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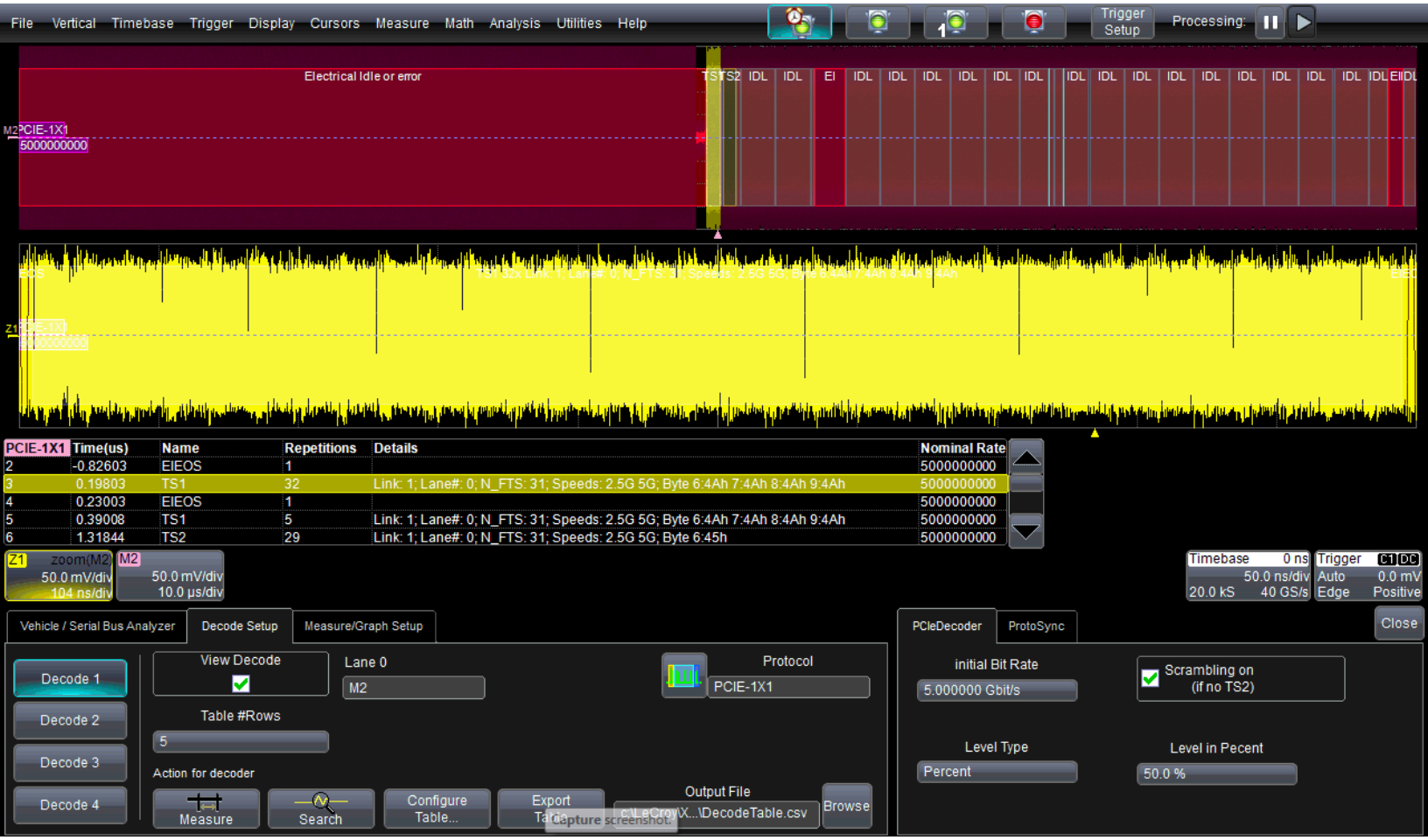

Instruction Manual

PCIebus
Decoder Software

PCIebus Decoder Software Instruction Manual

926373 Rev A
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About This Manual

Teledyne LeCroy offers a wide array of toolsets for decoding and debugging serial data streams. These toolsets may be purchased as optional software packages, or are provided standard with some oscilloscopes.

This manual explains how to use the PCIebus Decoder Software option.

Assumptions

This manual is presented with the assumption that:

- You have purchased and installed one of the serial data products described in this manual.
- You have a basic understanding of the serial data standard physical and protocol layer specifications, and know how these standards are used in embedded controllers.
- You have a basic understanding of how to use an oscilloscope, and specifically the Teledyne LeCroy oscilloscope on which the option is installed. Only features directly related to serial data decoding are explained in this manual.

Compatibility

Teledyne LeCroy is constantly expanding coverage of serial data standards and updating software. Some capabilities described in this documentation may only be available with the latest version of our firmware. You can download the free firmware update from:

teledynelecroy.com/support/softwaredownload

While some of the images in this manual may not exactly match what is on your oscilloscope display—or may show an example taken from another standard—be assured that the functionality is identical, as much functionality is shared. Product-specific exceptions will be noted in the text.

About the PCIebus Option

PCI Express (PCIe) is a serial computer expansion card interface standard developed to replace parallel PCI, PCI-X, and AGP standards. It is now pervasive in computing systems and embedded systems. PCIe utilizes point-to-point connections and typically consists of multiple lanes of both transmit (Tx) and receive (Rx) datastreams, with data being "striped" across multiple datastreams to achieve higher data transmission rate.

The PCIebus D option applies software algorithms to extract PCIe serial data information from physical layer waveforms measured on your oscilloscope. The extracted information is displayed over the actual physical layer waveforms, color-coded to provide fast, intuitive understanding of the relationship between message frames and other, time synchronous events.

PCIebus D decodes 1x1, 1x2, and 4x1 packets. It is compatible with the ProtoSync™ option and the PROTObus MAG™ option.

With the additional installation of the 8b/10b trigger and decoder option, you can trigger on PCIe primitives. See instructions for using the 8b/10b trigger in the *High Speed Serial Triggers* manual available from:

teledynelecroy.com/support/techlib

Decoding

Serial Decode Technical Overview

The algorithms described here at a high level are used by all Teledyne LeCroy serial decoders sold for oscilloscopes. They differ slightly between serial data signals that have a clock embedded in data and those with separate clock and data signals.

