1= mean + 2 sqrt (mean). 2. A second threshold is determined based on all populated bins under T1 in height, where: T2 = mean + 2 * sigma, and where sigma is the standard deviation of all populated bins under T1. 3. Once T2 is defined, the histogram distribution is scanned from left to right. Any bin that crosses above T2 signifies the existence of a peak. Scanning continues to the right until one bin or more crosses below T2. However, if the bins cross below T2 for less than a hundredth of the histogram range, they are ignored, and scanning continues in search of peaks that cross under T2 for more than a hundredth of the histogram range. Scanning goes on over the remainder of the range to identify additional peaks. Additional peaks within a fiftieth of the range of the populated part of a bin from a previous peak are ignored.
	NOTE: If the number of bins is set too high, a histogram may have many small gaps. This increases sigma and, thereby, T2. In extreme cases, it can prevent determination of a peak, even if one appears to be present to the eye.
Example:	Here the two peaks have been identified. The peak with the highest population is peak #1.

	 T2 peak #1 peak #2

range	Range
Definition:	Computes the difference between the value of the rightmost and that of the leftmost populated bin.
Description:	The rightmost and leftmost populated bins are identified. The difference in value between the two is returned as the range.
Example:	
	In this example, range is 2 mV.

totp	Total Population
Definition:	Calculates the total population of a histogram between the parameter cursors.
Description:	The count for all populated bins between the parameter cursors is summed.
Example:	
	The total population of this histogram is 9.

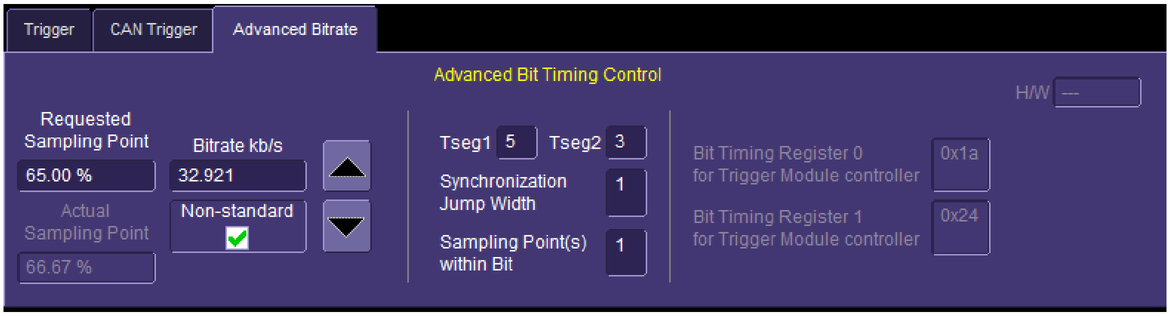
xapk	X Coordinate of xxth Peak
Definition:	Returns the value of the xxth peak that is the largest by area in a histogram.
Description:	First the peaks in a histogram are determined and ranked in order of total area (for a discussion on how peaks are identified see the description for the pks parameter). The center of the nth ranked peak (the point where the area to the left is equal to the area to the right), where n is selected by you, is then returned as xapk.
Example:	The rightmost peak is the largest, and is thus ranked first in area (1). The leftmost peak, although higher, is ranked second in area (2). The lowest peak is also the smallest in area (3).
	

APPENDIX E – ADVANCED BIT RATE SETUP

Overview

There are some common bit rate settings that are chosen when the CAN Trigger is operated in Standard mode (i.e., the "Non-Standard" checkbox is unchecked). Selections for 10, 25, 33.333, 50, 83.333, 100, 125, 250, 500, and 1000 kb/s are available in Standard mode.

When the **Advanced Bitrate** tab is touched, the following dialog is displayed:



There are a finite number of bit rates that can be set, based on the sampling point and bit timing control values. This list is included at the end of this Appendix.

There are two different sampling points displayed on the Advanced Bitrate setup dialog. The Requested Sampling Point is defaulted to 65%, unless the operator chooses to change it. The Actual Sampling Point is what is actually calculated based on the Bitrate settings and the "Advanced Bit Timing Control" settings. The software uses an algorithm to attempt to keep the "Actual Sampling Point" as close as possible to the "Requested Sampling Point" by adjusting the Advanced Bit Timing Control settings. Therefore, the Requested Sampling Point may not match the Actual Sampling Point. The Actual Sampling Point is what is used by the CANbus TD Series Trigger Module.

In Standard mode, the Requested Sampling Point is always defaulted to 65%. Again, the Actual Sampling Point may be different from the Requested value, unless an operator makes manual changes to the Bit Timing Control values.

General Operation

The bit timing is determined by the clock oscillator in the CAN circuit, the Baud Rate Prescaler (BRP) and the number of BTL cycles (sum of Tseg1 and Tseg2). Tseg1, Tseg2, and BRP are defined numerical values from the respective Bus Timing Registers (BTR0 and BTR1). Each CAN controller has defined BTR values. LeCroy uses an SJA1000 controller in the CANbus TD Series Trigger Module.

