

Oscilloscope Triggering

Continuous capture is the preferred operational mode for the oscilloscope, because this mode permits the immediate display of changes in the signal. With continuous capture, triggering becomes important. Without proper triggering, a stable signal display cannot happen. This document only deals with the continuous-capture mode and triggering. (When an oscilloscope is in stopped mode, the stability of a signal display is not an issue.)

An oscilloscope in continuous-capture mode is like a movie, consisting of a rapid sequence of still frames. For an oscilloscope, each frame is a snapshot of the signal or signals as a function of time for a relatively short span of time. For example, if the time base is $10\ \mu\text{s}/\text{div}$, the short span of time depicted by one frame is $100\ \mu\text{s}$, since there are 10 time divisions in the oscilloscope display. In continuous-capture mode, each successive frame represents an update.

An oscilloscope is unlike a movie in the following important respect. In a movie, each frame is intentionally different from the last. If the change is incremental, yet significant, than a rapid sequence of such frames gives the illusion of motion. (This explains the old-fashioned term for a movie: moving picture show.) For an oscilloscope, on the other hand, the goal is to present a stable display of a signal (as long as there is no change in the signal). In order for this to happen, each frame should look the same as the preceding frame (unless there has been a sudden change in the signal, such as a change of amplitude).

The problem with making each frame of an oscilloscope “movie” look the same may be illustrated by thinking about a sinusoidal signal. (The statements that follow, however, are valid for any periodic signal.) We consider two consecutive frames. In each frame, a curve is traced, and the curve is sinusoidal in shape with a common amplitude and common frequency. However, if the timing of a new frame is not selected carefully, the phase of the new curve will appear different from that of the previous curve. This failure to replicate the previous curve results in an unstable display. The purpose of triggering is to get each new frame to trace the same curve, having the same apparent phase, as the curve of the preceding frame. (We assume, of course, that the signal has not changed between frames. If the amplitude, for example, has changed, then the new frame *should* trace a different curve than that of the preceding frame.)

Triggering Criteria

Triggering is accomplished by “pinning down” one point on the curve in each frame. The point at which the pinning happens is called the trigger point. Three parameters are used to define the triggering criteria:

1. the pre-triggering percentage,
2. the trigger level, and
3. the slope.

The pre-triggering percentage identifies the imaginary vertical line on which the trigger point lies. The default value is a pre-triggering percentage of 50%. This default value corresponds to a vertical line that is exactly half way from the left edge of the display area to the right edge of the display area. With a pre-triggering of 50%, exactly one-half of the displayed curve lies to the left of the trigger point. This default value is appropriate for most situations, so you won't need to change it often.

The trigger level is the voltage of the trigger point. If the signal display is to be stable, the trigger level must remain within the excursion range of the signal. Otherwise we are asking for the impossible: to trigger at a level never reached by the signal.

The pre-triggering percentage and the trigger level together identify the trigger point. The pre-triggering percentage is essentially the x coordinate, and the trigger level is the y coordinate of the trigger point.

The third parameter, the slope, is a descriptor, not a number. This descriptor has one of two values: *positive slope* or *negative slope*. If a positive slope is specified, it means that the curve must have a positive slope while passing through the trigger point. Otherwise, the curve must have a negative slope while passing through the trigger point.

An example might help you visualize triggering. We consider the following situation. A sinusoid with an unchanging amplitude and unchanging frequency is connected to Channel A. The trigger source is Channel A. The pre-triggering percentage is the default value of 50%. The trigger level is 0 V. A positive slope is specified. Triggering is in *Auto* mode. How does this set of circumstances cause the curves on all frames to perfectly overlap each other? (Or, equivalently, why is the apparent phase unchanging from one frame to the next?) The trigger point is located, in this case, in the exact center of the display area. (It is on a vertical line that is horizontally centered in the display area, and the trigger level, having a value of 0 V, is centered on this vertical line.) The curve on each frame will pass through this trigger point with a positive slope. For a given amplitude and frequency, there is only one sinusoidal curve that satisfies the triggering criteria. Therefore, the triggering criteria determine the apparent phase of each sinusoidal curve. So, with matching phases, amplitudes, and frequencies, the curves of all frames overlap exactly. As the "movie" passes from one frame to the next, the display remains unchanged.

Trigger Source

In a given oscilloscope display, there is only one trigger source. In other words, triggering is done on only one signal, even though a second signal might be present in the display. Figure 1 shows an example oscilloscope display containing two signals, where the signal on Channel A is the trigger source. A marker shows the trigger point. In this case, we have asked for 50% pre-triggering, a trigger level of 0 V, and a positive slope. So the Channel-A sinusoid passes with positive slope through a trigger point located in the exact center of the display. The Channel-B

sinusoid does *not* pass through the trigger point. Triggering determines the time window for each frame. Within each frame, the phase relationship between the Channel-A and Channel-B sinusoids is preserved.