Bit-level Decoding

The first software algorithm examines the embedded clock for each message based on a default or user-specified vertical threshold level. Once the clock signal is extracted or known, the algorithm examines the corresponding data signal at the predetermined vertical level to determine whether a data bit is high or low. The default vertical level is set to 50% and is determined from a measurement of peak amplitude of the signals acquired by the oscilloscope. It can also be set to an absolute voltage level, if desired. The algorithm intelligently applies a hysteresis to the rising and falling edge of the serial data signal to minimize the chance of perturbations or ringing on the edge affecting the data bit decoding.

NOTE: Although the decoding algorithm is based on a clock extraction software algorithm using a vertical level, the results returned are the same as those from a traditional protocol analyzer using sampling point-based decode.

Logical Decoding

After determining individual data bit values, another algorithm performs a decoding of the serial data message after separation of the underlying data bits into logical groups specific to the protocol (Header/ID, Address Labels, Data Length Codes, Data, CRC, Parity Bits, Start Bits, Stop Bits, Delimiters, Idle Segments, etc.).

Message Decoding

Finally, another algorithm applies a color overlay with annotations to the decoded waveform to mark the transitions in the signal. Decoded message data is displayed in tabular form below the grid. Various compaction schemes are utilized to show the data during a long acquisition (many hundreds or thousands of serial data messages) or a short acquisition (one serial data message acquisition). In the case of the longest acquisition, only the most important information is highlighted, whereas in the case of the shortest acquisition, all information is displayed with additional highlighting of the complete message frame.

User Interaction

Your interaction with the software in many ways mirrors the order of the algorithms. You will:

- Assign a protocol/encoding scheme, an input source, and a clock source (if necessary) to one of the four decoder panels using the Serial Data and Decode Setup dialogs.
- Complete the remaining dialogs required by the protocol/encoding scheme.
- Work with the decoded waveform, result table, and measurements to analyze the decoding.

Decoding Workflow

We recommend the following workflow for effective decoding:

1. Connect your data and strobe/clock lines (if used) to the oscilloscope.
2. Set up the decoder using the lowest level decoding mode available (e.g., Bits).
3. Acquire a sufficient burst of relevant data, then run the decoder.

   NOTE: See Failure to Decode for more information about the required acquisition settings.
4. Use the various decoder tools to verify that transitions are being correctly decoded. Tune the decoder settings as needed.
5. Once you know you are correctly decoding transitions in one mode, continue making small acquisitions and running the decoder in higher level modes (e.g., Words). The decoder settings you verify on a few bursts will be reused when handling many packets.
6. Run the decoder on acquisitions of the desired length.

You can disable/enable the decoder as desired without having to repeat the set up and tuning provided the basic signal characteristics do not change.

Correcting Poor Quality or Inverted Signals

It is important to provide a high quality signal when using a Serial Decode package; this is true for the PCI Express decoder as well as all other types. If bits cannot be interpreted correctly, the decoding will be bad. Follow these guidelines to ensure good signal quality:

- Do not capture in the middle of the bus (at the PCIE connector) as reflections may seriously degrade the signal.
- Equalize at higher speeds. Signals traversing a significant length of FR4 (printed circuit board material) and coming through a PCIEbus D may show significant degradation at 5 GT/s to warrant some equalization, depending on the quality of the probe and where it was connected. At 8 GT/s, equalization is most definitely required, as it is in 8 GT/s PCIe receivers.
- Use correct polarity signal. An oscilloscope cannot automatically determine if the signal is inverted and compensate like real receivers do. Therefore, the PCIebus Decoder tries to parse the signal supplied – it has no choice because, as in the figures showing speed change, the capture may begin long after link initialization. Therefore it is important to give the decoder a signal with correct polarity. If the decode table shows lots of UNRECOGNIZED and single bytes of IDL (basically junk) then the signal probably needs to be inverted.

  If the signal is captured with the wrong polarity, it can easily be corrected later. If the capture is two single-ended waveforms, then just try both subtraction orders; one of them is correct. If the signal is captured using a differential probe, invert it (if necessary).

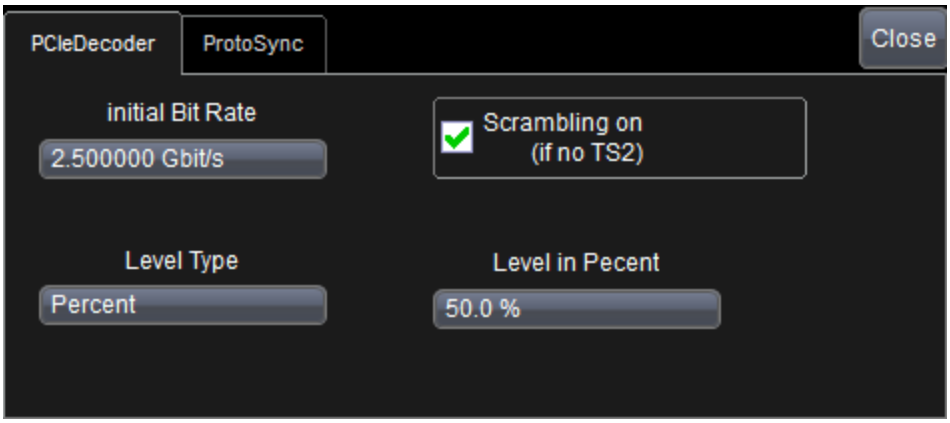
Setting Up the Decoder

The main Serial Decode dialog allows you to preset up-to-four, independent decoders, Decode 1 to Decode 4. Each decoder can use different (or the same) protocols and data sources, or have other variations, giving you maximum flexibility to compare different signals or view the same signal from multiple perspectives.

TIP: After completing setup for one decoder, you can quickly start setup for the other decoders by using the Decode # buttons at the left of the Decode Setup dialog. You don't have to step back to the Serial Decode dialog. Controls with the same label on either dialog share the same function.

1. Touch the **Front Panel Serial Decode button** (if available on your oscilloscope), or choose **Analysis > Serial Decode** from the oscilloscope menu bar to access the Serial Decode dialog.
2. On the same row as the **Decode #**:
   - Check **On** to enable the decoder now. This will let you view the decoding on screen as soon as there is an acquisition, which helps to begin tuning. If you wish, you can wait until all settings are complete to enable the decoder.
   - Select the desired **Protocol** to use.
   - Select the **Data (Source)** to be decoded. This can be any signal input channel (C*x*), memory (M*x*), or math function (F*x*).
3. Touch the **Setup** button (next to Search) to open the Decode Setup dialog. If you use this method rather than the tab, your settings will be correctly pre-selected on the Decode Setup dialog.
4. Go on to complete the settings on the right-hand dialogs next to the Decode Setup dialog.