The complexity of the Advanced Bitrate setup increases as you move from left to right in the dialog. For instance, in both Standard and Non-Standard modes, if you set the Requested Sampling Point to a value different from the default value, the Advanced Bit Timing Control values will be automatically changed. However, you may also choose to directly set the values of Tseg1, Tseg2, Synchronization Jump Width, and # Sampling Point(s) within each bit, in which case the Actual Sampling Point will be calculated based on these values. At the far right of the dialog are the calculated values for the Bit Timing Registers for the CANbus TD Series Trigger Module. These are displayed for operator convenience, but are not allowed to be changed by the operator.

More Information

ISO 11519 and 11898 provide details for the Physical Signaling sublayer specification. For customers who wish to configure the CANbus TD Trigger Module to a specific configuration to match a vehicle or other CAN Bus network, non-standard bit rates are provided. These bit rates can be set by using the non-standard check box in the Advanced Bitrate dialog. Then use either the up/down arrows, or the keypad to type the values directly. If the value is not exactly provided, the system will automatically round to the nearest possible value."

List of bit rates supported in the CANbus TD Series Trigger Module

```
10000, 10012, 10025, 10062, 10088, 10101, 10204, 10230, 10256, 10269, 10296, 10322,
10335, 10389, 10416, 10430, 10457, 10526, 10540, 10582, 10610, 10638, 10666, 10695,
10752, 10781, 10796, 10810, 10840, 10869, 10884, 10928, 10943, 10989, 11019, 11034,
11080, 11111, 11188, 11204, 11220, 11299, 11347, 11363, 11379, 11396, 11428, 11477,
11494, 11544, 11594, 11611, 11627, 11661, 11695, 11730, 11764, 11834, 11851, 11904,
11922, 11994, 12012, 12030, 12066, 12121, 12158, 12195, 12288, 12307, 12326, 12345,
12383, 12403, 12422, 12500, 12539, 12558, 12578, 12698, 12718, 12759, 12800, 12820,
12882, 12903, 12987, 13008, 13071, 13093, 13114, 13136, 13157, 13223, 13289, 13333,
13377, 13445, 13468, 13513, 13559, 13582, 13605, 13675, 13722, 13793, 13840, 13888,
13913, 13937, 13986, 14035, 14109, 14184, 14260, 14285, 14311, 14336, 14414, 14492,
14519, 14545, 14571, 14652, 14705, 14814, 14842, 15009, 15037, 15065, 15094, 15122,
15151, 15180, 15238, 15325, 15384, 15444, 15473, 15503, 15594, 15625, 15686, 15779,
15810, 15873, 16000, 16129, 16161, 16194, 16227, 16260, 16326, 16393, 16460, 16528,
16563, 16632, 16666, 16771, 16806, 16842, 16913, 16949, 17021, 17094, 17204, 17241,
17316, 17391, 17429, 17543, 17582, 17738, 17777, 17857, 18018, 18099, 18140, 18181,
18306, 18390, 18433, 18518, 18604, 18648, 18823, 18867, 18912, 19047, 19138, 19230,
19323, 19512, 19607, 19656, 19704, 19753, 19851, 20000, 20050, 20202, 20408, 20460,
20512, 20671, 20779, 20833, 21052, 21164, 21220, 21276, 21333, 21390, 21505, 21621,
21680, 21739, 21978, 22038, 22160, 22222, 22408, 22727, 22792, 22857, 22988, 23188,
23255, 23391, 23460, 23529, 23668, 23809, 24024, 24242, 24390, 24615, 24691, 24767,
24844, 25000, 25078, 25396, 25641, 25806, 25974, 26143, 26315, 26666, 26755, 26936,
27027, 27210, 27586, 27681, 27777, 27972, 28070, 28571, 28673, 28985, 29090, 29304,
29411, 29629, 30075, 30303, 30651, 30769, 31250, 31372, 31620, 31746, 32000, 32258,
32388, 32921, 33057, 33333, 33613, 34188, 34482, 34632, 34782, 35087, 35555, 35714,
36199, 36363, 37037, 38095, 38277, 38461, 38647, 39215, 40000, 40404, 40816, 41025,
41666, 42105, 42328, 42780, 43478, 43956, 44444, 45454, 45714, 46783, 47058, 47337,
47619, 48484, 49382, 49689, 50000, 51282, 51948, 52287, 52631, 53333, 54421, 55555,
55944, 57142, 57971, 58823, 59259, 60150, 60606, 61538, 62500, 63492, 64000, 66115,
66666, 67226, 68376, 69565, 70175, 71428, 72727, 74074, 76190, 76923, 78431, 80000,
```

80808, 81632, 83333, 84210, 86956, 87912, 88888, 90909, 94117, 95238, 98765,100000,
102564,103896,105263,106666,111111,114285,115942,117647,121212,123076,125000,126984,13333
3,140350,142857,145454,148148,153846,
156862,160000,166666,173913,177777,181818,190476,200000,205128,210526,222222,235294,24242
4,250000,266666,285714,296296,307692,320000,333333,347826,363636,380952,400000,421052,444
444,470588,500000,533333,571428,615384,666666,727272,800000,888888,1000000

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