



# Trigger an oscilloscope, get a stable display

[Arthur Pini](#) - March 13, 2018

The first oscilloscope I ever used professionally was an old synchronized sweep instrument. Obtaining a stable display on that old oscilloscope was an art. Now I appreciate all the triggering tools available on even the most basic oscilloscopes.

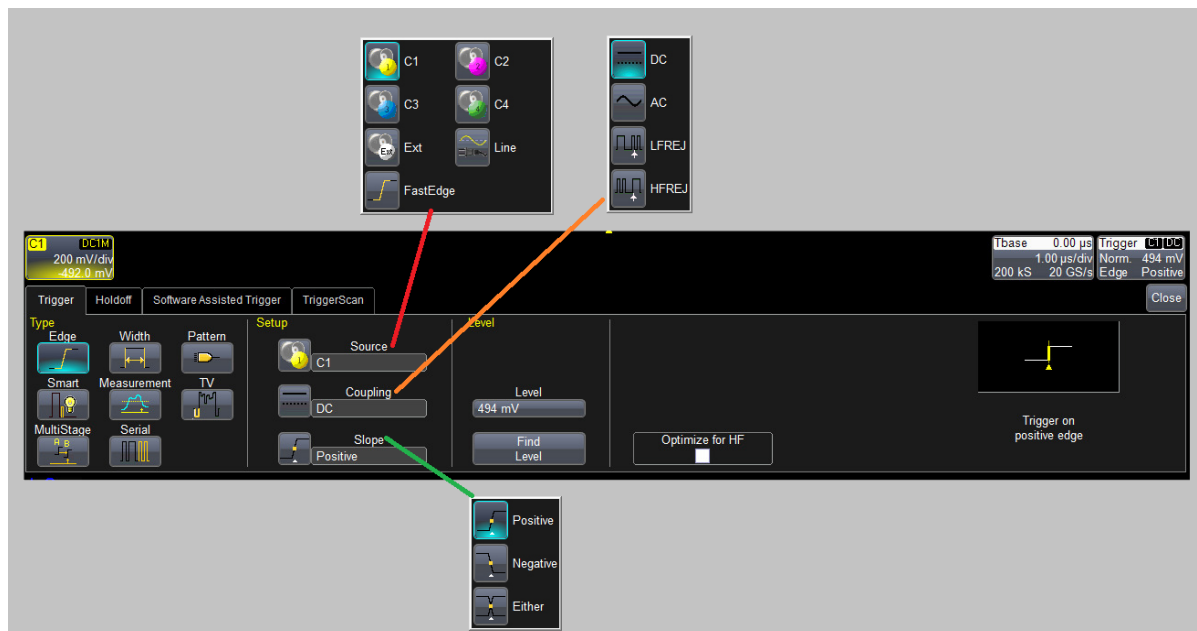
An oscilloscope trigger synchronizes the oscilloscope's timebase to the input signal, producing a stable display. In analog oscilloscopes, the trigger initiates the sweep generator so that the horizontal sweep is synchronous with the vertical signal. Digital storage oscilloscopes (DSOs) produce the same effect through a different method. In DSOs, the digitizer runs continuously and the trigger event marks the associated data in the acquisition memory, locking the signal data for display, measurement, and further processing.

Today's DSOs include relatively simple edge triggers, more sophisticated "smart" triggers, and still more complex "augmented" triggers. Let's look into these multiple trigger implementations.

## **Edge triggers**

Edge triggers are the most commonly used trigger method. With edge triggering, the oscilloscope triggers when the source trace crosses the trigger threshold level with the user specified slope (positive, negative, or either). Trigger hysteresis provides noise immunity by requiring the signal to transition through the hysteresis interval before the oscilloscope will trigger. Most oscilloscopes use a hysteresis level of 0.3 to 0.5 vertical divisions.

Trigger sources include the input channels, external trigger input, line power, and, in some cases, the built-in fast edge signal. The slope, polarity, and trigger threshold for each source can be set independently of the other sources. **Figure 1** shows the edge trigger setup for a typical mid-range oscilloscope.