PCIe Decoder



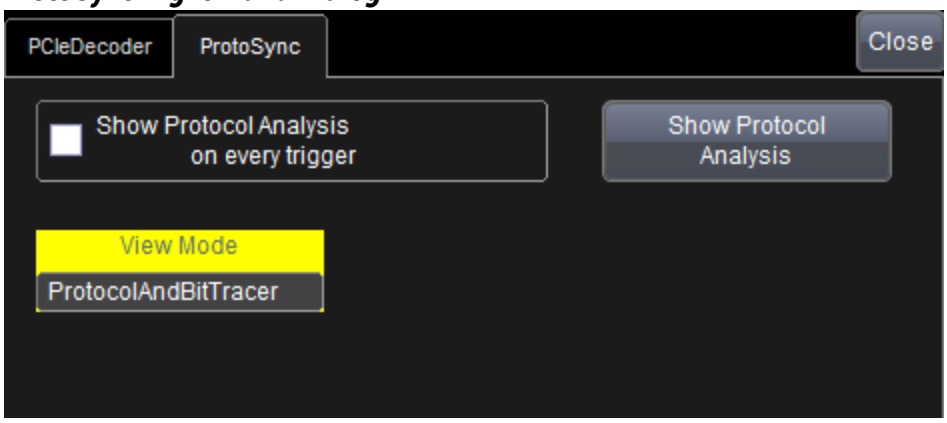
Select the **Initial Bit Rate** of the bus from one of the standard speeds.

NOTE: The PCIebus decoder follows speed changes. It detects the request, and the subsequent Electrical Idle Ordered Set (EIOS) triggers the speed change to the highest agreed upon supported rate. The Initial Bit Rate is the bit rate at the beginning of the waveform.

Enter the vertical **Level** used to determine the edge crossings of the signal. This value will be used to determine the bit-level decoding. Level is normally set as a percentage of amplitude, and defaults to 50%. It can alternatively be set as an absolute voltage by changing the **Level Type** to absolute. The set Level appears as a dotted horizontal line across the oscilloscope grid. If your initial decoding indicates that there are a number of errors, make sure that the level is set to a reasonable value.

Mark **Scrambling on (if no TS2)** if the signal uses a scrambling algorithm to reduce electromagnetic interference (EMI) caused by repetitive data patterns. The software automatically detects if scrambling is being used by reading values in the TS2. If no TS2 exists in the transmission, you can indicate its use by checking this box.

ProtoSync Right-Hand Dialog



This dialog appears if you have installed the ProtoSync option key *and* the PCI Express ProtoSync software on the instrument. Use it to display the decoded data in the format of a protocol analyzer. See ProtoSync.

Enabling/Disabling the Decoders

Once set up, the four decoders can be enabled simultaneously or separately (this number may be limited depending on the type of source channels selected). Decoders can be easily disabled without disrupting the configuration.

To enable: press the **Front Panel Serial Decode button** (if available on your oscilloscope) or choose **Analysis > Serial Decode** to open the Serial Decode dialog. Check **Decode On** next to the each decoder you wish to enable.

As long as **View Decode** is checked for that decoder on the Decode Setup dialog, a result table and decoded waveform appear. The number of rows of data displayed on each table will depend on the **Table#Rows** setting. The default is one, which can be increased, but doing so will decrease the amount of the screen available to display traces.

To disable: deselect the **Decode On** boxes individually, or touch **Turn All Off**.

Failure to Decode

Three conditions in particular may cause a decoder to fail, in which case a failure message will appear in the first row the the decoder result table, instead of in the message bar as usual:

- **Under sampled**. If the sampling rate (SR) is insufficient to resolve the signal adequately based on the bit rate (BR) setup or clock frequency, the message "Under Sampled" will appear. The minimum SR:BR ratio required is 4:1. It is suggested that you use a slightly higher SR:BR ratio if possible, and use significantly higher SR:BR ratios if you want to also view perturbations or other anomalies on your serial data analog signal.
- **Too short acquisition**. If the acquisition window is to short to allow any meaningfull decoding, the message “Too Short Acquisition” will appear. The minimum number of bits required varies from one protocol to another, but is usually between 5 and 50.
- **Too small amplitude**. If the signal’s amplitude is too small with respect to the full ADC range, the message “Decrease V/Div” will appear. The required amplitude to allow decoding is usually one vertical division.

In each case, the decoding is turned off to protect you from incorrect data. Adjust your acquisition settings accordingly, then re-enable the decoder.

NOTE: It is possible that several conditions are present, but you will only see the first relevant message in the table. If you continue to experience failures, try adjusting the other settings, as well.

Reading Waveform Annotations

When a decoder is enabled, an annotated waveform appears on the oscilloscope display, allowing you to quickly read the results of the decoding. A colored overlay marks significant bit-sequences in the source signal. The overlay contains annotations corresponding to the Header/ID, Address, Labels, Data Length Codes, Data, CRC, Parity Bits, Start Bits, Stop Bits, Delimiters, Idle segments, etc. Annotations are customized to the protocol or encoding scheme.

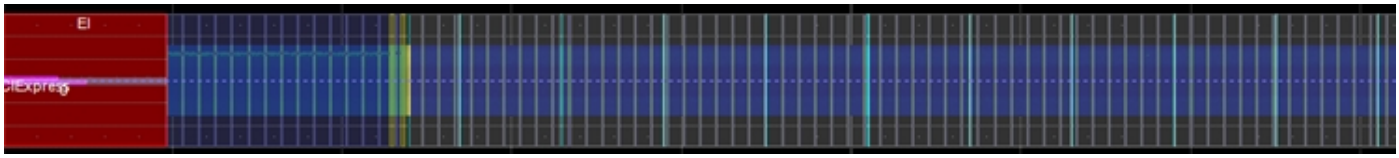
The amount of information shown on an annotation is affected by the width of the rectangles in the overlay, which is determined by the magnification (scale) of the trace and the length of the acquisition. Zooming a portion of the decoder trace will reveal the detailed annotations.

TIP: An easy way to zoom is to touch the number in the index column of the result table.

These overlays appear on a PCIe waveform to highlight key elements of the decoded signal (not all overlays shown on screen capture):

Annotation	Overlay Color (1)	Text (2)
TS1	Navy Blue	TS1 <repetitions>
TS2	Olive(Yellow)	TS2 <repetitions>
SKIP	(3)	SKIP
DLLP	Aqua Blue	DLLP
TLP	(3)	TLP
EIOS	(3)	EIOS
EIEOS	(3)	EIEOS
FTS	(3)	FTS
Logical Idle	Gray	IDL or Logical Idle
Electrical Idle	Red	EI or Electrcal Idle
Unrecognized	(4)	UNRECOGNIZED
Compliance	(4)	Comp
Modified Compliance	(4)	MComp
Compliance Delayed	(4)	CompD
Modified Compliance Delayed	(4)	MCompD
Protocol Error	Red	<type> error

1. Combined overlays affect the appearance of colors.
2. Text in brackets < > is variable. The amount of text shown depends on your zoom factors.
3. Shown in result table; annotation visible in 8b/10b decoder overlay.
4. Text annotation only.



