The MDO4000: Is It Truly The Scope Revolution?

by Steve Sandler, Picotest, Phoenix, Ariz.

On August 30, 2011, Tektronix unveiled the MDO4000 series oscilloscopes (MDO) with a built-in spectrum analyzer to much fanfare, including teaser advertisements and a webinar on the day of the release. The release was accompanied by some interesting application notes and the claim that this device was revolutionary.

Since the date of the release, I have been asked on more than one occasion, by colleagues and customers in the power electronics industry, if I believe the claim or think it is hype? If it is revolutionary, what makes it so? Other questions I have been asked include "Do I need one?" and "What would I use it for?" You might also wonder why ask *me* these questions? [1]

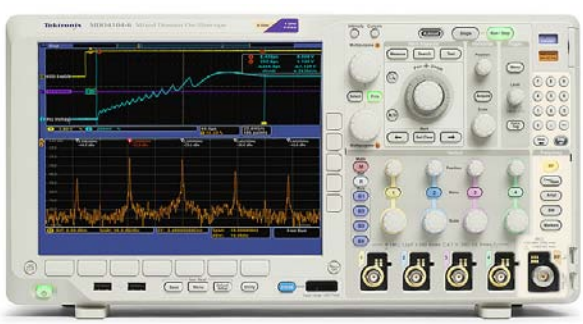
Since the last question is the easiest to address, I will start with that one. The most likely reason is that I frequently write about using test equipment, intended for an RF or high-performance instrument application, in a nontraditional role in the power electronics world. It is also assumed (correctly, I might add) that I have already checked it out and might even have one.

I do admit to being an equipment junkie and I also admit that I enjoy the challenge of figuring out how I might use some piece of test equipment for a purpose that is entirely different than the one it was designed for. The results of these challenges often end up as application notes or articles so that we can share this information with others that may find it useful.

In the coming year, I hope to write a lot more about equipment, as my experiences seem to indicate that many engineers are confused about the different offerings and how to select the proper test equipment. I also believe that the typical power engineer is underequipped.

But getting back to the main questions at hand: Is the MDO series revolutionary? And if it is, what makes it so?

It is revolutionary, in several ways. First, it combines two vastly different technologies in a synergistic relationship that offers something greater than the sum of its parts. The MDO series provides a high-speed mixed-signal oscilloscope (MSO), meaning that it provides a digital sampling oscilloscope as well as a logic analyzer plus a 6-GHz spectrum analyzer (SA). Certainly, the MSO is not revolutionary and there are many models to choose from. Most digital oscilloscopes offer impressive FFT capabilities so why include an SA?



Tektronix MDO4000 series oscilloscope with built-in spectrum analyzer.

The FFT function in an oscilloscope is an FFT of the displayed waveform, producing a single FFT which is tied to the analog channel. The SA produces many FFTs of the signal. The SA also has much greater sensitivity than an oscilloscope as well as a host of other features, such as automatic detection and labeling of up to 11 peaks and selectable measurement bandwidth (RBW).

The oscilloscope portion of the MDO and the SA portion of the MDO have separate hardware allowing both to operate simultaneously. An added benefit is that the oscilloscope and SA are time correlated, allowing the display of the SA response in specific time period within a time domain signal. Of course this also means that we can make use of the vast array of triggers that we have come to know and love.

The message that the MDO sends resonates with me, as it is a comforting validation of my own predictions. I have been known to say (possibly a bit too frequently and to anyone that will listen and some that won't) that the worlds of RF, instrumentation and power are converging.[2] As switching frequencies and switching speeds increase, power engineers increasingly find themselves dealing with challenges that are typically RF or instrumentation issues.

For example, the typical point-of-load converter (POL) today has MOSFET switching speeds of 2 ns to 3 ns and operates at switching frequencies greater than 2 MHz. This results in significant ripple and noise harmonics well into the gigahertz range. These frequencies will continue to increase in the future. Of course, the performance of our high-speed clocks, ADCs and LNAs are heavily dependent on the performance of our regulators, often requiring that we measure the regulator indirectly through the performance of the clock, ADC or LNA. It is often possible to improve the performance of our systems at no additional cost, by properly stabilizing our regulators.

One particularly interesting application for the MDO may be in the area of high-speed power distribution networks (PDNs). Companies that develop high-speed circuits, such as computer motherboards (Intel comes to mind) as well as the multitude of companies designing high-speed FPGA circuits (including oscilloscopes) are faced with the tremendous challenge of getting the power from the regulator to the load, without coupling noise into other circuits.[3]

When this distribution network fails to perform, it is often difficult to locate the noise source, which is generally synchronous with the POL switching edges. The frequency range of concern for a current day PDN extends to 6-GHz (a coincidence?) The MDO may prove to be a tremendous troubleshooting tool for these types of PDN issues as it can provide time-correlated spectrum data to 6 GHz.

Another possible application is wireless power, since it is generally based on resonant conversion and so has applications for the SA. Since the frequency is load dependent, any load and line transients are transformed to the frequency domain and the MDO can easily demodulate this signal in time correlation with the analog event. As one of the efficiency limitations of the wireless chargers is the losses in the coils, the harmonics in the coils might also provide some useful information.