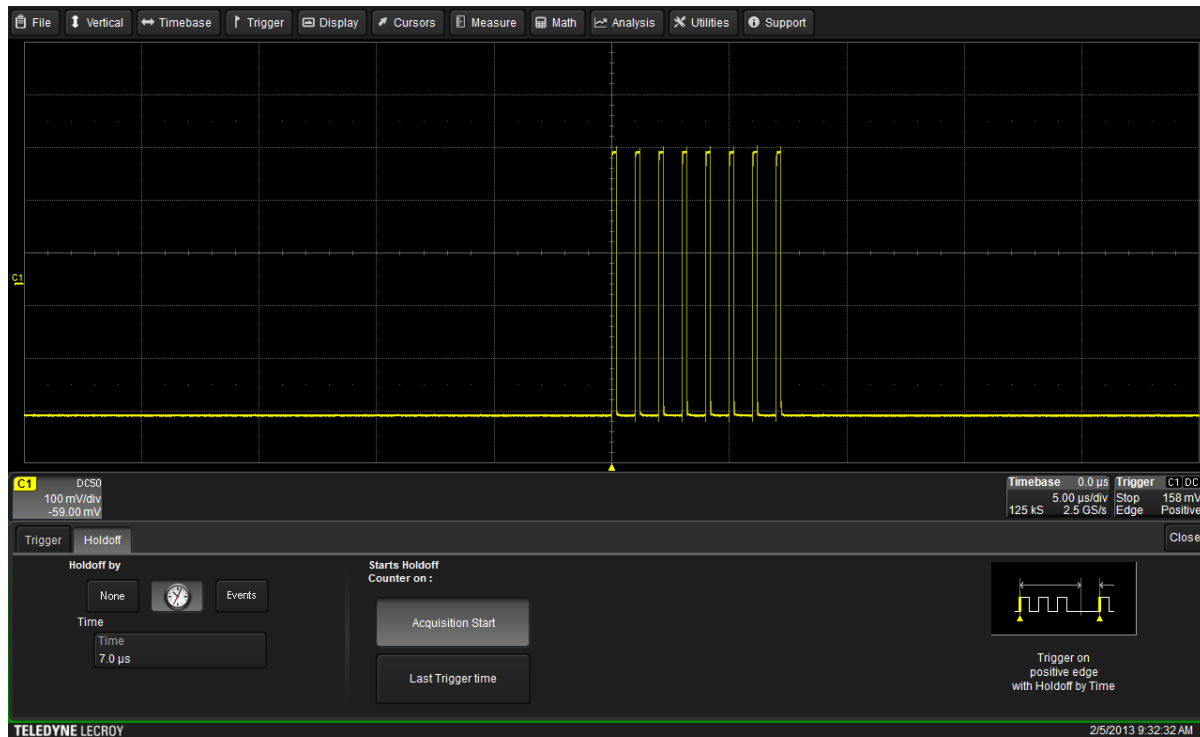
**Figure 1** The elements of an edge trigger setup include trigger source, level, slope, and coupling.

In addition to setting the source, trigger level, and slope, you have a choice of coupling selections: AC or DC coupling along with low or high frequency reject. The frequency selective coupling paths are used to attenuate extraneous signals. The low frequency reject inserts a 50 kHz high-pass filter in the trigger signal path while the high frequency reject uses a 50 kHz low-pass filter. These frequency selective coupling modes find use in applications such as troubleshooting switch mode power supplies. High-frequency reject makes it easier to trigger on mains related signals while low-frequency reject simplifies triggering on switching regulator signals.

Some oscilloscopes have a Find Level button that when pressed, will automatically find the trigger level for the current trigger source. Another convenience is the trigger icon (right side of the **Figure 1**), which summarizes the trigger setup.

### Trigger hold off

Hold off is a trigger function used when there are multiple trigger events per acquisition. It lets the oscilloscope ignore extra trigger events and stabilize the display as if there was only a single trigger event per acquisition. Hold off can be based on time or a trigger event. **Figure 2** shows an example of hold off by time. The waveform being acquired is a burst of eight pulses with a duration of 7  $\mu$ s. There are eight possible trigger events. A trigger event is a signal condition that would normally result in the oscilloscope triggering. Think of hold off as a command to ignore the trigger for a specified time or event count.