Decoded PCIebus waveform.

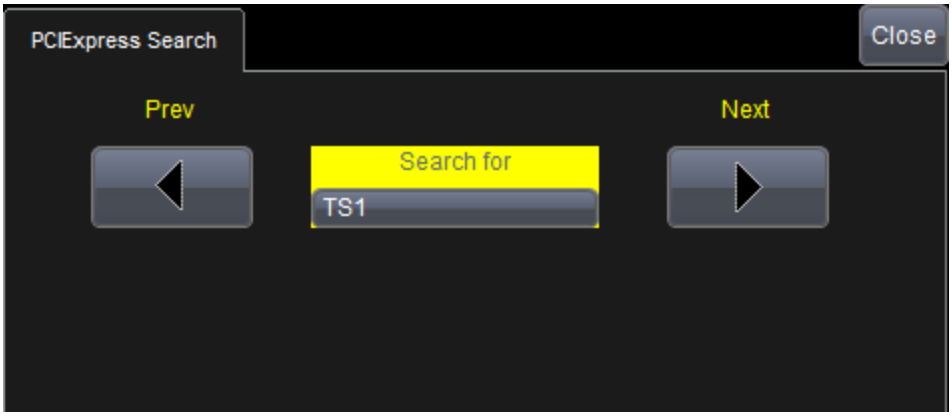
Note that:

- Compliance annotations appear at 2.5 and 5GT/s.
- At 8GT/s, both Compliance and Modified Compliance appear simply as blocks of Logical Idle separated by EIEOS, and in Modified Compliance, by SKP Ordered Sets.
- In Compliance, the repeating pattern is one EIEOS followed by 32 Data Blocks of IDL.
- In Modified Compliance, after the EIEOS, there are 256 Data Blocks of IDL, then 255 repetitions of SKP Ordered Set followed by 256 Data Blocks of IDL. The state can be determined from the Details column for the SKP Ordered Set. There is no concept of delayed compliance at 8GT/s, instead each lane has a unique initialization of its LFSR.

Searching Waveforms

Selecting the **Search** Action button on the Decode Setup dialog opens the decoder Search dialog, where you can enter criteria for finding events of interest in the waveform: various protocol elements, data values, errors, etc. Touch the **Prev** and **Next** buttons to navigate to matches found in the decoded waveform, simultaneously creating a zoom of each match.

The default zoom always shows the matching data at the full width of the grid. Use the standard Zoom controls to rescale the zoom to the desired level of magnification.



Choose the protocol element to **Search for** matching data. Search will go to the beginning of the next occurence of that transmssion type in the acquisition. Choose "any" to go to the beginning of the next transmission.

Serial Decode Result Table

By default, a table summarizing the decoder results appears below the grid area whenever a decoder is enabled. The result table provides a view of message data as decoded during the most recent acquisition, even when messages are too compact to allow annotation on the waveform trace.

The table is displayed only when the **View Decode** checkbox is marked on the Decode Setup Dialog *and* a source signal has been decoded using that protocol.

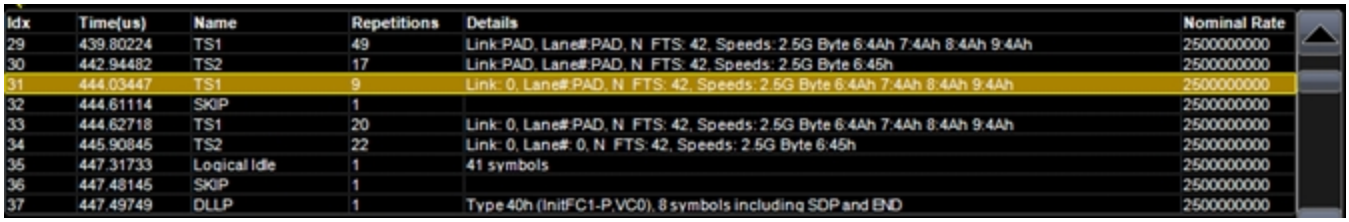
Selecting a number in the first (index) column of the table will display a zoom of the corresponding position in the decoded waveform.

You can customize the result table, changing both the number of rows and the columns displayed. The default is one row. On a single-row table, touch the Down arrow at the far right to open a scrollbar that lets you display the previous or next row of data.

You can also export result table data to a .CSV file, and the table itself is useful for measuring.

This extracted data appears on a PCIe decoder result table.

Column	Extracted or Computed Data
Index (always shown)	Number of the line in the table; also number of the message in the annotation overlay on the trace
Time	Time from start of acquisition to start of symbol sequence.
Name	The name of the sequence of symbols.
Repetitions	Since startup begins with 1024 TS1 all of which are identical, and then possibly dozens more TS1 and TS2 sequences in each state as the Link and Lane# are agreed upon, the table shows one line for all identical, contiguous, TS1 and TS2 sequences. The number of repetitions is shown in this column. The table also encodes a continuous run of IDL as one line, but since Logical Idle is scrambled IDL and not repetitions of the same symbols, the number of symbols in a continuous run of Logical Idle is given in the Details column.
Details	Selected information from within the structure being annotated. For TS1 and TS2: Link, Lane#, N_FTS, Speeds advertised, and if present: Speed Change Request, Autonomous Change, Training Control: Hot Reset, Disable Link, Loopback, Disable scrambling, Compliance receive. The value of the next byte is annotated for TS2, the next 4 bytes for TS1; these bytes may contain equalization setup information for 8GT/s, if that speed is supported. For TLP, the Type (or Type and Fmt) are spelled out using exactly the TLP Type names given in Table 2-3 of the PCI Express Base Specification. For DLLP, the Type is spelled out using exactly the DLLP Type names given in Table 3-1 in the PCI Express Base Specification. At 8GT/s, details about the three bytes following SKP END are annotated, including LFSR value, in Loopback, Master, in Loopback, Slave or in Compliance, Err Cnt = . Also, if an invalid sync header is found, UNRECOGNIZED shows "Invalid sync:" and the value of the sync header (either 0 or 3).
Nominal Rate	The nominal bit rate the decoder is currently using to separate bits. It is not a measurement. It shows as 2500000000 or 5000000000 or 8000000000.



