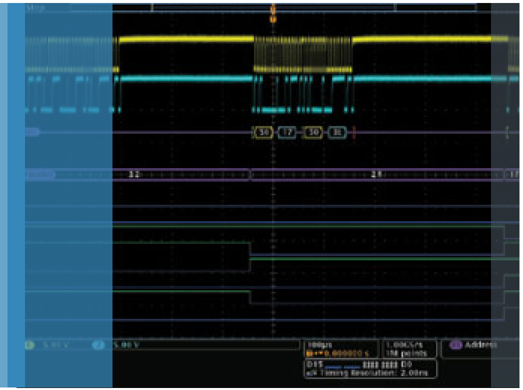

Tektronix MDO4000C Series Oscilloscopes

Demonstration Guide

Tektronix®

071-3472-00

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Tektronix MDO4000C Series Mixed Domain Oscilloscope

Mixed Domain Oscilloscope delivers high performance for validating and debugging challenging designs. These integrated 6-in-1 oscilloscopes offer a spectrum analyzer, arbitrary function generator (AFG), logic analyzer, protocol analyzer, and digital voltmeter (DVM) to provide system-level insight as well as versatility.

Oscilloscope – At the core of the MDO4000 Series is the most popular oscilloscope in this class.

- 200, 350, 500 MHz, and 1 GHz bandwidth models
- Up to 5 GS/s sampling rate
- 20 Mpoint record length on every channel with Wave Inspector® navigation and search controls
- Maximum waveform capture rate up to >340,000 waveforms per second
- Standard passive probes with 3.9 pF of capacitive loading and 1 GHz or 500 MHz bandwidth
- Suite of advanced triggers including optional serial triggering and analysis
- Additional application support includes automated power analysis, limit and mask testing, and advanced video analysis

Spectrum Analyzer (Optional)

Every MDO4000C can be equipped with an integrated spectrum analyzer, providing better RF performance than a traditional oscilloscope FFT, and synchronized displays of analog, digital, and RF signals. The spectrum analyzer has an ultra-wide capture bandwidth ≥1 GHz and input frequency ranges from 9 kHz to 3 GHz or 6 GHz with the SA3 and SA6 options, respectively.

Arbitrary Function Generator (Optional)

With the MDO4AFG option, choose from 13 predefined standard waveforms like sine, square or ramp, or replicate virtually any signal with the arbitrary waveform generation with 128k record length and 250MS/s sample rate. Even add noise to your waveform to perform margin testing on your circuits.

Logic Analyzer (Optional)

The MDO4000C provides a 16 digital channel logic analyzer with the MDO4MSO option, enabling you to look at multiple points in your design at once.

Protocol Analyzer (Optional)

The MDO4000C Series offers a robust set of tools for debugging serial buses with automatic trigger, decode, and search for I^2C, SPI, CAN, LIN, FlexRay, RS-232, RS-422, RS-485, UART, I2S/LJ/RJ/TDM, USB 2.0, MIL-STD 1553, and Ethernet.

Digital Voltmeter (DVM) / Frequency Counter (Free with product registration)

For fast voltage and frequency measurements, the optional 4-digit digital voltmeter and 5-digit frequency counter is easy-to-use.

Upgradability

The MDO4000C is completely upgradeable. Upgrade scope bandwidth, add more functionality with a spectrum analyzer, AFG, logic analyzer, and DVM, or add analysis capability such as serial bus triggering and decode, power measurement, limit/mask test, and advanced video analysis, whenever you need it.

About This Guide

This demonstration guide takes you through a series of step-by-step demonstrations on how the MDO4000C Series oscilloscope helps simplify the debug of mixed signal designs with its powerful functionality and integrated test instruments. This oscilloscope can help you discover new ways to quickly debug some of today's most challenging and common design problems.

