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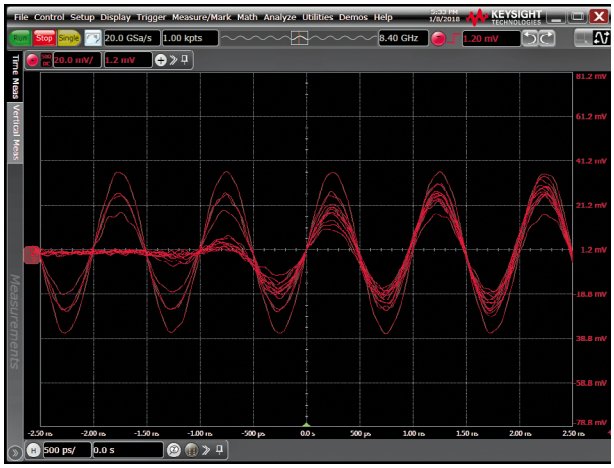
Oscilloscope Trigger Techniques for the RF Engineer

This article discusses several triggering techniques that can be utilized to effectively analyze RF signals with an oscilloscope.

Modern real-time oscilloscopes are so powerful and feature-rich that for many engineers, the *AutoScale* button is all they ever need to learn. However, this is not usually the case for RF engineers. Bursty RF signals can be difficult to work with in the time domain, due in no small part to the difficulty many engineers have dialing in a stable trigger. In this article, we'll walk through several different strategies for oscilloscope triggering on RF signals and, by the end, you'll wonder why you haven't been using a scope more often!

1. Here we see a modulated RF signal displayed on a Keysight Infiniium S-Series oscilloscope with a default configuration. Unless you're only concerned with the vertical parameters of your signal, this isn't going to be very helpful.



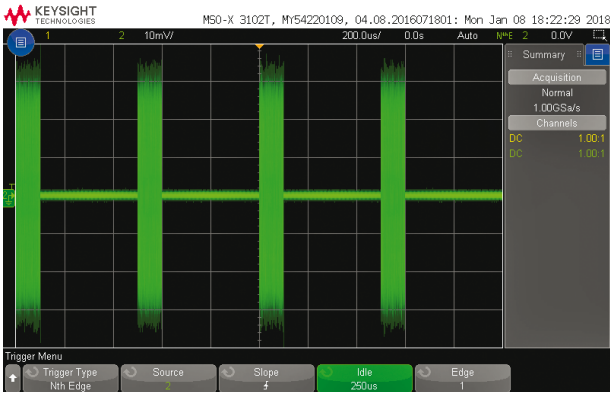
2. Unsatisfied with the default setup from Fig. 1, we tried the *AutoScale* button, and this is what we got. Still not very useful.

WHAT IS TRIGGERING?

It's common for modern real-time scopes to have model numbers that start with "DSO," short for "digital storage oscilloscope." The term "storage" is important; modern scopes operate kind of like an old tape recorder. Just like an audio tape recorder that picks up sound waves with a microphone, stores them on a magnetic tape, and then plays them back from that tape, a modern real-time scope picks up analog electrical signals, digitizes them, stores them to memory and then "plays them back" (aka, displays them onscreen for you to view and measure).

The oscilloscope's trigger system causes the acquire/store/playback process to start. In the tape player analogy, the trigger system is what pushes the "record" button. When viewing a stable, "live" (continuously updating) waveform on a real-time scope, what you're seeing is many repeated record/playback cycles, one after the other. Each of these cycles begins with a trigger event. If the signal activity around the trigger event is consistent from acquisition to acquisition, the repeated playback cycles fall on top of each other and form a clear picture on the scope screen; this is often referred to as a "stable" trigger.

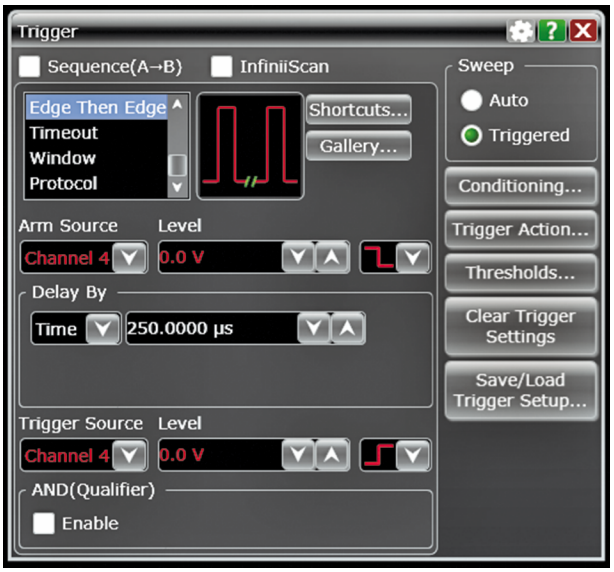
On the other hand, if the activity near the trigger event is different from trigger to trigger, the consecutive playback im-



