View noisy signals with a stable oscilloscope trigger

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Noise on a signal creates a triggering challenge for test equipment, especially oscilloscopes. Because the instrument itself also contributes noise, small signals in the millivolt range need proper instrument settings prevent noise from overwhelming the signal of interest. Even with larger-amplitude signals, noise can create a condition where a stable trigger is difficult to achieve.

Oscilloscope have built-in features to help deal with the noise. These features can sometimes be buried in menus, or not well known by infrequent oscilloscope users.

You should distinguish between simply suppressing and/or dealing with the displayed noise, and actually delivering a less noisy signal to the trigger circuit. Only the latter will create a stable trigger in these environments. Because oscilloscopes often route a small portion of the incoming electrical energy to a separate analog trigger circuit, any noise suppression techniques need to occur on the incoming signal, not the ADC processed or displayed signals. By triggering on post-ADC data, additional techniques for creating a stable trigger in noise become possible.

Suppressing noise

Common techniques for dealing with noise utilize averaging and/or using High Resolution mode. Averaging, which works on repetitive data only, is effective at combining data points from multiple acquisitions to reduce the displayed noise. Because this is a displayed data technique, it won't suppress noise to the trigger circuit, and thus won't create a stable trigger. Averaging won't work on a single-shot event.

Many oscilloscopes have a high-resolution mode that can be useful for averaging out noise even on a single-shot capture. This method takes advantage of the fact that many signals don't require the oscilloscope's full sample rate. If, for example, you look at a 10-MHz signal with a 1-GHz oscilloscope sampling at 5Gsamples/s, you're acquiring 500 samples for each signal period. Most oscilloscope vendors recommend 5-10 samples per period for adequate signal reconstruction, so this is about 50X more than needed.

High Resolution mode utilizes these extra samples within a trace to average them into a less noisy signal reconstruction. Because it is done post-ADC on the incoming signal, it can suppress noise. Again, this is after the ADC, so therefore not delivered to the trigger circuitry, and it won't create a stable trigger on the oscilloscope. An additional consideration is that it can only be used on lower speed signals, so effectively it will limit the bandwidth of signal the oscilloscope can view.

Create a stable trigger

No one technique will work across the board for gaining a stable trigger. Often the task of obtaining a stable trigger is a trial-and-error process. Three techniques below can be tried to see if the trigger
stabilizes the display. Usually one of these three will achieve the desired result. The signal we will use as a test case (Figure 1) is the simulation of an output of a switch-mode power supply ripple. The output of switched mode power supplies carry high-frequency noise and can be difficult to trigger. That's because the signal we want to measure or view is a small ripple on top of a DC offset signal. This ripple is often small (mV) and in the presence of high-frequency noise and much larger noise generated by the switched-mode supply. Simply viewing the ripple isn't possible due to the lack of a stable trigger.

![Image of a simulated power supply output ripple](image)

**Figure 1. Raw Simulated Power Supply Output Ripple contains noise.**

**Hardware low-pass filters**

**Using the hardware Filter**

Techniques that begin to create a potentially stable trigger include using hardware low-pass filters supplied on most oscilloscopes. These bandwidth filters are often at defined points—most typically 20 MHz and/or 200 MHz, limiting the bandwidth almost immediately after the incoming signal enters the channel path. Although the bandwidth is limited, the signal is filtered before the trigger system.

Depending on your signal and the frequency of your noise, filters can be an effective method for creating a stable trigger. Figure 2 shows the effects of a 20-MHz filter. Much of high-frequency noise is reduced, but we still haven't achieved a stable trigger because there's still noise present and the ripple is far below the filter's cutoff frequency. Because this filter didn't work, we know that the 200-MHz filter also won't. This means we should move on to technique #2. (Typically, the use of a
20-MHz filter on a higher-speed signal will filter out too much signal content and create a poorly reconstructed sinusoidal-looking waveform.)

**Figure 2.** With a 20-MHz low-pass filter, there's still too much noise to get a stable trigger.

**Hysteresis/Noise reject**

Oscilloscopes commonly come with a noise-reject feature on the trigger input. Also called a trigger-hysteresis band, the filter works by rejecting signal movements within a certain tolerance band of the trigger level (**Figure 3**). The noise-reject option is often located within an oscilloscope’s trigger menu.
Figure 3. A hysteresis filter requires that a signal cross through it in both directions to be considered noise.

