Troubleshooting high speed modern electronic components

With the first handheld oscilloscope to achieve 500 MHz at a 5 GS/s

Application Note

Testing Functions
Case Study

Tool: Fluke 190-502 500 MHz ScopeMeter® Portable Oscilloscope

Operator: Chief engineer and business unit manager Leigh Copp, Linamar Advanced Systems Group

Measurements: Diagnose problems with the electronic controls on large inverters in induction heat treating systems

Electronics technicians and engineers face a number of challenges when troubleshooting high speed modern electronic components. They constantly work around high voltage and current. Many of the plants they work in are extremely dusty and humid, which creates a hostile environment for sensitive troubleshooting instruments like bench oscilloscopes. Sometimes they have to climb a ladder on the side of a machine, which limits the weight and size of the equipment they carry.

Still, technicians often need wide bandwidth to deliver a high degree of accuracy and detail, and an oscilloscope with a fast signal edge response speed to measure signal rise times in the tens of nanoseconds. We recently heard from a customer, Leigh Copp, Chief Engineer and Business Unit Manager for the Linamar Advanced Systems Group, who had been addressing those needs with the 200 MHz Fluke 190-204 ScopeMeter® Test Tool for lower frequency applications and then turning to a bench oscilloscope for applications that required higher frequency and/or faster rise times.

Catching nanosecond events

Among his many projects, Copp periodically gets calls to diagnose problems with the electronic controls on large inverters in induction heat treating systems. Those inverters have many parallel or series devices, including Insulated Gate Bipolar Transistors (IGBTs) and metal–oxide–semiconductor field-effect transistors (MOSFETs) that operate at very high frequencies and run in short cycles.

"In power electronics I want to see cause and effect," says Copp. "If the inverter fails, faults, trips, or blows up a device, I want to be able to see in the millisecond range what the current and voltage were doing at the exact instant the event occurred."

The output resonant frequency on inverter controls is relatively high, and these controls operate on very high power, so troubleshooters have to watch the switching overlap between opposing power semiconductor devices. Accurate rise time readings, identifying parasitic oscillations, and understanding what those mean is crucial to pinpointing the problem.

The digital pulses on some of those applications produce rise times in the tens of nanoseconds and require a scope that has a rise time in the low nanosecond range to accurately view those wave forms. Those applications also require a fast sampling rate and enough bandwidth to capture the rise time in a single shot. In the past that typically meant bringing out a bench scope that had at least 500 MHz bandwidth.

Streamlining differential measurements

It's not surprising that when Copp needed more than 200 MHz bandwidth, he would pull out a 500 MHz or 1.5 GHz bench scope and use differential probes. The obvious drawback was the fact that bench scopes are designed for the bench, so they aren't sealed against dust and moisture and they aren't exactly easy to lug around. All channels of most bench scopes are tied to a single ground, which makes it extremely difficult to safely take floating measurements.

To compensate for that, Copp used differential probes with the bench scope, but those probes had only 100 MHz bandwidth. "I have a 500 MHz scope but the differential probes are only 100 MHz, so I would only use the bench scope in that particular scenario for the additional record length," says Copp.

When Copp needed to take advantage of the higher bandwidth available with the bench scope to measure rise time, for example, he would use 250 or 500 MHz single-ended probes and put the Channel A probe on the positive test point and the Channel B probe on the negative test point and then set the scope on the Ch1 – Ch2 math function. The sum of Channel A minus Channel B provided the floating voltage. However, that process immediately reduced the four channel scope to a two channel scope. It also had the potential to reduce the accuracy of the readings due to noise picked up in each probe, which introduced an additional degree of uncertainty to the results.

When Copp learned that Fluke had a 500 MHz ScopeMeter—the 190-502 500 MHz—with a 5 GS/s sample rate, he saw it as potentially a much quicker and more convenient solution for accurately troubleshooting his induction heating inverters. So he put it to the test.

The first difference he saw was that ScopeMeter 190-502 has 500 MHz capabilities at the probe tip and two independent floating inputs, up to 1000V so it can take differential measurements in one shot. "Having a 5 GS/s sampling rate to nail it the first time is really important," says Copp. "And my two channel scope remains a two channel scope because I have an isolated ground on each channel. That means I can measure across two switching devices simultaneously and have 2.5 times more resolution than the 190-204."

Analyzing the need for 500 MHz

Copp uses the 500 MHz 190-502 ScopeMeter to troubleshoot some of his inverters that require the higher fidelity measurement of a 500 MHz scope. However, the need for high bandwidth wasn't entirely obvious. "The fastest inverter I have is running at 400 KHz, so some might say I only need a 10 MHz scope," says Copp. "That would be fine if I just want to see that the inverter is turning on and off and not see how it's turning on and off. We're switching a square wave; a perfect square wave is the infinite sum of odd harmonics of the base frequency. So if the inverter is running at 400 KHz there are harmonics well into the hundreds of MHz to make it a square wave. That's why you need wide bandwidth to capture these rapid switching transients."