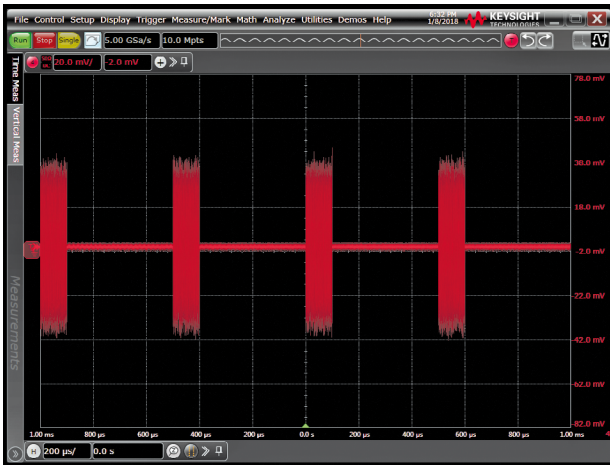
3. Shown is the same signal from Figs. 1 and 2 displayed on a Keysight InfiniiVision MSO-X 3000 Series oscilloscope using *Nth Edge Burst* trigger mode, which allows you to specify an idle time and edge count. Every signal transition resets the idle time counter, and if the counter finishes, the scope will trigger on the nth edge event afterwards.

ages of your signal, layered on top of each other, tend to look like garbage. This is the fundamental problem we aim to solve when dealing with bursty RF signals; we need to qualify the trigger event such that it only occurs when the signal activity near the trigger (the scope screen) is relatively consistent.

So, what is a trigger event? It's whatever you tell the scope you want it to be! Although *Edge* trigger mode is most commonly used, most modern scopes have an arsenal of different trigger modes based on signal transitions, timing, counting, polarity shifts, and more. We can use these to our advantage when trying to configure a stable trigger for an RF signal. Let's look at a few different strategies.



5. Here we see the Trigger setup dialog for *Edge-Then-Edge* mode on a Keysight Infiniium S-Series scope.



4. Here we see the same signal again on a Keysight Infiniium S-Series scope. This time, we're using *Edge-Then-Edge* trigger mode. Like the Burst mode described in Fig. 3, *Edge-Then-Edge* allows you to specify an idle time (called "Delay Time" here) and a trigger edge.

RF/BURST SPECIALTY TRIGGER MODES

Some modern oscilloscopes offer trigger modes specifically designed for RF applications. Often referred to as "Burst" mode, or something similar, these modes will use a combination of edge-counting and timing to qualify trigger events. Typically, they will allow you to specify an arm event, an idle period or another time parameter, and then a trigger event. For the trigger to fire and the scope to acquire data, each of the configured events must be fulfilled in the order specified. Specialty modes like this are almost always the best way to go when trying to define a stable trigger event for bursty data.

GENERIC TIME-QUALIFIED TRIGGER MODES

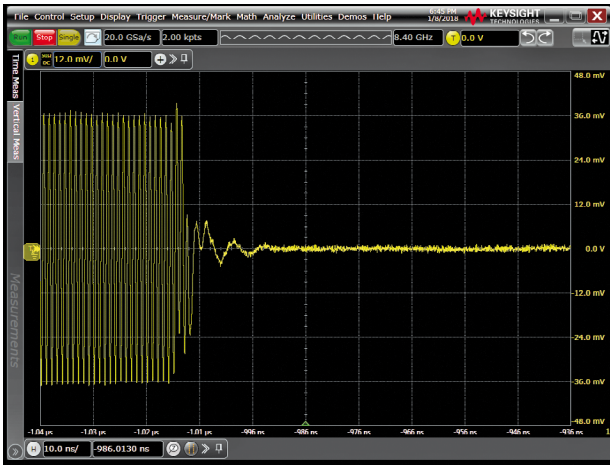
Unfortunately, RF-specific trigger modes are somewhat uncommon, especially on older and less-fully-featured (cheaper) scopes. Fear not! Most scopes still have a slew of generic timed trigger modes that we can use to our advantage. They'll have names like *Timeout* and *Pulse Width*, but when used carefully, they can work well with RF signals.