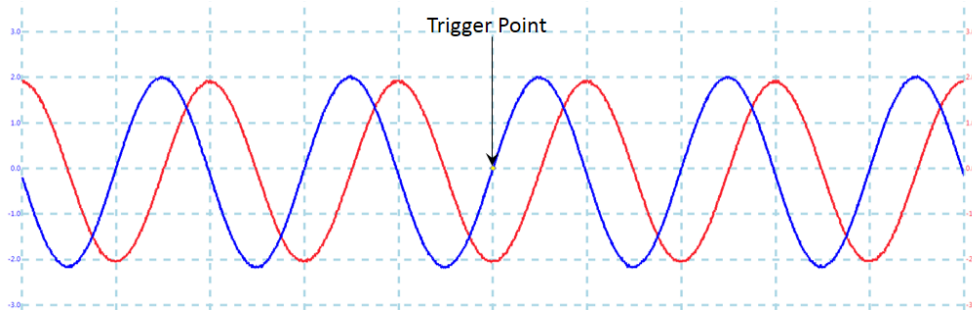


Figure 1: The Channel-A signal is the trigger source in this display.

The signal on Channel B can also serve as the trigger source. This option is selected using the PicoScope's Trigger Toolbar.

It is also possible to use an external trigger source. The signal that will serve as the external trigger source is connected to the *E* input port of the PC-Based Instrument Inputs panel, and the PicoScope is configured for the trigger source *Ext*. When that is done, the triggering criteria are applied to the signal serving as the external trigger source. In such a case, the Channel-A and Channel-B signals will not, in general, pass through the trigger point. The trigger point is not even marked on the display. The triggering criteria applied to the external signal determine the time window used for each frame.

Display Stability

Even when the signal serving as the trigger source is stable on the display, a second signal on the display might not be stable. Also, when an external trigger source is used, the displayed signals might not be stable. Here we consider what it takes to make sure all signals on the display are stable.

The display of a signal can be stabilized if:

1. the displayed signal is coherently related to the trigger-source signal, and
2. the frequency of the displayed signal is a whole-number multiple of the frequency of the trigger-source signal.

The first condition above means that the displayed signal and the trigger-source signal must be derived from a common oscillator. All signals (sinusoids and TTL signals) provided by the Master Signals panel are coherently related; they are all synthesized from one high-quality crystal oscillator inside the TIMS instrument.

Example 1. A sinusoid of frequency $(100/48)$ kHz is on Channel A. (This sinusoid is labeled “2 kHz” on the Master Signals panel. That label is an approximation. This sinusoid is generated within the TIMS instrument by dividing the frequency of a 100-kHz sinusoid by 48.) A 100-kHz sinusoid from the Master Signals panel is on Channel B. If the trigger source is Channel A, the display will be stable for both signals (assuming the triggering criteria are met). This is because the Channel-B signal frequency is a whole-number multiple (48) of the trigger-source signal frequency. If the trigger source is Channel B, the display can be made stable for the 100-kHz sinusoid, but it will not be stable for the $(100/48)$ -kHz sinusoid.

Example 2. A 100-kHz sinusoid from the Master Signals panel is on Channel A. An external trigger source is used; it is a $(100/12)$ -kHz TTL signal. (This TTL signal is labeled “8.3 kHz” on the Master Signals panel. That label is an approximation. This TTL signal is generated within the TIMS instrument by dividing the frequency of a 100-kHz TTL signal by 12.) The display will be stable for the Channel-A signal (assuming the triggering criteria are met). This is because the Channel-A signal frequency is a whole-number multiple (12) of the trigger-source signal frequency. It should be noted that the trigger level must be greater than 0 V and less than 5 V when the trigger source is a TTL signal. It is recommended that you use a trigger level of 2 V for a TTL trigger source.

Example 3. A sinusoid from the Audio Oscillator module is connected to Channel A. The frequency of this oscillator is adjusted to approximately 1 kHz. A 100-kHz sinusoid from the Master Signals panel is connected to Channel B. The trigger source is Channel A. If the triggering criteria are met, the display will show the 1-kHz sinusoid as stable. But the Channel-B sinusoid will not appear stable on the display because that sinusoid is not coherently related to the sinusoid from the Audio Oscillator.

Example 4. Two sinusoids from the Master Signals panel are added together: the $(100/48)$ -kHz (“2 kHz”) sinusoid and a 100-kHz sinusoid. This composite (sum) signal is connected to Channel A. The $(100/12)$ -kHz (“8.3 kHz”) TTL signal is used as the external trigger source. It is true that 100 kHz is a whole-number multiple of $(100/12)$ kHz, but the composite signal cannot be stabilized because the other component, the $(100/48)$ -kHz component, of the composite signal is *not* a whole-number multiple of $(100/12)$ kHz. If instead we use a $(100/48)$ -kHz signal as the external trigger source, the composite signal can be stabilized. On the TIMS instrument it generally works better to have a TTL signal as the external trigger source. So we will want to use a $(100/48)$ -kHz TTL signal as the external trigger source in this case.