The bandwidth also affects the rise time. Copp needs a scope with a rise time that is orders of magnitude faster than the rise time of the device under test. His inverters typically have rise times ranging from microseconds down to tens of nanoseconds so the 0.7 ns rise time of the ScopeMeter 190-502 meets that requirement as well.

Although Copp doesn't see the 190-502 completely replacing the need for bench scopes in the field, he does see its high resolution measurements, isolated ground safety features, and convenient form factor as major factors in reducing the frequency of having to drag out an expensive bench scope. He also sees the 190-502 as a real time saver in a couple of ways. First, he can carry the 190-502 in his tool bag, rather than have to drive back to the office for the bench scope. It is also much faster to set up than a bench scope and has its own built-in isolated ground on each channel for increased safety. And it is IP51 rated to be dust and drip proof, which makes it compatible with both the indoor and outdoor environments.

Why 500 MHz bandwidth matters

It's just common sense that the higher the oscilloscope bandwidth, the higher the resolution of the results. The question is: How important is that in the day-to-day troubleshooting of most electricians and engineers?

It depends on your applications. The wider the bandwidth and the faster the oscilloscope sample rate, the greater the accuracy and clarity of shape and amplitude of unknown waveform phenomena like transients, induced noise, and ringing or reflections. Those phenomena are showing up a lot more due to the increased use of high speed electronic components in today's medical imaging, avionics, communications, military, and audiovisual and security equipment.

At least the fifth harmonic of a signal

Of course a device doesn't have to have a maximum clock speed of several hundred megahertz (MHz) to require a scope with wide bandwidth. A common rule of thumb is that to correctly display at least the fifth harmonic component of a signal, you need a scope with a bandwidth of at least five times the maximum clock rate of the device under test. That means if your device runs at a maximum of 100 MHz, which most X-ray, MRI, ultrasound, avionic navigation and communications, and surveillance and monitoring equipment does, you need a 500 MHz scope to troubleshoot that device. Since most of that equipment has to be serviced in the field, a portable scope with 500 MHz capabilities is the only way to avoid the hassle of dragging an expensive and delicate bench scope to the location.

Fast edges

In addition, fast digital circuits, or inverter circuits that produce pulses with fast edges, contain an infinite spectrum of frequencies. To accurately capture and display these fast edges, you need a scope with a rise time that is less than one-fifth of the fastest rise time of the signal under test. The Fluke 190-502 ScopeMeter test tool with its 0.7 nano second rise time satisfies this requirement for a broad range of applications.

Practical application

So what does this mean in practical application? Figure 1 illustrates the difference between an oscilloscope with a fast sample rate and a bandwidth of five times the fundamental and one with four times the fundamental. This screen shot compares two pulses: one that includes the 5th harmonic component and one with up to the maximum frequency of only the fourth harmonic component . As you can see, there is a significant difference in the displayed shape.

Figure 2 illustrates an additional comparison of rise time and signal slew rate between a measurement that includes frequency components up to the fifth harmonic and one that includes components up to the fourth harmonic.

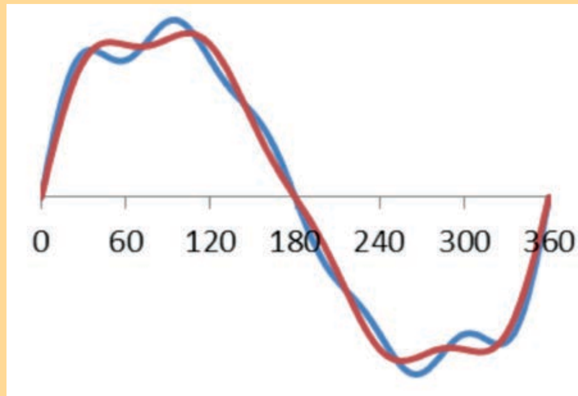

Figure 1. The blue trace includes frequency components of up to the fifth harmonic of the fundamental frequency. This illustrates the significant difference in shape and amplitude when compared to the red trace that includes only components up to the fourth harmonic.

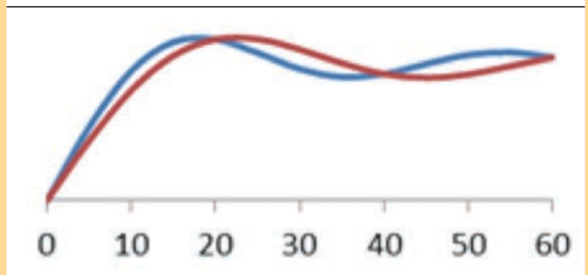

Figure 2. The blue trace includes frequency components of up to the fifth harmonic of the fundamental frequency, illustrating the significant difference in rise time and signal slew rate (dV/dt) when compared to the red trace that includes only components up to the fourth harmonic.)

So, with its 500 MHz bandwidth and fast sampling rate, the Fluke ScopeMeter™ 190-502 accurately captures and displays fast clock signals, including distortion-induced noise and spurious transients. As a result, it can make a significant difference in the speed and accuracy of troubleshooting high speed electronics components.

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