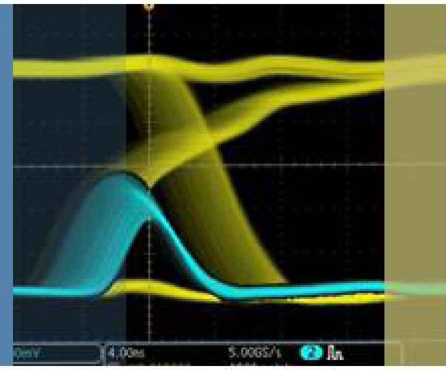


MDO3000 Series Integrated Scope

Designed to make your job simpler and faster!

Five common tasks covered inside:

1. Finding a Signal Anomaly
2. Verifying Serial and Parallel Bus Designs
3. Searching for a Noise Source
4. Margin Testing with a Noisy Signal
5. Validating a Switching Power Supply Design

Six Essential Tools in One Scope!

Save hours verifying and debugging your designs. Work from DC to RF, with analog and digital signals, and serial and parallel buses.

The Tektronix MDO3000 Series provides all the essential tools to get your job done fast!

Standard:

- Oscilloscope
- Integrated Spectrum Analyzer
- Digital Voltmeter

Optional, Upgradable at any Time:

- Arbitrary / Function Generator
- Logic Analyzer
- Protocol Analyzer

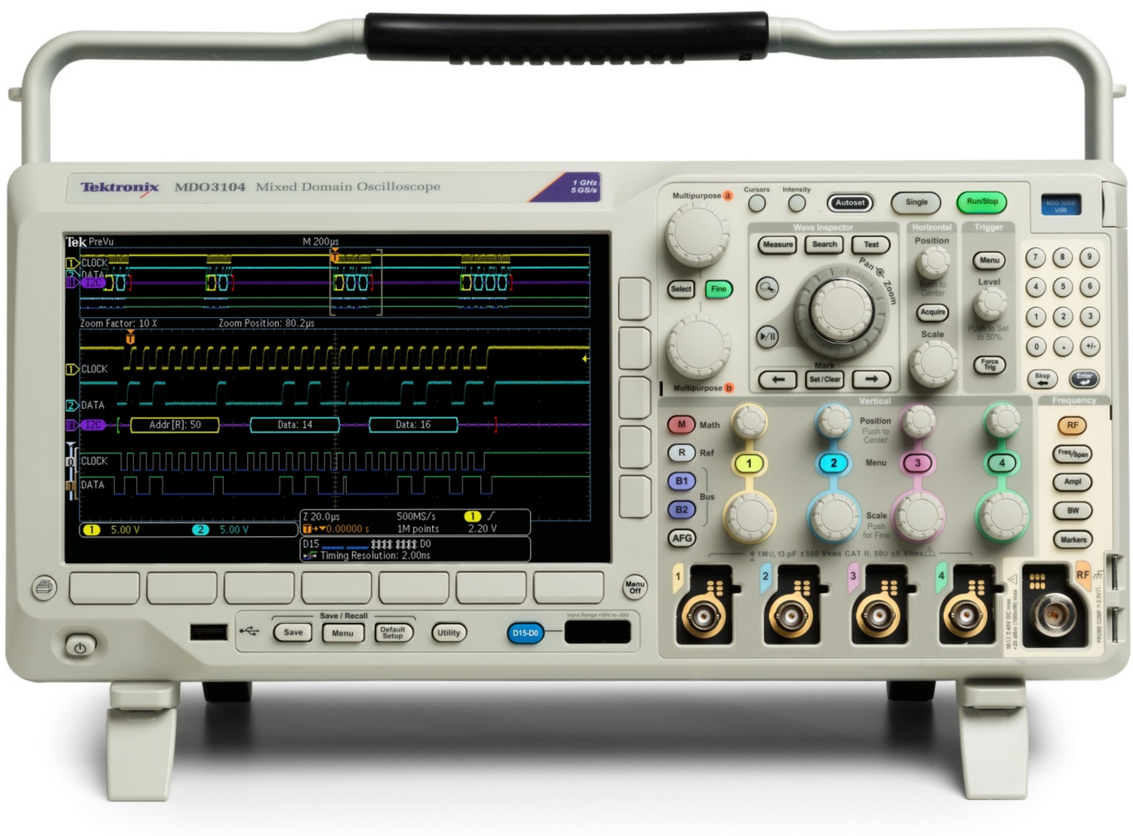


Figure 1. MDO3000 Series Mixed Domain Oscilloscope with Digital Phosphor Display.

1. Finding an Anomaly in a Signal

Discovering and capturing signal anomalies can be one of the most difficult challenges in the debug process. Subtle or infrequent anomalies on just one signal can mean the difference between a design that works reliably and one that does not.

In this section, an MDO3000 with FastAcq, advanced triggering, and automated search is used to discover, capture, and characterize an infrequent event in a digital signal.

