RAKO STUDIOS

Digital oscilloscope guidelines

A digital 'scope is a unique beast with some strange behaviors. Understand them or suffer.

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There are many caveats about digital storage oscilloscopes (DSOs). The Nyquist theorem relates the sampling rate to the highest frequency component, not the highest frequency of a signal. A frequency component is one of the sinusoids summed together to represent a signal in Fourier analysis. An impulse function has infinite frequency components so nothing could digitize it perfectly. However, one must recall the parable of the mathematician, the engineer and he naked lady. If you repetitively halve your distance to her you will never reach her...but you can get close enough for all practical purposes. DSO's are the same. As to sampling a signal at its zero crossings, well that's why twice the highest component is a limit, approached but not achieved. You could just as well be sampling at the absolute maxima. This would relate all the information in the frequency component since it is sinusoidal by definition and its amplitude is given by the maxima. That's why you hang a low pass filter on the DAC output. It turns the connect-the-dots sawtooth back into a sinusoid. If the system is fast enough the parasitics will do this for you at no extra charge. Here are some examples of the misuse of digital 'scopes I have seen recently:

Watch that time base

We set up a temperature test to qualify an ASIC part for a military project. We programmed the part (an Altera EPM5032) as two sixteen-bit counter chains.We told the tech to measure the output frequency and the output rise and fall times at several points in the chain as the temperature was varied.

The results showed correct frequencies but wildly divergent switching times. Some of the times exceeded 300 microseconds. Nothing seemed to correlate.We knew the first counter in the chain could not be working at eight Mhz if the rise times were really that slow.

We asked the tech to show us his procedure. When measuring a slow signal he would verify the frequency with a single acquisitions at 500 milliseconds per division. Then he would turn up the time base to look at the rising edge without reacquiring the signal.

A slow time base setting lowers the sampling rate so that the longer time can be held in the fixed storage memory. If you sample once every 300 microseconds I can assure you that any digital signal will show a 300 micro-second rise time. Remember, the scope connects the dots for you on the display.

Lesson: Think of the time base as a sample rate too.

Use the cal pin

I was told an asic chip had stopped outputting a pulse train when the transmit button was being pressed. I verified the chip and gave it back. The same problem was reported. I programmed a new chip. Same problem. I looked at the schematic and recommended grounding the unused inputs. I programmed another new chip. Same problem. I went to the bench and watched the signal (or lack of it) being acquired. We were looking for a 16 micro-second one Mhz pulse train. The scope was set on "auto", 10 millivolts per division and the trigger level was at five volts.

You might have seen a little flicker on an analog scope, but not on a DSO. I set the mode to normal, time base to one microsecond per division and trigger level to 200 millivolts indicated/two volts true (yeah, we had the wrong brand of scope probes so the times 10 attenuation factor was not being compensated for on the screen displays). The voodoo magic programmable chip that everybody was sure was broken had been working all along.

Lesson: Use that handy dandy cal pin on the front of the scope to verify the probes. Set the time base close to the expected signal. Know the difference between auto and normal modes. Set the trigger level (which is displayed for you on the screen) to an appropriate value.

Beware of under-sampling

Another engineer called me over to the really expensive DSO with four channels and FFT option ect. ect. The screen showed a noisy sinusoid. His tech had called him to show him the signal. He asked my opinion. I said it looked like a raspy sine wave with a little frequency modulation thrown in. He asked me the what the signals period was. I looked at the screen annunciators, counted a few divisions and said "about 300milliseconds". He smiled, grabbed the timebase knob and rapped it up to 10 microseconds per division. A beautiful clean sinusoid appeared.

Lesson: If you severely undersample a signal all kinds of interesting things can appear on the screen.

Normal mode can be useful

A tech was sampling a signal train output caused by a push-button switch. He had the scope in single shot mode. Prior to pressing the push-button he would hit the "acquire" button on the scope. I watched this routine repeated about 10 times. Then, despite the President's Council on Physical Fitness wanting us to improve our upper body strength, I showed him how setting the scope to the "normal" mode would obviate the need of pressing the "acquire" button.

Lesson: Know the difference between "Normal," "Auto," and "Single shot" modes. this applies to analog scopes as well.

Beware the "save" mode

A no-signal condition observed was caused by the scope having been put into a "save" mode. Once you hit "save" the scope won't show anything new until you hit "acquire".

Lesson: Remember that cal pin?

Make sure you got a trigger

A tech reported the same signal at two points in a circuit (scope in "norm"). The first point was TTL levels. The second point was ECL levels. In fact the scope hadn't triggered a second time and he was looking at the first acquisition.

Lesson: Set the trigger levels appropriately. Watch the scope when you press the start button or whatever is generating the signal being acquired. If the trigger light doesn't flash and the screen change at least a little then you're still looking at old news.

Be patient with slow signals

We were measuring a very slow signal. This is where DSO's really shine. I set the time base to five seconds per division. The tech clipped the probe on the appropriate pin. I set the trigger level. After 15 seconds the tech exclaimed that the pin was dead. He started to remove the probe. I told him to sit back and relax.

By then the trigger light had flashed. Since I had set the trigger position on 1/8 into the acquisition I knew we still had to traverse 7/8 times 20 divisions at five seconds each to acquire the signal. In due time the screen refreshed and we saw what we expected.

Lesson: Slow signals take a long time to acquire. You can set the scope on "auto" and use the horizontal position control to look at the right-hand side of the display. This shows the most recent acquisitions. Use this level and gradient to set the trigger level and trigger slope. Then kick it into "norm". This will at least reduce the time to achieve trigger.

Fast analog scope might be better

An engineer was trying to troubleshoot a cascaded MOSFET string that had to switch from +200 to -200 volts in 60 nanoseconds. There were 3 high-side FETs and three low-side FETs in series to increase the voltage handling ability of the small high speed switching FETs.

The FETs were "going intrinsic" which is to say they were essentially melting. The engineer had a decent older (in 1989) Tek digital scope looking at the gate waveform. It looked clean and snappy on the screen. But I knew this scope to have a sampling rate of 100Mhz or so. This is too slow to pick up one-time transients in a signal switching in 60 nanoseconds.

I looked around and found an old 400 MHz analog Tek scope. I wheeled it to his bench and suggested he use it instead of the digital scope.

A few minutes later he came up to me and said "Boy, I can't believe it, the gate was oscillating just as it went through the turn-on part of the FET. No wonder the FETs were cooking. Its a problem in the ECL driver circuit. I've already fixed it."

Lesson: You can't fix it if you can't see it. 400 MHz analog bandwidth is a **lot** better than 400 MSamples in a digital scope. Don't trade those analog units in just yet.

Summary

Giving a digital storage scope to some people is like giving an UZI to a Cub Scout. They can do a lot of damage. However, not having a DSO can be like making an Israeli commando use a sling shot. I prefer to train people as to the advantages and limitations of digital scopes. Then the DSO can be included in the arsenal against terrorizing electrical behavior. It might not be a bad idea to train Cub Scouts in automatic weapons too

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