**Figure 2** The hold off by time trigger can obtain a stable trigger on a pulse burst waveform with a 7 $\mu$ s duration from the first to the last positive going edge.

In **Figure 2**, hold off was set to ignore triggers for the burst's 7  $\mu$ s duration. When the oscilloscope trigger is enabled, any trigger will be followed by a 7  $\mu$ s interval. Because 7  $\mu$ s is the duration of the burst, the next trigger will occur at the beginning of the next burst.

You can do the same thing with hold off by events. In this case, you hold off by eight trigger events. This is the entire duration of the pulse burst. Again, the acquisition will synchronize itself with each pulse burst. Note that hold off does not guarantee triggering on a specific point in the burst, just synchronizing with the burst. Synchronization will be maintained until there is an interruption of the signal and then will resynchronize, perhaps at a different point, when the connection is resumed.

The starts hold off counter determines if the hold-off counter is reset at the beginning of each acquisition (the acquisition start selection) or if it accumulates continuously (the last trigger time selection). Keep in mind that the trigger input is active at all times. If trigger pulses arrive, even if not during an acquisition, they may be counted in the hold off condition unless the hold off counter is restarted at the beginning of the acquisition. Similarly, if the process you're synchronizing with is continuous you can count all trigger events by selecting to start the count at the last trigger time.

Hold off is a useful tool, but it does require some experience. Reviewing the oscilloscope manual and any application notes or tutorials supplied by the manufacturer can be helpful.

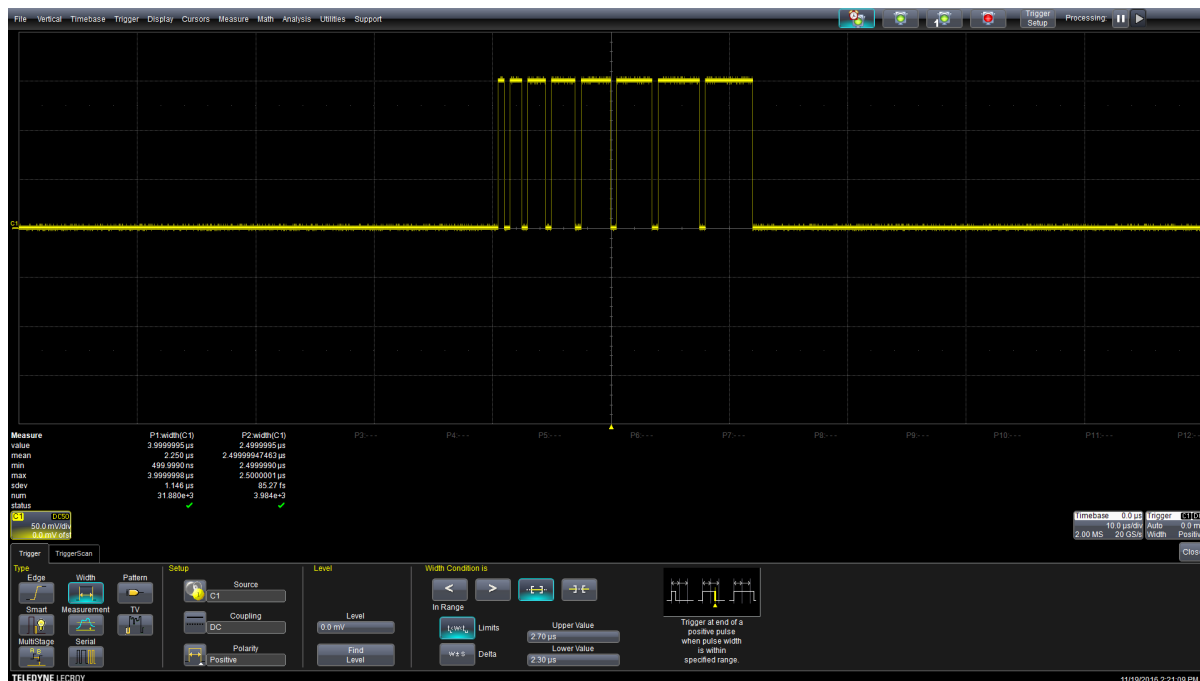
### Smart triggers

Mid-range oscilloscopes usually include a powerful set of smart triggers that are based on timing and amplitude parameters of the trigger signal. Smart triggers may include glitch, width, window, interval (period), drop out, logic pattern, runt, TV, and slew rate.