There is also a potential application for the MDO in assessing the switching speed of MOSFETs well as the new GaN and SiC devices. We have learned to think of device rise and fall times as linear waveforms. However, the capacitances in these devices are quite non-linear and this fact is exploited by the device manufacturers to minimize switching loss, as opposed to minimizing switching speed. The spectral content of the edge may hold useful information, despite the fact that we have not yet learned to interpret it.

For the individual engineer, the question of whether you need this particular instrument is a difficult one to answer. Since this device represents a new category of equipment, it will take time to develop and fine tune the applications and to publish the application notes that will allow you to determine whether the MDO will solve some particular problem that you need to solve and also how to use the device to solve that particular problem.

When I have been asked this question, I have responded in kind with some questions of my own. First, do you want to be a leader or a follower? Not everyone wants to (or needs to) be at the leading edge of technology. That is not a criticism, and each engineer has to determine this based on their own goals as well as the goals and aspirations of the companies they work for.

Second, do you have a vision of how you might use such a test instrument? In my company, we have very clear aspirations for this equipment, and time will tell which work well and which will not. We see applications in EMI, switching frequency dithering, high-speed PDN troubleshooting and the interaction between high-performance/high-speed systems and the power system.

Another point to consider: Do you currently have an SA? If you do, how much benefit do you believe will be realized from the time correlation aspects of this new instrument?

One of the major decision points might be what type of scope you currently have and how old it is. In my visits to many of my customers' labs, it is clear (to me at least) that the average power engineer does not have nearly sufficient bandwidth to measure today's power circuits and often find themselves surprised by something that we show them from our own measurements of their products.

As discussed earlier, the typical POL has a rise time of approximately 3 ns, requiring a scope in excess of 500 MHz to accurately measure this rise time. The approximate transformation between bandwidth and rise time for a single-pole system is

$$T_r = \frac{0.35}{Bandwidth}$$

With today's DSP-enhanced scopes, this ratio increases from 0.35 to possibly 0.45. Using this relationship, a 500-MHz scope has a rise time of nearly 1 ns. If we use the old rule of thumb that we want the equipment to be a factor of 10 better than the measurement, a 500-MHz scope is not up to the task to measure a typical POL.

If we consider that speeds continue to increase and we hope to use our scopes for several years, it becomes clear that power engineers really need a 1-GHz scope today. In the world of linear regulators and LDOs the typical bandwidths are much lower, in the range of 10 MHz. This is a bit misleading, as one of the issues with the new parallel structure devices is that they tend to have poor local stability at very high frequencies. We have even seen some regulators that oscillate in the range of 150 MHz. In our own lab, admittedly for academic purposes at this point, we have linear regulators with bandwidths of 500 MHz. So if it is time for a new scope, the MDO4000 series might be a good choice, since the incremental cost above the MSO is not that great.

Another important consideration is probes. I often tell engineers in my seminars that they are too focused on the cost of the equipment and losing sight of the more important issue of probes. Good probes are essential to obtaining accurate measurements and are also quite expensive. Find the probes that you will need to make all of your measurements and try to select equipment that will mate with those probes. You would not want to purchase duplicate probes to work with different pieces of test equipment.

Tektronix may have made a wise decision by incorporating the TekVPI interface into the MDO4000 series oscilloscopes allowing their vast selection of probes, including passive and active probes, differential probes and current probes to interface with the device. Access to the variety of TekVPI probes might be another good reason to purchase one of these for your lab.

In the end, your decision whether to purchase a new piece of equipment such as the MDO4000 will depend on many factors, only some of which relate to whether the instrument is revolutionary. And whether power engineers can realize the potential of this instrument, only time will tell.

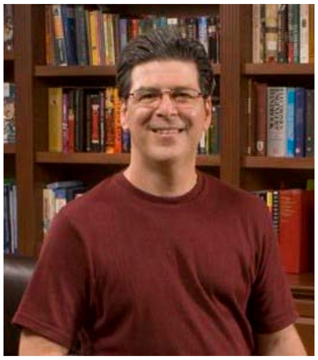
Notes and References:

1. Tektronix is a sponsor of our Advanced Power Measurement seminars and our test equipment company, Picotest, is currently writing application notes that discuss the use of our signal injectors with Tektronix equipment.

2. "These Seven Trends May Change Power Design Dramatically," by Steve Sandler, How2Power Today, April 2011.

3. "Switching Voltage Regulator Noise Coupling Analysis for Printed Circuit Board Systems," by Amy Luoh, Gene Garrison, and Jon Powell, Intel Corp., DesignCon 2009.

About The Author



Steve Sandler is the managing director of Picotest, a Phoenix company that specializes in precision test and measurement equipment. Sandler is also the founder and chief engineer of AEi Systems, where he leads development of high-fidelity simulation models for all types of simulators as well as the design and analysis of both power and RF systems. Sandler has over 30 years of experience in engineering and is a recognized author, educator and entrepreneur in the areas of power, RF and instrumentation.