In this example, while probing signals on the circuit board, faint traces are occasionally visible on this waveform, indicating infrequent and unexpected events that do not look like the digital signals.

The faint traces in the intensity-graded display in Figure 2 indicate infrequent anomalies exist on the signal, but they disappear from the display too quickly to measure. Although infinite persistence could help when looking at a single signal, it is not compatible with rapid probing across a circuit board.

To quickly discover signal anomalies as the user probes around the design, and to get a sense for how often the anomalies are occurring, color-graded FastAcq mode is enabled. The FastAcq acquisition mode speeds up the waveform acquisition rate to over 280,000 waveforms per second, quickly capturing and displaying any anomalies. The temperature display indicates the most frequent signals in red and the least frequent signals in blue.

In this 3.3 Volt digital signal, occasional narrow pulses or glitches are visible in Figure 3, and low-amplitude runt pulses, which are a little over 1 Volt high, also appear in a blue color.

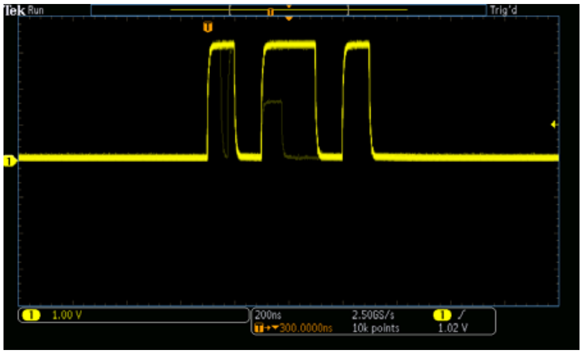


Figure 2: Digital pulse train with occasional anomalies

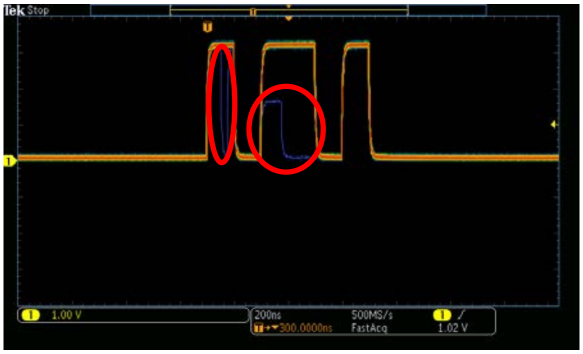


Figure 3: *FastAcq capture of signal anomalies*

1. Finding an Anomaly in a Signal

Figure 4 shows how a runt trigger enables the oscilloscope to isolate and capture each runt pulse.

But how often are the runt pulses occurring?

The front panel Wave Inspector ® controls provide convenient access to manual and automatic waveform navigation tools. With the large Wave Inspector pan and zoom controls, even long acquisitions can be easily examined.

However, manual navigation through long signal acquisitions can be tedious and error-prone. Events of interest can easily be missed when manually scrolling through millions of data points. When manually navigating through the signals, how can the user be confident of finding all occurrences of an event?

With Wave Inspector (see Figure 5), the MDO3000 can automatically search the signal for all instances of a specified event. Specifying search events is similar to specifying trigger events. Then Wave Inspector will automatically mark every event and enable the user to easily find them by navigating between marks with the front panel arrow buttons.

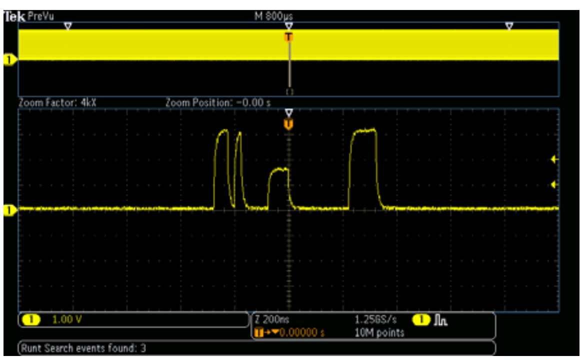


Figure 4: Runt pulses captured with runt triggering

Figure 5: Front panel Wave Inspector controls

1. Finding an Anomaly in a Signal

In this case, the runt trigger setup was copied into the automatic search setup.

In Figure 6, Wave Inspector found 3 runt pulses in the acquired signal, spaced approximately 3.25 ms apart. Armed with this information, the user can quickly correlate events that occur at this rate and isolate the cause of this signal anomaly.

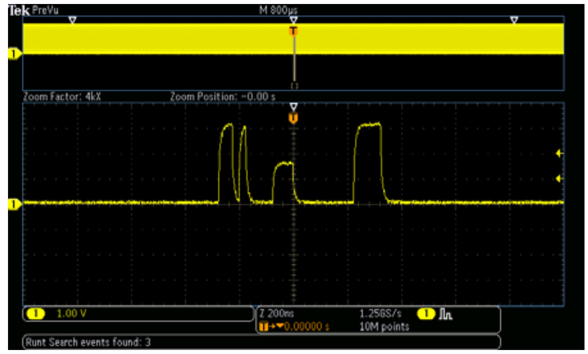


Figure 6: Automated search found 3 runt pulses, approximately 3.25 ms apart.