As an example of a smart trigger we'll focus on the width trigger. The width trigger is sensitive to the width of a signal and is generally applied to a rectangular pulse. Provisions to trigger on pulses wider than, narrower than, within a range, and outside of a range make this a powerful tool for

triggering on complex signals.

**Figure 3** shows the waveform that will be used to demonstrate the use of the width trigger. This is a pulse width modulated waveform with eight distinct widths from 500 ns to 4  $\mu$ s.



**Figure 3** Using the width trigger to trigger the oscilloscope on a pulse width of 2.5  $\mu$ s.

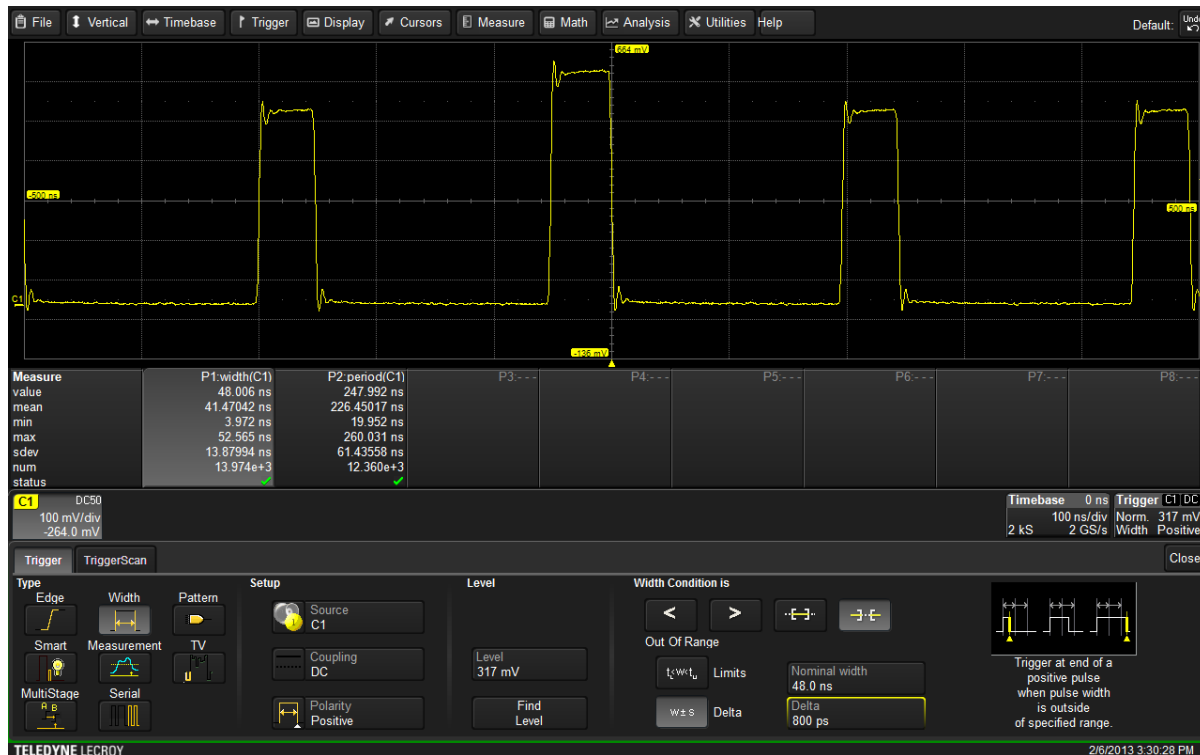
As previously mentioned, there are four width conditions that you can use to define the trigger. **Figure 3** shows a width trigger based on the width of the pulse being between 2.3  $\mu$ s and 2.7  $\mu$ s. The width trigger dialog box in **Figure 3** shows the setup for triggering on the width "within a range" condition. As a result, a pulse with a width of 2.5  $\mu$ s is the trigger event. Other smart triggers behave in a similar manner offering a wide range of trigger events based on signal characteristics.