Idx	Time(us)	Name	Repetitions	Details	Nominal Rate
29	439.80224	TS1	49	Link:PAD, Lane#:PAD, N_FTS: 42, Speeds: 2.5G Byte 6:4Ah 7:4Ah 8:4Ah 9:4Ah	2500000000
30	442.94482	TS2	17	Link:PAD, Lane#:PAD, N_FTS: 42, Speeds: 2.5G Byte 6:45h	2500000000
31	444.03447	TS1	9	Link: 0, Lane#:PAD, N_FTS: 42, Speeds: 2.5G Byte 6:4Ah 7:4Ah 8:4Ah 9:4Ah	2500000000
32	444.61114	SKIP	1		2500000000
33	444.62718	TS1	20	Link: 0, Lane#:PAD, N_FTS: 42, Speeds: 2.5G Byte 6:4Ah 7:4Ah 8:4Ah 9:4Ah	2500000000
34	445.90845	TS2	22	Link: 0, Lane#: 0, N_FTS: 42, Speeds: 2.5G Byte 6:45h	2500000000
35	447.31733	Logical Idle	1	41 symbols	2500000000
36	447.48145	SKIP	1		2500000000
37	447.49749	DLLP	1	Type 40h (InitFC1-P,VC0), 8 symbols including SDP and END	2500000000

Section of typical PCIe decoder result table.

Customizing the Result Table

NUMBER OF COLUMNS

Follow these steps to change what data appears in the result table:

1. Press the Front Panel **Serial Decode button** or choose **Analysis > Serial Decode**, then open the **Decode Setup tab**.
2. Touch the **Configure Table** button.
3. On the **View Columns** pop-up dialog, mark the columns you want to appear in the table, clear any columns you wish to remove. Only those columns selected will appear on the oscilloscope display.

   NOTE: If a selected column is not relevant to the decoding selections, the column will not appear in the table.

   To return to the preset display, touch **Default**.
4. Touch the **Close** button when finished.

BIT RATE TOLERANCE

On some decoders, you may also use the View Columns pop-up to set a **Bit Rate Tolerance** percentage. When implemented, the tolerance is used to flag out-of-tolerance messages (messages outside the user-defined bitrate +- tolerance) by colorizing in red the Bitrate shown in the table.

NUMBER OF ROWS

You may customize the size of the result table by changing the **Table # Rows** setting on the Decode Setup dialog. Keep in mind that the deeper the table, the more compressed the waveform display on the grid, especially if there are also measurements turned on.

Zooming with the Result Table

Besides displaying the decoded serial data, the result table enables you to quickly Zoom regions of the decoded waveform and access other functionality.

Touching the **Index (row) number** in the first column opens a Zoom of the corresponding region in the decode trace. This is a quick way to navigate to events of interest in the acquisition.

The **Index column heading** (top, left-most cell of the table header) bears the name of the corresponding protocol, and the cell's fill color matches the color of the input source. Touching this cell opens the Decode Setup dialog if it has been closed.

Touching any other **data cell** in the table opens a pop-up menu with several choices of action:

- **Off** turns off the decode.
- **Zoom** creates a zoom of the region where the data appears (same as touching the row number).
- **Setup** opens the Decoder Setup dialog (same as touching the first column heading).
- **Export** exports the decode results table to a .CSV file.
- **Measure** displays a choice of measurements that can be made on the decoded signal.

Exporting Result Table Data

You can manually export the decoder result table data to a **.CSV** file:

1. Press the Front Panel **Serial Decode button**, or choose **Analysis > Serial Decode**, then open the **Decode Setup tab**.
2. Optionally, touch **Browse** and enter a new **File Name** and output folder.
3. Touch the **Export Table** button.

Export files are by default created in the D:\Applications\<protocol> folder, although you can choose any other folder on the oscilloscope or any external drive connected to a host USB port. The data will overwrite the last export file saved in the protocol directory, unless you enter a new filename.

In addition, the oscilloscope Save Table feature will automatically create tabular data files with each acquisition trigger. The file names are automatically incremented so that data is not lost. Choose **File > Save Table** from the oscilloscope menu bar and select **Decode#** as the source. Make other file format and storage selections as you wish.

ProtoSync

ProtoSync™ adds many of the same algorithms used by the Teledyne LeCroy hardware protocol analyzers to your decoder, enabling you to view the logic layer display of a protocol analyzer in sync with the physical layer display of an oscilloscope. There is no need to export the decoded data to another device, and the integrated graphical user interface makes it easy to switch between the views, or to arrange them side by side on the screen. Changing the decoder on the oscilloscope updates ProtoSync in real time for comprehensive physical layer and protocol layer debug and analysis.

The ProtoSync BitTracer option is also available for PCIe decoders. This adds a data link layer display to the standard ProtoSync logic layer display.

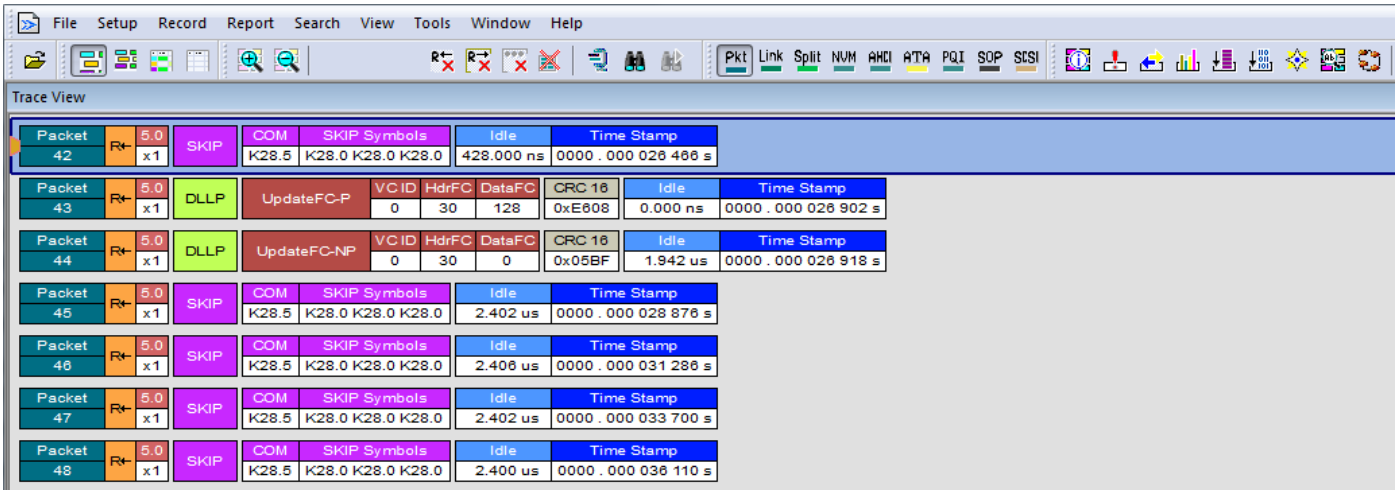
NOTE: ProtoSync requires the installation of both the option key and the PCIe ProtoSync software. The PCIe ProtoSync software is available as a free download from teledynelecroy.com/. After installing the software, go to the Start/Programs/LeCroy/<protocol> Protocol Suite folder to find more extensive documentation for understanding the Protocol Analyzer and BitTracer views.