The MDO3000 Series offers the powerful tools needed to efficiently discover and capture anomalies in signals.

MDO3000 Series Standard Configuration

- FastAcq
- Advanced triggering
- Wave Inspector® automated search

Recommended Configuration

- Any model MDO3000 Series with your required analog bandwidth (as all models come standard with FastAcq, advanced triggering, and Wave Inspector® search).
- The TPP1000 or TPP0500B low-capacitance passive probes, that come standard with the MDO3000, for minimal probe loading.

2. Verifying Serial and Parallel Bus Designs

For fast debug of embedded systems, including those with both parallel and serial buses, the MDO3000 Series offers an integrated protocol analyzer for working with a variety of serial buses and an integrated logic analyzer for working with parallel buses.

To begin, the oscilloscope captures the three signals which make up an SPI serial bus, as shown in Figure 8.

After simply defining a few serial bus parameters such as digital threshold levels and serial signal configurations, the scope will automatically decode the bus data, saving hours of time and costly mistakes by avoiding manual decode of the bus data. Figure 9 shows the decoded SPI bus.

This SPI serial bus drives a serial-to-parallel converter. To verify the timing relationship between the serial and parallel buses, the eight parallel bus signals are acquired by the digital channels. After defining a few bus parameters, the parallel bus is automatically decoded and displayed (Figure 10).

Figure 7: Decoding an I²C bus, while viewing waveforms.

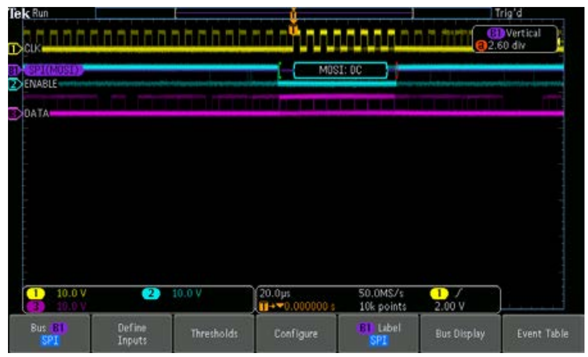


Figure 9: Automatic decode of the SPI serial bus.

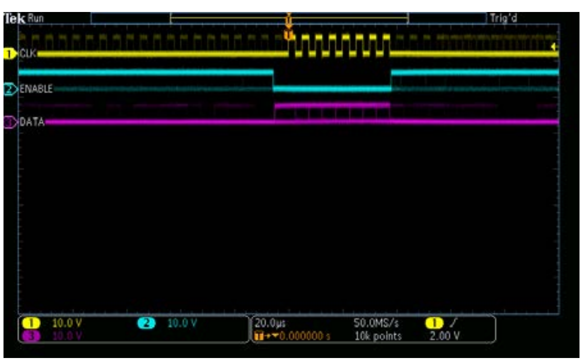


Figure 8: 3-wire SPI serial bus signals**.**

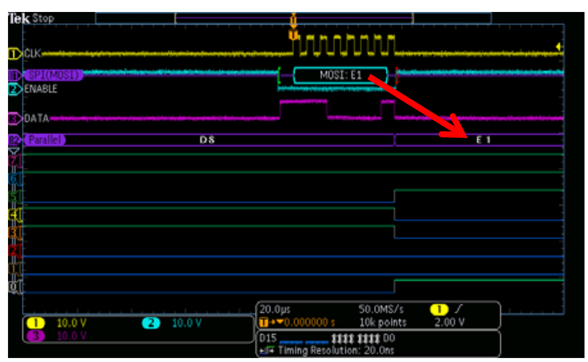


Figure 10: Digital channels and an 8-bit parallel bus added to the display.

2. Verifying Serial and Parallel Bus Designs

The MDO3000 can decode and display up to two parallel or serial buses at a time. With the synchronized display of the two buses, the timing relationships between the serial and parallel bus data become obvious. In most cases, the parallel bus value is set to the serial bus data value right after the serial packet has been transmitted.

The serial trigger can be set to stabilize the display and capture specific serial events. In this case, the trigger is set up to capture the signals every time the hex data value B0 is transmitted on the serial bus. As shown in Figure 11, the parallel bus value does not change when the serial value B0 hex is transmitted. Further investigation showed that the design wasn't working quite as expected.

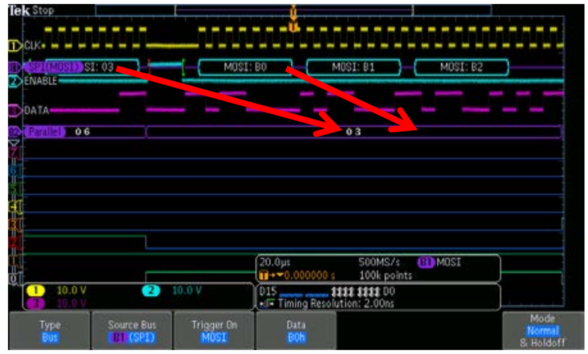


Figure 11: Mixed signal display stabilized with serial trigger capturing B0 hex data packet.