Note: There are additional built-in product demos in MDO4000C. To explore other product demos and features, press the **Utility** front panel button, then press the MDO4000C **Utility Page** lower-bezel button, and use Multipurpose **a** to select **Demo.**

To go through the exercises, you need:

- MDO4000C Series Mixed Domain Oscilloscope and power cord.
- Four (4) TPP1000 or TPP0500B passive probes.
- MDO demonstration board (includes a USB Y-cable used to power the demo board) with waveforms that represent a number of mixed-signal challenges facing today's designers. To find the desired signal on the demo board, refer to the "Locating Signals" section at the end of this demonstration guide.
- N-BNC adapter to connect BNC cable to RF input channel (standard accessory).
- BNC cable to connect AFG output to analog channel and to connect to the spectrum analyzer input.
- Serial bus triggering and analysis application modules.
- MSO, DVM, AFG, Spectrum Analyzer options.

Note: For demonstration purpose, many application modules and options are enabled in MDO4000C demo units. They are listed on the following page:

Category	Product	Description
Serial Bus Analysis	DPO4AERO	MIL-STD-1553 serial bus triggering and analysis module
	DPO4AUDIO	Audio serial triggering and analysis module (I_2S, LJ, RJ, TDM)
	DPO4AUTO	Automotive serial triggering and analysis module (CAN, LIN)
	DPO4COMP	Computer serial triggering and analysis module (RS-232/422/485/UART)
	DPO4EMBD	Embedded serial triggering and analysis module (I_2C, SPI)
	DPO4ENET	Ethernet serial triggering and analysis module
	DPO4USB	USB2.0 (LS, FS) serial bus triggering and analysis and (HS – 1GHz models only) analysis module
Analysis	DPO4LMT	Limit/mask test
	DPO4PWR	Power measurement and analysis package
Measurement	DPO4VID	Advanced Video Analysis
	N/A	Adds digital voltmeter to any MDO4000C, free with product registration
Instrument Options	MDO4AFG	Adds arbitrary function generator to any MDO4000C
	MDO4MSO	Adds 16 digital channels to a MDO4000C; includes P6616 digital probe and accessories
	MDO4SA6	Adds spectrum analyzer with 9kHz - 6 GHz input frequency range

Powering on the Board

To connect and power on the demonstration board, follow these steps:

1. Plug the dual USB A connectors from one end of the “Y” USB cable, which comes with your board, into two USB ports of a PC or an oscilloscope. Do this before plugging the single USB B connector from the other end of the USB cable into the demonstration board. You need to attach both USB A connectors to provide adequate power to the demo board.
2. Plug the single B connector from the other end of the USB cable into the demo board. Two green and one red LEDs on the board turn on and remain steady when you apply adequate power to the board.