Trigger hysteresis can be an effective way to "ignore" the noise going into the trigger circuit, thus allowing a stable trigger. The hysteresis band must be large enough to reject the noise carried on your signal. This can also create a trial-and-error case to understand if the trigger hysteresis supplied by the noise reject is enough for your signal. By understanding your equipment and the signal in question, you can make trigger hysteresis work.

Some oscilloscopes have a variable trigger-hysteresis band, which lets you "tune" the hysteresis band to match the level of noise on the signal. This can be particularly useful because it will reject high-frequency noise, but still allow for a higher frequency signal to be viewed amongst noise. An example of our power-supply ripple with a larger hysteresis band enabled by this oscilloscope having a variable trigger hysteresis function is used to capture a stable trigger (Figure 4). The hysteresis band is overlaid on the signal and we can adjust it to just the right amount. With this stable trigger, we can now perform measurements. Furthermore, we also see the original noise on the signal so that we know just how much noise is present.

Figure 4. A variable hysteresis band enables a stable Trigger on the ripple signal.

Variable DSP and digital triggers

Variable DSP and digital triggers

While post-processed DSP (digital signal processing) filters are fairly common on oscilloscopes today, the fact that they are processed on acquisition data stored in the memory, after the ADC, prevents them from being used to create a stable trigger. Unlike low-pass hardware filters, a
traditional analog trigger circuit is viewing a copy of the analog data that was picked off before it is digitized. To assist with things like stable triggering, some oscilloscopes offer a digital triggering system.

A digital triggering system performs the trigger evaluation on the digitized data after the ADC. This is same exact data that is used by the memory system. By putting the DSP filter ahead of the trigger circuit, we can apply the same filtering to both the trigger system, and to the displayed acquisition data. Although significantly different in implementation, it functions similar to the hardware filters described above with two useful exceptions.

The first exception is that we have more filter steps to use. By having a variable set of low-pass filter cutoff values, we can intentionally reject just the right amount of noise in our signal. We aren't just beholden to the 20 MHz and 200 MHz values in a hardware filter. As Figure 5 demonstrates, we can filter down to 1 MHz, which removes all of the high-frequency noise on the ripple signal, but allows for a stable trigger and clean signal.

![Figure 5. A 1-MHz filter produces a stable trigger on a power-supply ripple signal.](image)

The second useful difference between a DSP filter used in conjunction with a digital trigger and a hardware filter involves choice. A hardware front-end filter simply rejects all signal content to the oscilloscope above the cutoff frequency, effectively making it a 20 MHz or 200 MHz oscilloscope. The DSP filter is simply operating on the data, so the oscilloscope retains full frequency. If used in a flexible architecture that allows selectively applying the DSP filter independently to the trigger and/or the acquisition/display system, we can have the best of both worlds. Figure 5 was rejecting all frequencies above 1 MHz to both the triggering system and the acquisition/display system. Choosing to have the trigger see the filtered signal, but not the acquisition/display produces a stable trigger.

The original signal still includes all of the inherent noise (Figure 6). This ends up with an identical picture for this signal as the variable hysteresis, but utilizing a different technique.
Figure 6. A DSO filter produces stable Trigger because it's applied to the trigger only. The original signal is still displayed.

An additional potential benefit of utilizing a variable DSP Filter and digital trigger system can be for debug or design prototyping if a signal was unexpectedly noisy. By alternating between the filtered and non-filtered acquisition/display, you could use variable DSP steps to determine the right amount of filtering needed to clear up a noisy signal path. This might speed up the re-design efforts for the next phase of your project.

A variety of techniques can be deployed on signals that contain noise or are operating in a noisy environment. Ensuring a stable trigger in noise isn’t a one size fits all technique, but utilizing a methodology of different techniques and some more advanced features on an oscilloscope can wrestle down the problem.

Utilizing the same example for the three different techniques, they may seem interchangeable. But they operate in different ways on the signal so each has benefits and tradeoffs.

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