The Tektronix MDO3000 Series offers the powerful toolset needed to get the job done fast, saving hours when verifying and troubleshooting designs containing serial and parallel buses.

MDO3000 Series Supported Serial Buses

- I^2C
- SPI
- USB 2.0
- RS-232/422/485/UART
- CAN / LIN
- FlexRay
- MIL-STD-1553
- I^2S/LJ/RJ/TDM

Recommended Configuration:

- Any 4-channel MDO3000 with the required analog bandwidth.
- Add the MDO3MSO option, including the 16-channel digital probe and accessories, to enable the 16 digital channels.
- Add the MDO3EMBD application module to add I^2C and SPI serial triggering, decoding, and analysis

3. Searching for a Noise Source in an Embedded Design

Another common task is tracking down the source of noise in a design. The integrated spectrum analyzer in the MDO3000 Series provides the right tools for mixed-domain debug in a single instrument (Figure 12).

While probing around the circuit board, a very high-frequency signal can be seen riding on one of the low-frequency signals, as in Figure 13.

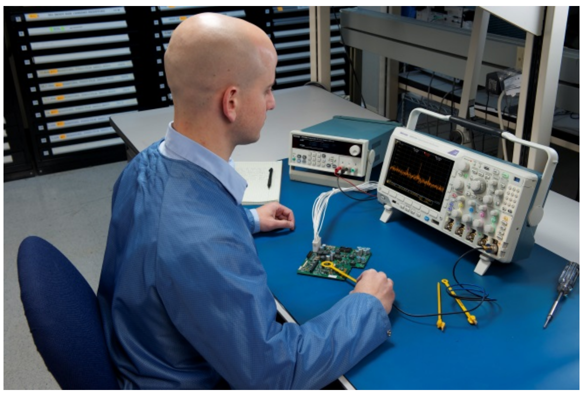


Figure 12: Using the integrated spectrum analyzer with a near-field probe

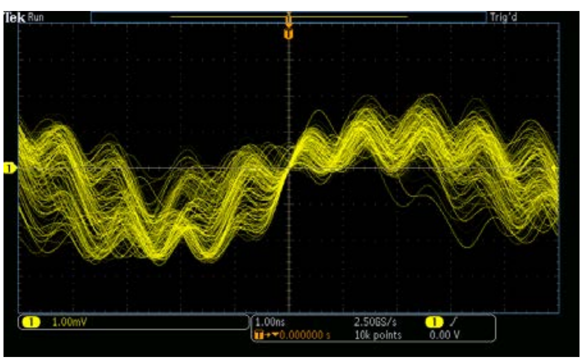


Figure 13: High-frequency noise riding on critical signal.

In the time-domain display, a cursor measurement shows in Figure 14, that the dominant noise is at about 900 MHz.

Switching to the integrated spectrum analyzer, a near-field probe is used to capture radiated signals. The spectrum analyzer's center frequency is set to 900 MHz and the span is set to 2 MHz (see Figure 15). The dedicated front panel keypad makes it quick and easy to set these RF parameters.

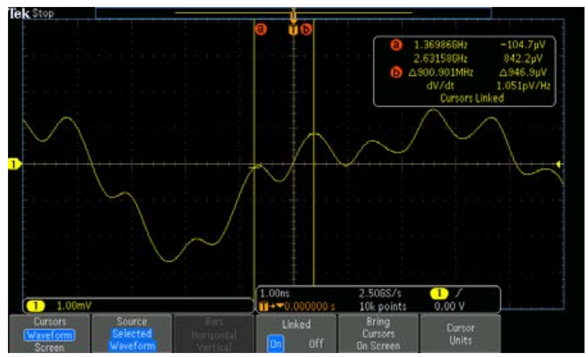


Figure 14: Cursor measurements identify noise as 900 MHz

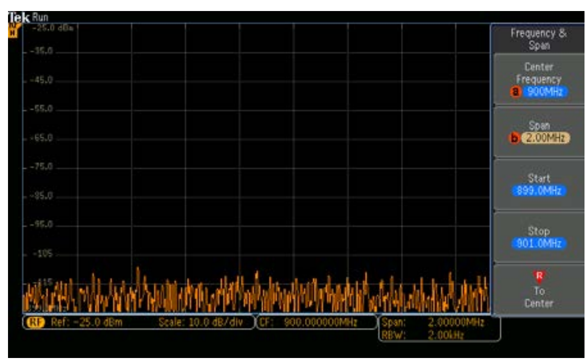


Figure 15: Spectrum analyzer setup to capture 900 MHz noise

3. Searching for a Noise Source in an Embedded Design

Then the near-field EMI loop antenna is slowly moved over the circuit board looking for the highest signal level at 900 MHz. The strongest signal is found at the output of a clock generator circuit in an FPGA, as in Figure 16.