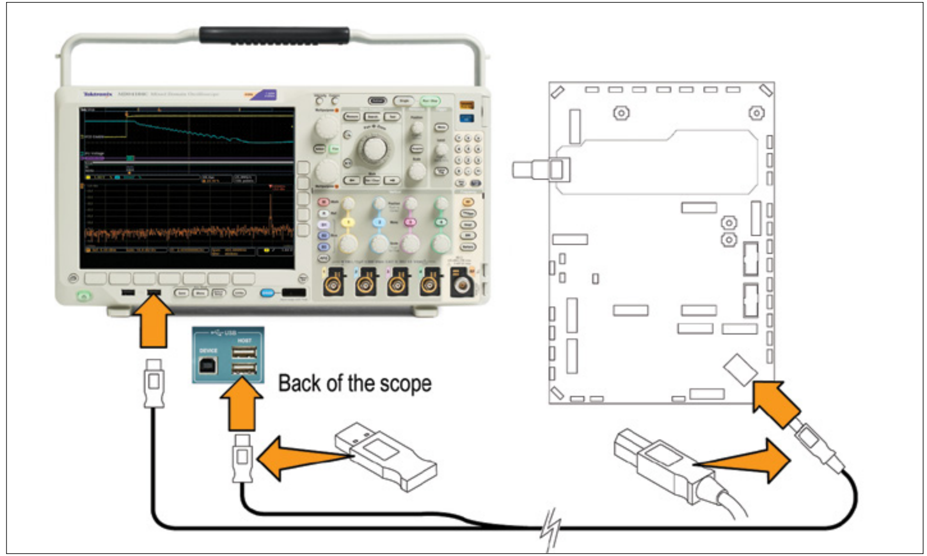
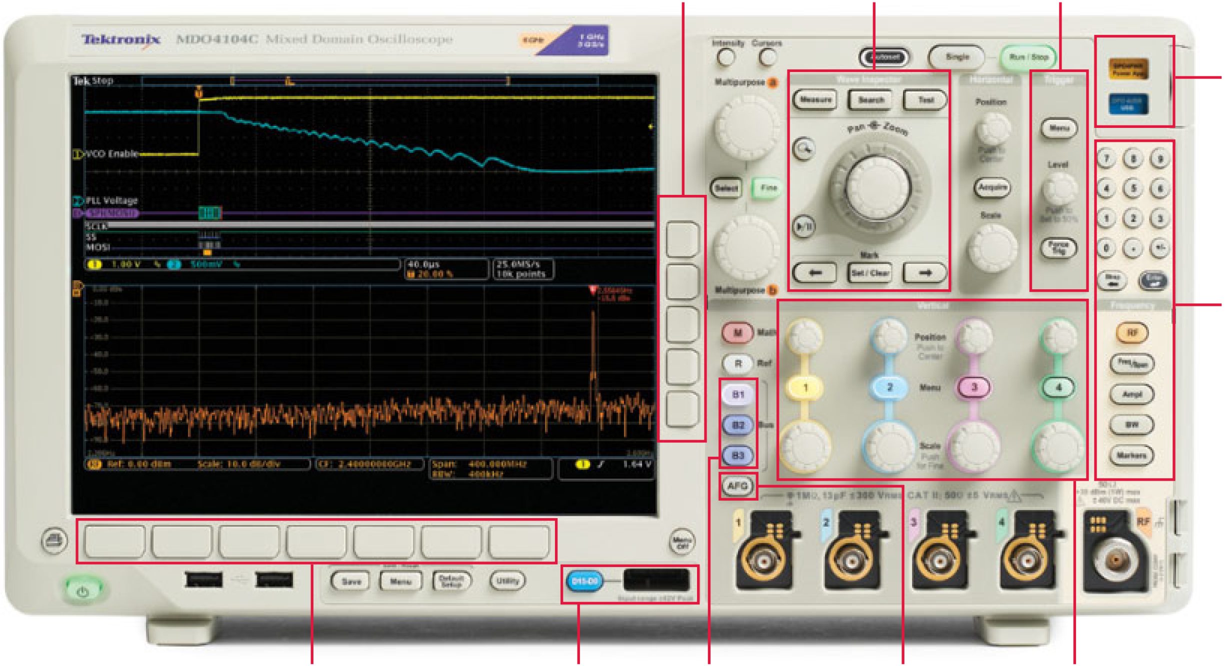


Figure 1.

MDO4000C Series Front Panel Overview



Exercise 1

Capturing Elusive Events with FastAcq™ High Waveform Capture Rate

To debug a design problem, first you must know it exists.

The MDO4000C Series oscilloscope offers Tektronix proprietary FastAcq™ technology. It delivers a fast waveform capture – up to 340,000 waveforms per second – that enables you to see glitches and other infrequent transients within seconds, revealing the true nature of device faults.

To further enhance the visibility of rarely occurring events, intensity grading is used with multiple waveform palettes to choose from, indicating how often rare transients are occurring relative to normal signal characteristics. The FastAcq waveform palettes are Temperature (color-grading frequency of occurrence), Spectral (color-grading frequency of occurrence), Normal (gray-scale where frequently occurring events are bright) and Inverted (gray-scale where rare events are bright).