ProtoSync Protocol View

To display the decoding in Protocol View, open the ProtoSync right-hand dialog and choose a **ViewMode** of Protocol. Then, either:

- Touch **Show Protocol Analysis** to manually launch ProtoSync
- Select **Show Protocol Analysis on every trigger**. This option repeatedly sends data to ProtoSync.

This action will launch a software display similar to that below:



PCIe decode in Protocol View display.

The Protocol View displays data packets in a format consistent with hardware protocol analyzers:

- Each row represents one packet, with each cell color-coded to indicate different data types.
- Transactions are shown as either upstream or downstream.
- Actual decoded bits are shown in each cell.

While the decoder Result Table displays data differently than the Protocol View, there is some correlation between the two displays.

Decoder Result Table	Protocol View	Note
Idx	**Packet #**	Actual numbers may vary since repetitions are handled differently. The decoder result table shows one entry and indicates the number of repetitions. The Protocol View shows each repetition as a packet header row.
Time (µs)	**Time Stamp**	Times shown are likely to differ, unless your trigger delay is set to the exact left edge of the oscilloscope display grid.

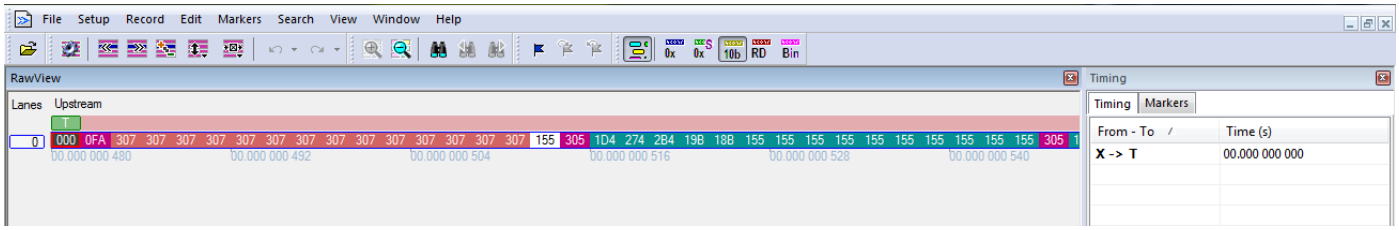
Protosync BitTracer View

Available when using ProtoSync with PCIe options, the BitTracer view shows the Hexadecimal form of each transferred data bit.

To turn on BitTracer view, open the ProtoSync right-hand dialog and choose a **ViewMode** of BitTracer or ProtocolAndBitTracer. Then, either:

- Touch **Show Protocol Analysis** to manually launch ProtoSync
- Select **Show Protocol Analysis on every trigger**. This option repeatedly sends data to ProtoSync.

You will see a display similar to the following in BitTracer ViewMode:



Measuring (PROTObus MAG)

The installation of the PROTObus MAG option adds a set of measurements designed for serial data analysis to the oscilloscope's standard measurement capabilities. Measurements can be quickly applied without having to leave the waveform or tabular views of the decoding.

Serial Data Measurements

These measurements designed for debugging serial data streams can be applied to the decoded waveform. Measurements appear in a tabular readout below the grid (the same as for any other measurements) and are in addition to the result table that shows the decoded data. You can set up as many measurements as your oscilloscope has parameter locations.

NOTE: Depending on the protocol, measurements may appear in a sub-menu of the Measure Setup menu and may have slightly different names. For example, the CAN sub-menu has measurements for CANtoValue instead of Message to Value, etc. The measurements are the same.

Measurement	Description
View Serial Encoded Data as Analog Waveform	Automatically sets up a Message to Value parameter and then tracks the assigned measurement. In doing so, a Digital-to-Analog Conversion (DAC) of the embedded digital data is performed and the digital data is displayed as an analog waveform.
Message to Value	Extracts and converts a specific portion of the data/payload in the message and displays it as an analog value.
MsgToAnalog (Message to Analog)	Computes time from start of first message that meets conditions to crossing threshold on an analog signal. Result is negative if analog event precedes message. You must choose the digital input in Source1 and the analog input in Source 2 for this measurement to work properly.
AnalogToMsg (Analog to Message)	Computes time from crossing threshold on an analog signal to start of first message that meets conditions. Result is negative if message precedes analog event. You must choose the analog input in Source 1 and the digital input in Source 2 for this measurement to work properly.
MsgToMsg (Message to Message)	Computes time difference from start of first message that meets conditions to start of next message.
DeltaMsg (Delta Message)	Computes time difference between two messages on a single decoded line.
Time@Msg (Time at Message)	Computes time from trigger to start of each message that meets conditions.
BusLoad	Computes the load of user-defined messages on the bus (as a percent).
MsgBitrate	Computes the bitrate of user-specified messages on decoded traces.
NumMessages (Number of Messages)	Computes the total number of messages in the decoding that meet conditions.

Using the Measure/Graph Dialog

The Measure/Graph dialog, which appears behind the Decode Setup dialog when measurements are supported, is a quick way to apply parameters specifically designed for serial data measurement and simultaneously graph the results.

1. Select the **Measurement** to apply and the **Destination** parameter location (Px) in which to open it.
2. The active decoder is preselected in **Source 1**, indicating the measurement will be applied to the decoder results; change it if necessary. If the measurement requires it, also select an appropriate Source 2 (e.g., an analog waveform for comparison).
3. Optionally, choose to plot the measurement in a graph format or set a measurement filter or gate.

NOTE: The Serial Decode measurements are also available from the standard Measure setup menu. You can use the that functionality to set up as many measurements as your instrument has parameters.