To monitor variations in the spectrum over time, the spectrogram display is turned on. As shown in Figure 17, the signal appears to be fairly stable.

After examining the FPGA layout, it was determined that the signal corresponds to the ninth harmonic of the 100 MHz Ethernet clock. In this case, a poor circuit board layout resulted in magnetic coupling to other signals in the design.

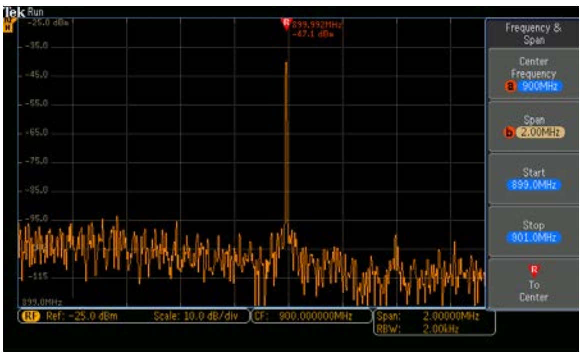


Figure 16: Strong 900 MHz radiation detected at the FPGA.

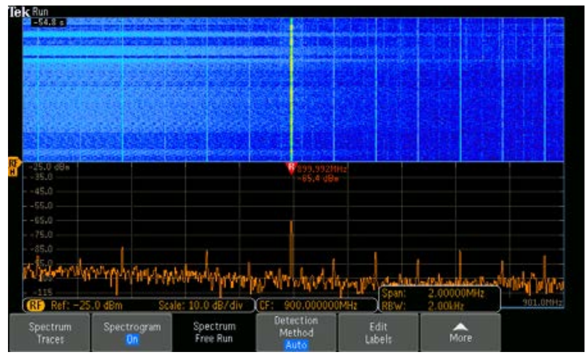
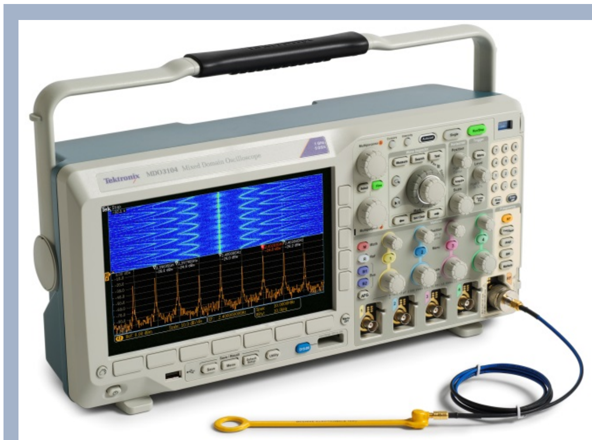


Figure 17: Spectrogram display indicates that the 900 MHz signal is fairly stable over time



Recommended Configurations:

- MDO3102 or MDO3104 for 1 GHz RF bandwidth.
- Or add the MDO3SA option to any MDO3000 to increase the RF bandwidth to 3 GHz.
- Near-field EMI loop antenna.

With the integrated spectrum analyzer, the MDO3000 Series is the perfect instrument for mixed-domain debug.

MDO3000 Series
Integrated Spectrum Analyzer:

- Standard bandwidth: 9 kHz to scope BW.
- Optional bandwidth: 9 kHz to 3 GHz.
- Operates like a standard spectrum analyzer.
- Better performance than a scope FFT.
- Set center frequency, span, or start and stop frequencies with front panel keypad.

4. Margin Testing with a Noisy Signal

Figure 18: Using the integrated arbitrary / function generator as a source.

Margin testing is another everyday task. The integrated signal generator in the MDO3000 Series can create a programmable stimulus for margin testing a design.

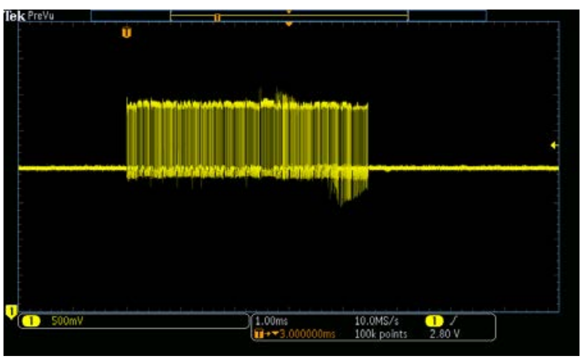


Figure 19: The CAN serial signal captured by the MDO3000

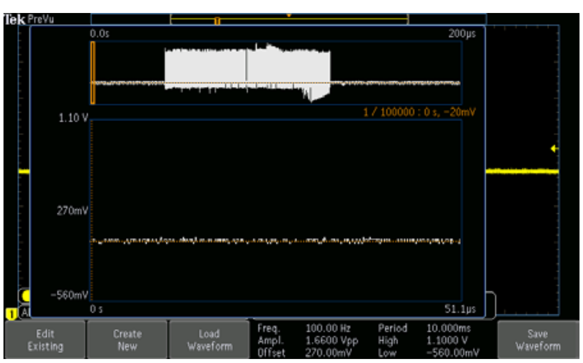


Figure 20: Acquired CAN signal copied into the ARB memory

In this example, the noise margin of a CAN bus serial receiver circuit is being characterized. To test the margin of the receiver, a live CAN signal is captured with an analog channel on the oscilloscope and loaded into the integrated arbitrary / function generator's edit memory, as shown in Figures 19 and 20.