## Exclusion and other triggers

### Exclusion trigger

Exclusion trigger is the ability to trigger on waveform anomalies and avoid triggering on 'normal' waveforms. It is based on smart triggers using the out-of-range trigger condition. Exclusion trigger is useful in discovering waveform anomalies and glitches. The main advantage of using an exclusion trigger is that you do not need to know anything about the anomalies because the trigger is based on the easily measured nominal waveform characteristics.

**Figure 4** shows an example of a clock waveform with a nominal width of 48 ns and a period of 250 ns. We can set up an exclusion trigger to eliminate triggers on the "normal" pulses and trigger on those pulses that are different from the normal pulses, namely, the anomalous pulses. With exclusion trigger, the oscilloscope won't acquire data until the trigger condition is met. Capturing the anomaly isn't dependent on the oscilloscope's update rate.



**Figure 4** Using a width-based exclusion trigger lets you find an anomalous pulse in a clock signal. The oscilloscope triggers on pulses with widths that differ from the nominal 48  $\mu$ s width

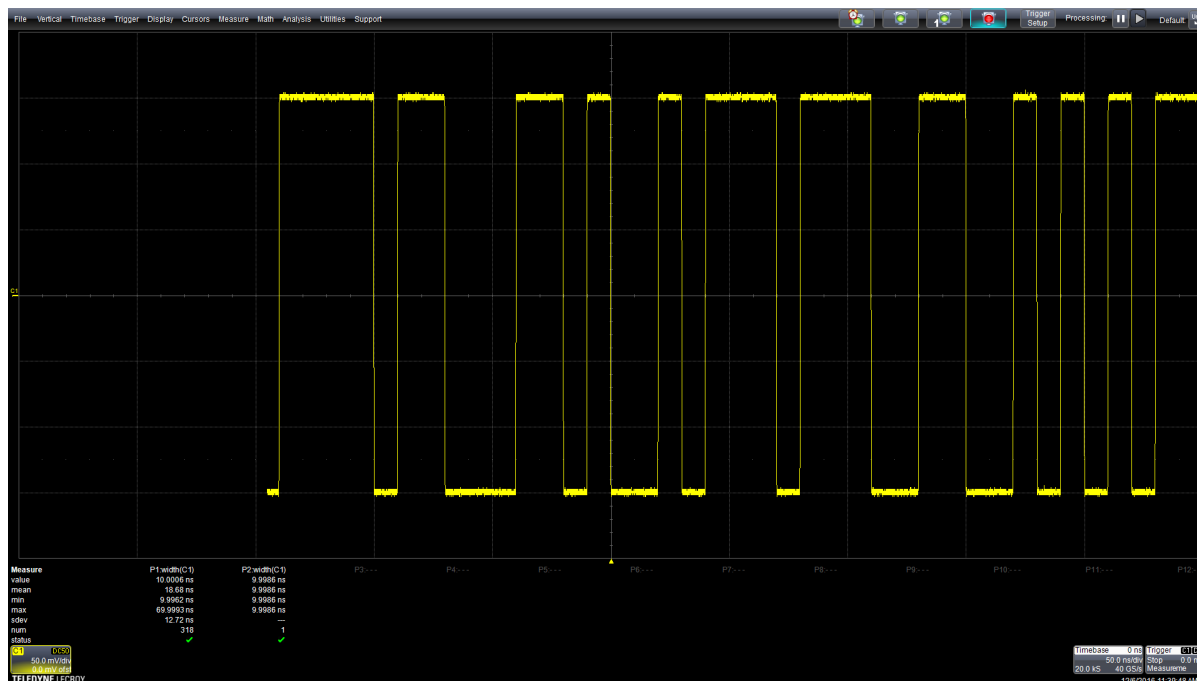
The width parameter is used to determine the mean width of the clock signal, which is 48  $\mu$ s in this case. You can use that value as the basis of an exclusion trigger. The width trigger was used with a condition that the width is outside a range of  $\pm 800$  ps from the nominal value of 48 ns so that only pulses differing from the nominal by at least 800 ps will trigger the oscilloscope.

### Post-acquisition triggers

Many oscilloscopes offer special triggers that operate after an acquisition, these include digital or software assisted triggers, zone triggers, and measurement triggers. This type of trigger acquires a trace, using an auto trigger, and then after acquisition searches through the data to find the required trigger condition. If the trigger condition is found, then the trace display is shifted to place the trigger event at the oscilloscope trigger indicator.