Graphing Measurements

PROTObus MAG includes simplified methods for plotting measurement values as:

- **Histogram** - a bar chart of the number of data points that fall into statistically significant intervals or bins. Bar height relates to the frequency at which data points fall into each interval/bin. Histogram is helpful to understand the modality of a parameter and to debug excessive variation.
- **Trend** - a plot of the evolution of a parameter over time. The graph's vertical axis is the value of the parameter; its horizontal axis is the order in which the values were acquired. Trending data can be accumulated over many acquisitions. It is analogous to a chart recorder.
- **Track** - a time-correlated accumulation of values for a single acquisition. Tracks are time synchronous and clear with each new acquisition. Track can be used to plot data values and compare them to a corresponding analog signal, or to observe changes in timing. A parameter tracked over a long acquisition could provide information about the modulation of the parameter.

These plots effectively perform a digital-to-analog conversion that can be viewed right next to the decoded waveform.

To graph a measurement, just select the plot type from the Measure/Graph dialog when setting up the measurement.

All plots are created as Math functions, so also select a **Destination** function location (Fx) in which to draw the plot. The plot will open along side the deocoding in a separate grid.

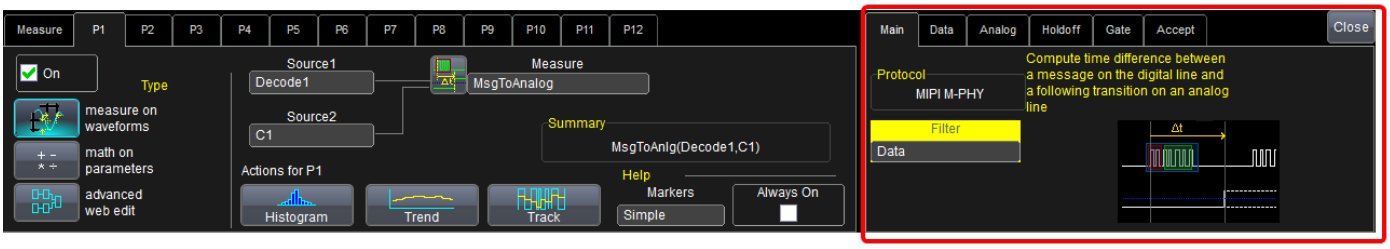
Filtering Serial Decode Measurements

In many cases, measurements can be filtered to include only the specified frame types, IDs, or data patterns. As with all traces, you can set a gate to restrict measurements to a horizontal range of the grid corresponding to a specific time segment of the acquisition.

NOTE: Not all protocols or measurements support all filter types.

After creating a measurement on the Measure/Graph dialog, touch **Apply&Configure**. The touch screen display will switch to the standard Measure setup dialogs for the parameter you selected.

Set filter conditions on the right-hand dialogs that appear next to the P*x* dialogs.

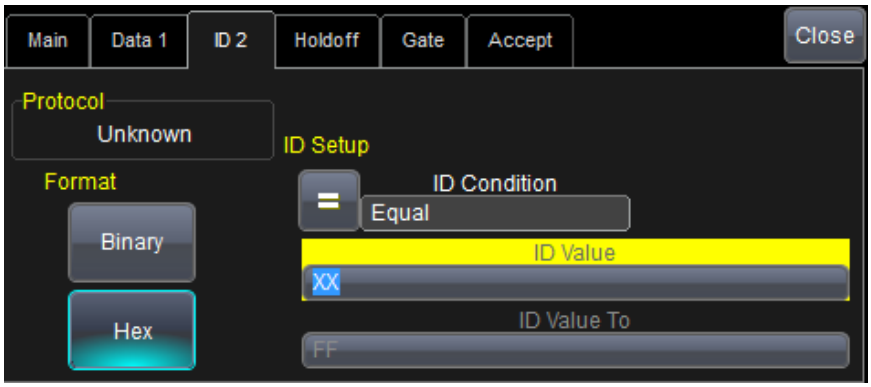


Frame ID Filter

This filter restricts the measurement to only frames with a specific ID value.

NOTE: Settings on this dialog may change depending on the protocol.

1. On the Main dialog, in **Filter** choose ID or ID+Data.
2. Open the **ID tab** that appears.



3. Choose to enter the frame ID value in **Binary** or **Hex**(adecimal) format.
4. Using the **ID Condition** and **ID Value** controls, create a condition statement that describes the IDs you want included in the measurement. To set a range of values, also enter the **ID Value To**. On the pop-up dialog that appears when you touch ID Value:
   - Use the Left and Right arrows to position the cursor.
   - Use Back to clear the previous character (like Backspace), Use Clear to clear all characters.

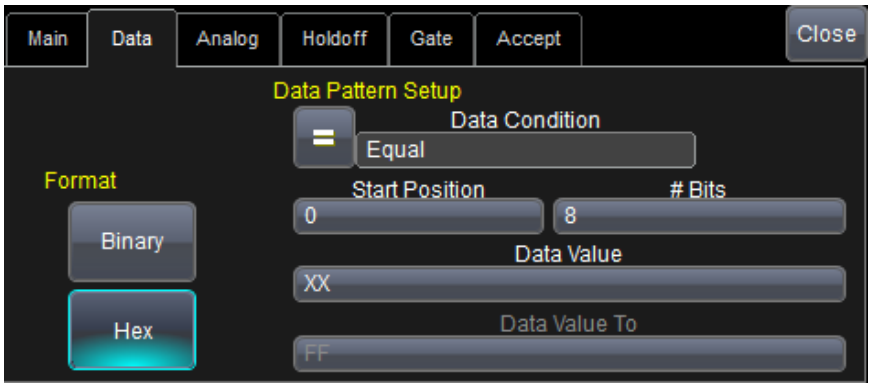
Data Filter

This restricts measurements to only frames containing extracted data that matches the filter condition. It can be combined with a Frame ID filter by choosing ID+Data on the Main dialog.

Use the same procedure as above to create a condition describing the **Data Value(s)** to include in the measurement. Use "X" as a wild card ("Don't Care") in any position where the value doesn't matter.