Then the ARB repetitively outputs the serial stimulus signal to drive the receiver circuit's input, shown in the channel 2 (cyan) waveform in Figure 21.

The serial output of the receiver circuit is acquired with channel 3 (waveform not shown) and the decoded serial output is displayed in Figure 22. Note that a bus trigger has been added to stabilize the display.

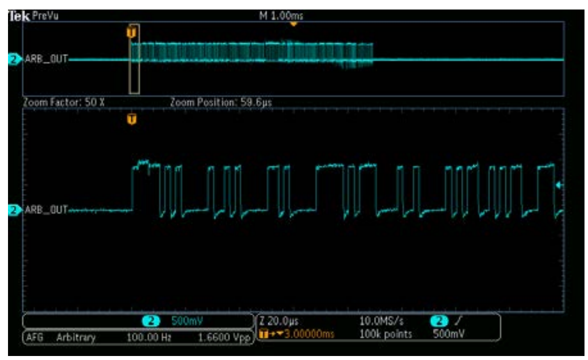


Figure 21: Noise-free CAN signal generated by the ARB.

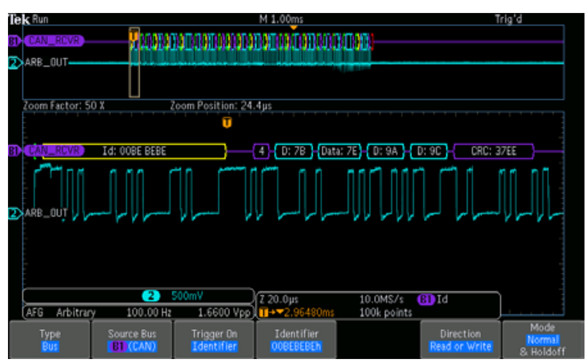


Figure 22: Stabilized display of decoded serial output signal using CAN serial triggering.

4. Margin Testing with a Noisy Signal

Gaussian noise is then added to the serial signal and the decoded output of the receiver circuit is monitored, looking for data packets to begin to change or disappear, indicating bit errors. This is shown in Figure 23.

By monitoring the decoded output of the receiver, the receiver design is found to work well with noise levels up to about 40% of the serial signal amplitude, but demonstrates significant errors when the noise level reaches 45-50% of the signal amplitude. This test method quickly verifies the noise margin in the receiver design.

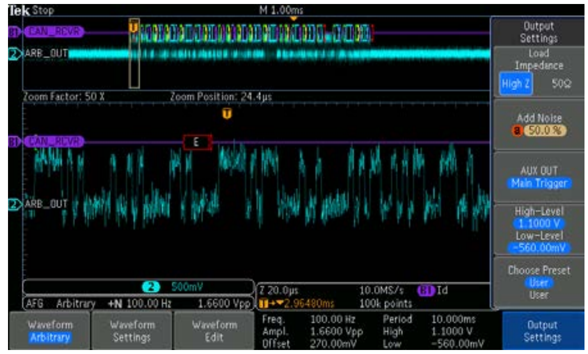
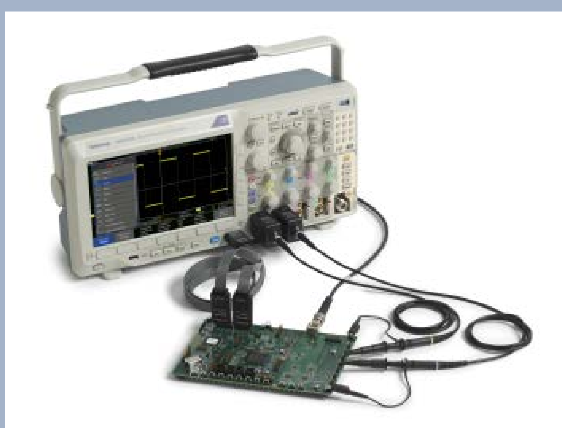


Figure 23: Capturing missing serial packets at the output of the serial receiver, indicating bit errors.



The MDO3000 Series' Arbitrary / Function Generator provides signals for a wide variety of testing, like margin testing, to help thoroughly validate and debug embedded designs.