DIFFERENTIATING BURSTS WITH AMPLITUDE

So far the techniques we've discussed have all focused on generating stable trigger events using idle time (*Burst*, *Edge-Then-Edge*) or carrier period (*Timeout*). But what if your signal includes bursts of different amplitudes and you're interested in having a stable trigger on one of them? By adjusting the oscilloscope channel trigger threshold appropriately, you can effectively single out bursts that have either higher amplitude or greater dc offset than others; simply adjust the threshold outside of the vertical range of the other bursts and use the time-based techniques described above in conjunction.

TRIGGER HOLDOFF

While almost all scopes available today have advanced trig-

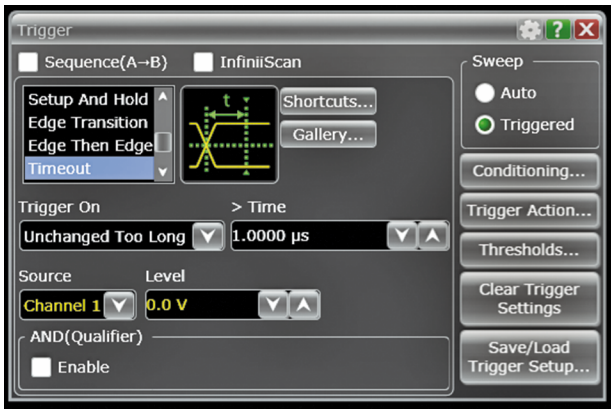


6. Once again we see a modulated RF signal on a Keysight Infiniium S-Series scope. This time we're using Timeout trigger mode set to "Unchanged Too Long." This means the scope starts a timer and resets it every time there's any signal transition through the trigger threshold (trigger level). When the timer finally completes, the scope triggers.

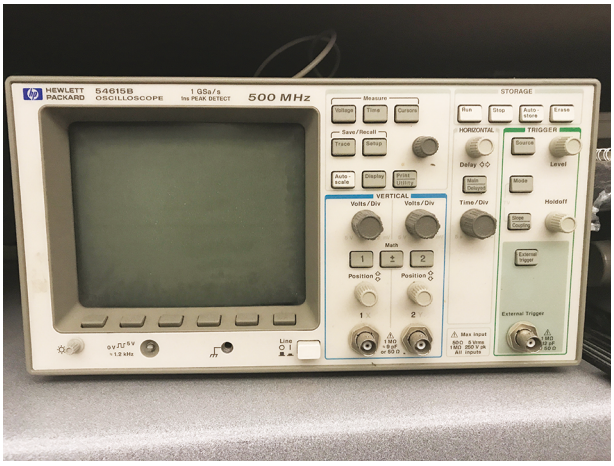
ger modes, if your scope is older, you may be stuck with plain old *Edge* mode only. Don't worry—we're not out of tricks yet. All real-time scope trigger systems (or at least, those the author has ever seen or heard of) allow the user to adjust the holdoff time. Holdoff is the amount of time the trigger system waits after a trigger event before arming the system again (i.e., it represents the minimum possible time between triggers).

By configuring a sufficiently large holdoff time, you can sync the trigger up with the repetition of bursts in your signal (in a rough sense). Using holdoff time to stabilize the trigger won't yield results such as those that can be achieved with advanced trigger modes, and it will likely take more tweaking to get right. But if the only scope you've got is older than you are—and you can't convince your boss to buy you a new one—it may be your only choice.

Trigger holdoff time adjustment isn't just for old boxes. It can also come in handy on even the newest and fanciest scopes. Regardless of how a scope implements the trigger, either with analog circuitry as with most scopes, or with digitized acquisition data as with a few recent models, the trigger system is a totally separate apparatus from the acquisition system in the scope. It has different performance characteristics, including frequency response and bandwidth.



7. Shown is the trigger setup dialog for Timeout mode on a Keysight Infiniium S-Series scope.



8. This Hewlett Packard 54615B oscilloscope is more than 20 years old, and even it allows the user to adjust trigger holdoff time via the "Holdoff" knob on the far-right side of the instrument.

It is typical with high-performance scopes for the trigger system to have significantly lower bandwidth than the acquisition system. Even if your scope has sufficient bandwidth to acquire the signal you're working with, it may not be able to trigger on it very well. In this case, carefully adjusting threshold and holdoff time may be able to coax the scope into giving you a stable trigger when advanced modes won't work.

That wraps up our discussion on oscilloscope trigger techniques for RF engineers. May you never rely on the *AutoScale* button again!