### Measurement triggers

Measurement triggers let you trigger the oscilloscope based on the result of a measurement. You can use any of the oscilloscope's measurement parameters. Measurement conditions including "less than," "greater than," "inside a range," "outside a range," or "don't care" can be applied to trigger on specific measurement values. The oscilloscope first acquires the data and if the measurement condition is observed, the measurement location is shifted to the trigger indicator point. **Figure 5** shows an example of the measurement trigger based upon a width measurement.



**Figure 5** The measurement trigger scans an acquired waveform, measuring each instance of a measurement. When the a user-defined condition is found, the oscilloscope aligns that occurrence with the trigger point.

In this example, the trigger condition is for a positive pulse width of 10 ns. If the acquired waveform has a pulse of that width, the oscilloscope aligns the trigger point with the end of that pulse.

### Software assisted trigger

Software assisted trigger is used to find the trigger level crossing point closest to the hardware trigger point. It then adjusts the time offset of the waveform so that it is aligned with the specified trigger level and slope. The software trigger provides you with a time gate about the trigger point within which to search for the threshold crossing. It also lets you set the software trigger hysteresis manually.

### Multi-stage or conditional triggers

Multi-stage triggers involve two or more trigger sources. The events are set up exactly as are the basic triggers (edge, width, pattern, etc.) but one or more trigger events serves to arm the oscilloscope to trigger on the final trigger source.

The earliest multi-channel trigger is the qualified trigger, which uses two events. The qualifier arms the oscilloscope on the event A, then the trigger source triggers it on event B. In normal trigger mode, it automatically resets after event B. Event A can be an edge, state, logic pattern, or pattern state (a pattern that persists over a user-defined number of events or time). The options for the B event depend on the type of event A. If event A is a digital pattern or pattern state, then event B can be an edge only.

Qualified trigger is useful if you're troubleshooting an IC on a bus. You can look at the signals on the IC only when it is enabled. Arm the trigger on the chip select and then trigger on the desired bus signal.

Cascaded trigger is a more sophisticated trigger based on multiple events that arm the trigger on a single first ("A") event or a succession of multiple events (up to three) and then trigger the

oscilloscope on a specified condition. Hold off and reset capabilities are provided for each set of events for multiple layer qualification. **Figure 6** is a composite screen image showing a typical cascade trigger and the setups for each stage



**Figure 6** A composite screen image showing the setup of a three-stage cascade trigger. The oscilloscope will arm after C2 experiences a positive edge exceeding 0.5 V. The trigger will occur on the positive edge of C1 crossing 0 V with a rise time greater than 325 ps.

Referring to **Figure 6**, the oscilloscope trigger was armed by a positive edge on channel 2 exceeding 0.5 V (event A), followed after the 200 ns hold off by a positive edge on channel 1 exceeding 0 V (event B). After the dual-arming condition is met, the oscilloscope triggers on a rise time in excess of 325 ps (event C).

In **Figure 6**, the parameter P1 measures the rise time over multiple acquisitions across the entire capture window. P2 gates the rise time measurement to show only the values about the trigger point. The value of P2 is the rise time when the trigger occurs. The general range of all rise times is 300 ps to 344 ps. The rise-time measurement corresponding to the trigger was 326 ps.

The cascade trigger can use measurements, logic patterns, or smart trigger as events in the qualification chain for triggering. It is an extremely flexible triggering tool.

### Trigger bandwidth

The oscilloscope's signal path and trigger path are generally different. This results in the edge trigger bandwidth being different (usually lower) from the bandwidth of the signal path. Smart trigger bandwidth is generally significantly lower than the edge trigger bandwidth. A check of the manufacturer's data sheet should reveal the trigger bandwidth for either trigger mode.

### Conclusion

Modern DSOs offer a broad range of trigger types and capabilities. From simple edge triggers to more sophisticated smart and augmented triggers. Knowledge of the characteristics and applications of these triggers guarantees that you capture the signals you need the first time, speeding measurement results and improving test throughput.

*[Arthur Pini](#) has over 50 years' experience in electronics test and measurement.*

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