Recommended Configurations:

- Any model MDO3000, selected by required analog bandwidth
- Add the MDO3AFG option to enable the arbitrary / function generator
- Add the MDO3AUTO application module to enable CAN and LIN serial triggering, decoding, and analysis

MDO3000 Series
Arbitrary / Function Generator Capabilities:

- Up to 50 MHz function generation
- 13 predefined functions
- Add noise
- Arbitrary waveform generation
  - 128k waveform memory
  - 250 MS/s sample rate

5. Validating a Switching Power Supply Design

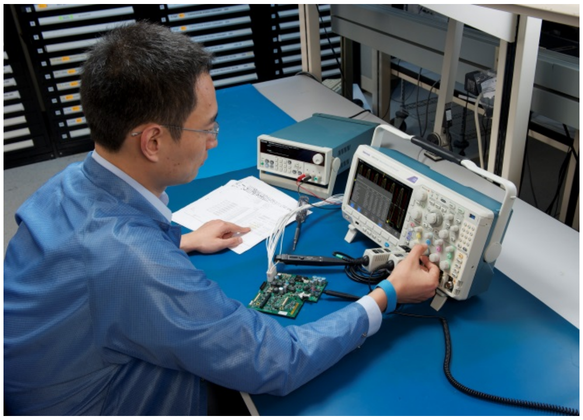


Figure 24: MDO3000 with differential voltage probe and current probe.

The MDO3000 Series power measurements enable any user to quickly get the same accurate and repeatable results as a power supply expert, even if they rarely deal with power measurements.

This final example shows common power measurements and how they're done with the MDO3000, using the automatic power measurements, the integrated DVM, and differential and current probes.

Figure 25 shows the voltage and current at the input to an AC-to-DC converter.

3.5-digit Digital Voltmeter

The integrated 3.5-digit DVM is then turned on to monitor the DC output voltage. The measurement statistics at the right side of the DVM display indicate that the output voltage is very stable, and the graphical readout provides a quick visual indication of voltage variations (Figure 26).

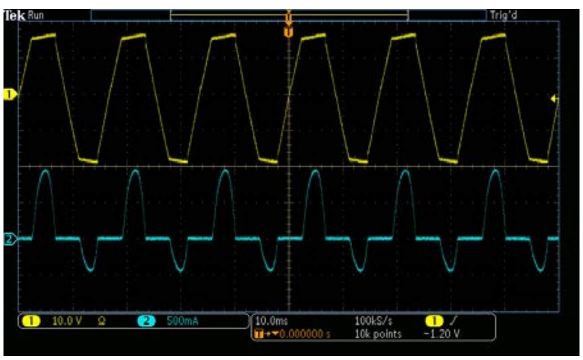


Figure 25: AC input voltage (yellow) and current (blue) waveforms.

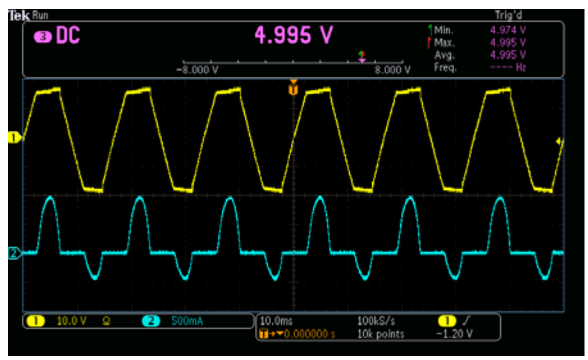


Figure 26: Monitoring the DC output voltage with the DVM.

5. Validating a Switching Power Supply Design

The optional MDO3PWR power measurement application (Figure 27) automatically makes a variety of measurements with the push of a button, easily and repeatedly.

Figure 28 shows the input power quality measurements - including power, crest factor, and power factor - which characterize the effects of the power supply on the AC power source.

The current harmonics measurements provide a frequency-domain analysis of the input current, in both graphical and tabular formats (Figures 29 and 30).

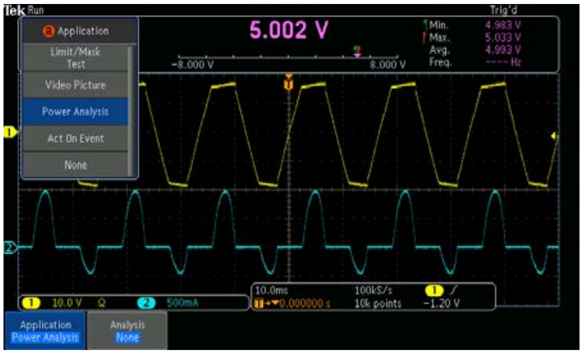


Figure 27: Selecting automated power measurements.

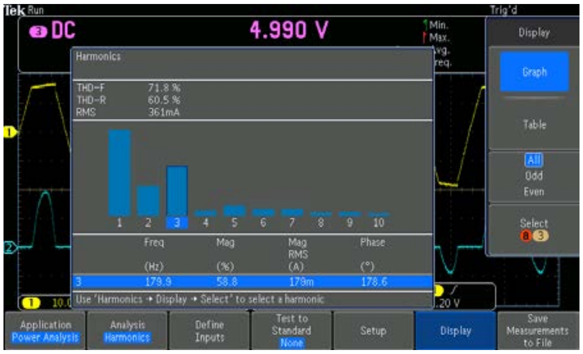


Figure 29: Graphical display of input current harmonics.