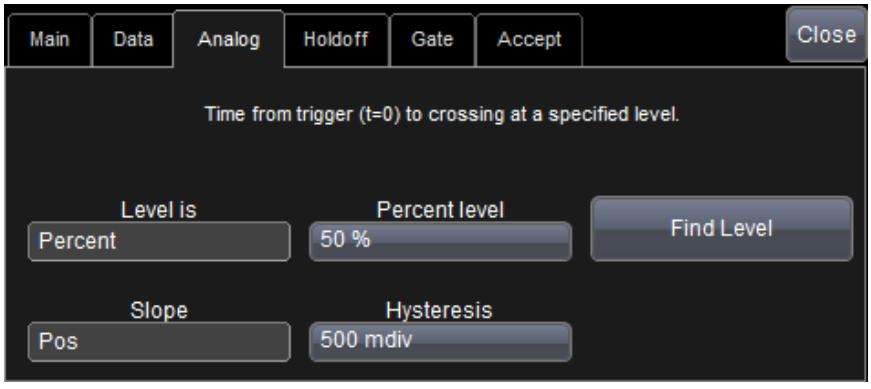
Optionally, enter a **Start Position** within the data field byte to begin seeking the pattern, and the **# Bits** in the data pattern. The remaining data fields positions will autofill with "X".

NOTE: For MsgtoMsg measurements, the data condition is entered twice: first for the Start Message and then for the End Message. The measurement computes the time to find a match to each set of conditions.



Analog Filter

This filter applies only to parameters that measure the decoded waveform relative to an analog signal: AnalogtoMsg and MsgtoAnalog. It allows you to set the crossing level and slope of the Analog signal event that is to be used in the measurement. Level may be set as a percentage of amplitude (default), or as an absolute voltage level by changing Level Is to Absolute. You can also use Find Level to allow the oscilloscope to set the level to the signal mean.



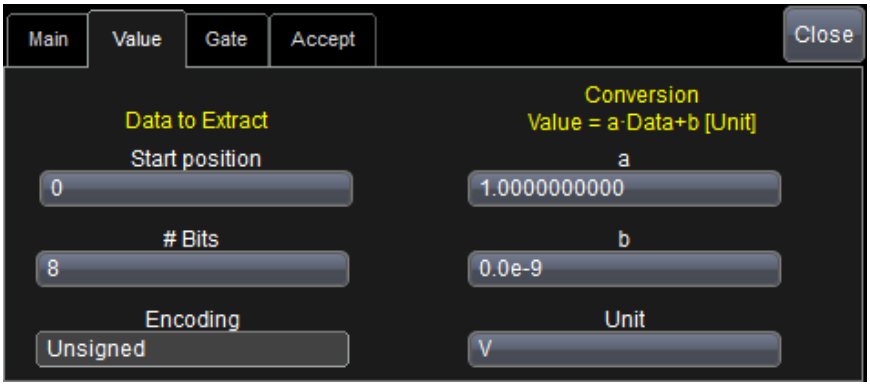
The optional Hysteresis setting imposes a limit above and below the measurement Level, which precludes measurements of noise or other perturbations within this band. The width of the band is specified in milli-divisions.

Observe the following when using Hysteresis:

- Hysteresis must be larger than the maximum noise spike you wish to ignore.
- The largest usable hysteresis value must be less than the distance from the Level to the closest extreme value of the waveform.

Value Conversion Filter

This filter applies only to the MsgtoValue parameter. It enables you to apply a value conversion to extracted data. The converted values appear in the result table.



1. Under Data to Extract, begin by entering the **Start position** and the **# Bits** to extract.
2. Choose the **Encoding** type if the signal uses encoding, otherwise leave it Unsigned.
3. Under Conversion, enter the **a. Coefficient** and **b. Term** that satisfy the formula: *Value = Coefficient * Raw Value + Term*.
4. Optionally, enter a **Unit** for the extracted decimal value.

Holdoff, Gate, and Accept

Certain measurements support holdoff, gating, or additional qualifiers (Accept). You will see the tab appear among the Measure set up dialogs when the function is supported. When applied to serial data measurement, these functions work exactly as they do elsewhere in the oscilloscope:

- **Holdoff** specifies the amount of time or number of events to wait before starting the measurement.
- **Gate** specifies the Start Div and Stop Div that bound the portion of the acquisition to include in the measurement.
- **Accept** allows you to set qualifiers based on waveform state, either the measurement source or a second "gating" waveform, or to only accept measurement values that fall within pre-defined ranges.

See the oscilloscope *Operator's Manual* for more information.

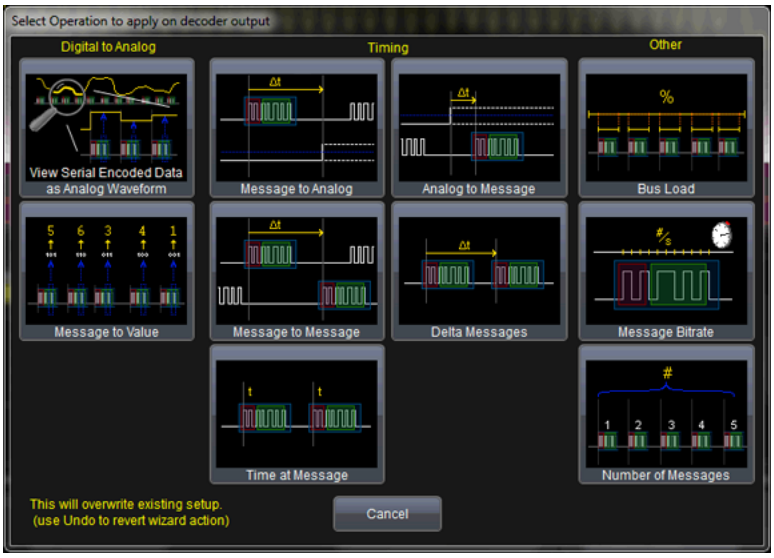
Accessing Measurements from the Result Table

To quickly apply serial data measurements when the serial data setup dialogs are closed:

1. Touch any **data cell** of the decode result table.

   NOTE: If running more than one decoder simultaneously, be sure to select a cell from the correct table. The measurement source will be the waveform belonging to the table you touch.

2. From the pop-up menu, select **Measure** to display the Select Operation... dialog.



3. Touch any measurement operation to select it.
4. On the next dialog, choose a **parameter** location (P1-P*x*) in which to run the measurement.

   NOTE: If the location already stores a measurement, this selection will overwrite that setup.

5. To filter or gate the parameter, touch the Px cell of the readout table and make the desired settings on the right-hand dialogs that appear.

Accessing Measurements from the Decode Setup Dialog

You can also access serial data measurements by touching the **Measure button** on the Decode Setup dialog. When using this button, measurements are set on the source of whichever Decoder (1-4) is currently selected on the Decode Setup dialog.

Accessing Measurements from the Measure Menu

The full menu of available measurements can be accessed through the menu bar. Standard measurements are available even if you do not have a Measure option installed.

Choose **Measure > Measure Setup** and follow the usual procedures for setting up a measurement. In this case, you will have to manually choose the source waveform to measure, as the Decoder output is not pre-selected.

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