Figure 28: Power Supply input power quality measurements.

Figure 30: Tabular display of input current harmonics.

5. Validating a Switching Power Supply Design

Another key power measurement is switching loss in the switching device, a major limitation to the efficiency of the power supply.

The differential voltage across the MOSFET (yellow waveform) is measured, as is the current flowing through the switching device (blue waveform). Then, with the touch of a button, the instantaneous power waveform is generated (red waveform) and switching loss power and energy measurements are displayed as in Figure 31.

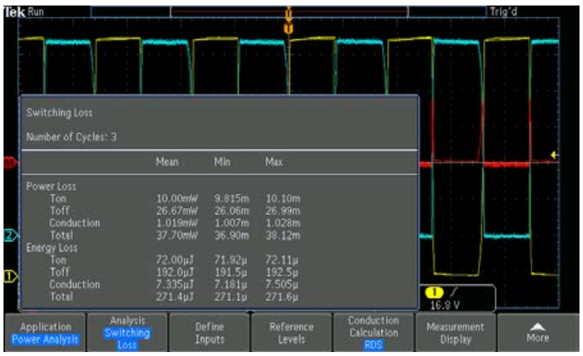


Figure 31: Switching Loss measurements.

Finally, the Safe Operating Area measurement allows automatic monitoring of switching behavior over various input and load conditions In Figure 32. By comparing the switching device's voltage, current, and instantaneous power levels relative to the device's maximum ratings, this measurement assures that the device reliability is not compromised by exceeding the specifications.

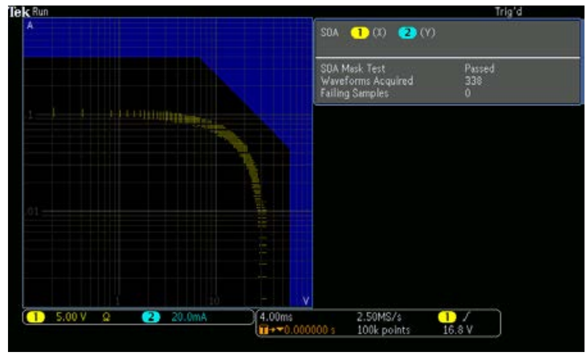
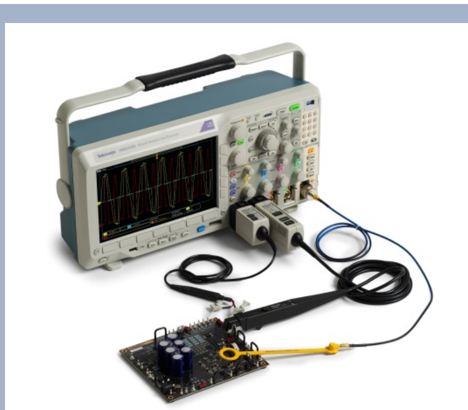


Figure 32: Safe Operating Area with automatic pass/fail testing.



MDO3000 Series
Automated Power Measurements:

- Power Quality
- Switching Loss
- Harmonics
- Ripple
- Modulation
- Safe Operating Area

Recommended Configurations:

- 4-channel MDO3000, selected by required analog bandwidth
- Included DVM
- Add the MDO3PWR option for automatic power measurements
- Add a TDP1000 or THDP0200 differential probe for safely and easily measuring non-ground-referenced voltages
- Add a TCP0030A or TCP0020 AC/DC current probe for accurate current measurements

Everyday Design and Debug with an MDO3000 Series Oscilloscope

This application note has shown just a few of the many everyday tasks that can be done with the MDO3000 Series, the ultimate 6-in-1 integrated oscilloscope.

Five everyday design and debug tasks:

1. Finding a Signal Anomaly
2. Verifying Serial and Parallel Bus Designs
3. Searching for a Noise Source
4. Margin Testing with a Noisy Signal
5. Validating a Switching Power Supply Design

For further information, please visit www.tek.com/mdo3000

ASEAN / Australia (65) 6356 3900
Austria* 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium* 00800 2255 4835
Brazil +55 (11) 3759 7627
Canada 1 (800) 833-9200
Central East Europe and the Baltics +41 52 675 3777
Central Europe & Greece +41 52 675 3777
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Macau 400-820-5835
Mongolia 400-820-5835
Mexico, Central/South America & Caribbean 52 (55) 56 04 50 90
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Switzerland* 00800 2255 4835
Taiwan 886-2-2656-6688
United Kingdom* 00800 2255 4835
USA 1 (800) 833-9200

* If the European phone number above is not accessible, please call +41 52 675 3777
Contact List Updated March 2013

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