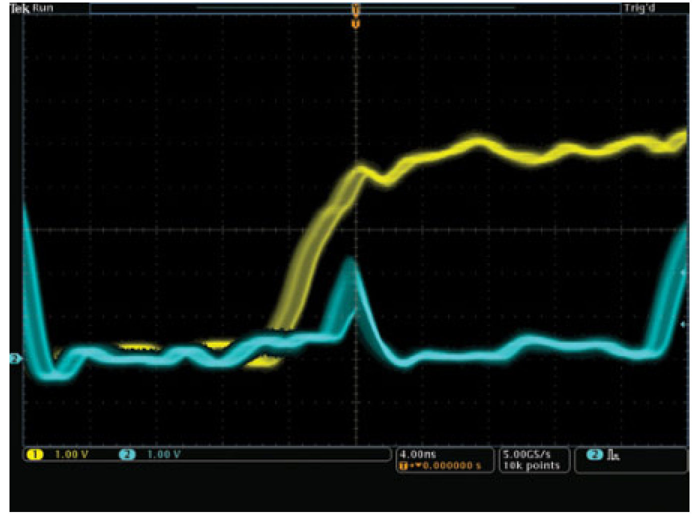


Figure 2.

This demo illustrates how FastAcq high waveform capture rate can find anomalies quickly and display them with color-grading. The demonstration looks for an erroneous runt signal that occurs approximately every 838.8ms.

1. Connect a passive probe to channel 1 on the oscilloscope.
2. Connect the ground lead of the probe to the GND point and the probe tip to the RARE_ANOMALY signal on the demonstration board.
3. Press the **Default Setup** button to set the oscilloscope to the factory setup, and then press **Autoset.**

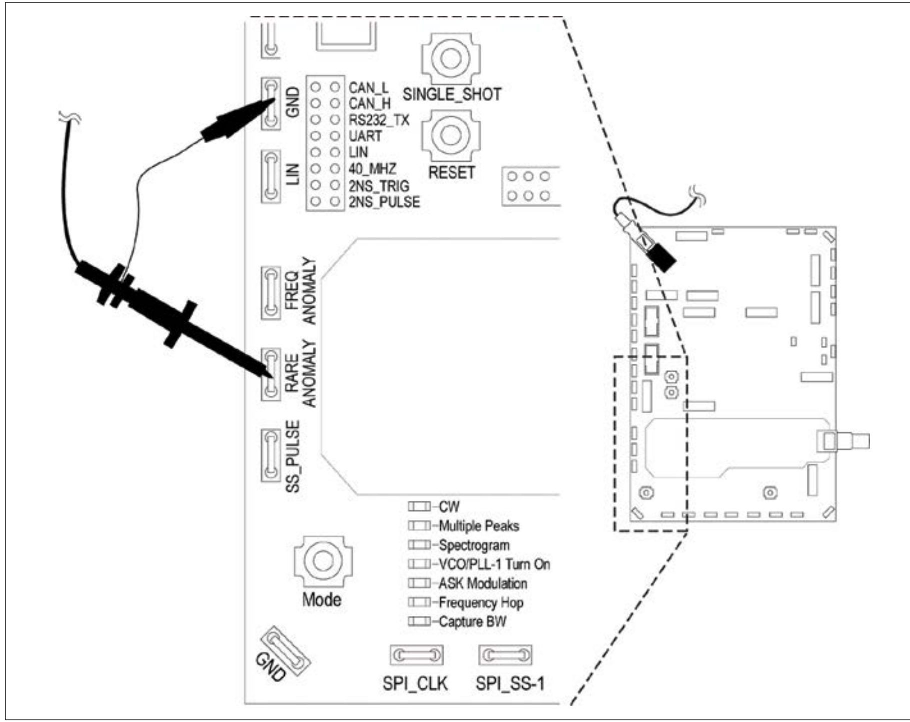


Figure 3.

4. Press the **Menu Off** front panel button.
5. Press the **Intensity** front panel button and turn Multipurpose **a** control clockwise to set the Waveform Intensity to **95%.**
6. Press the **Intensity** front panel button.

Figure 4.

7. Press the **Acquire** front-panel button.
8. Press the **FastAcq** lower-bezel button. Turn on the FastAcq by pressing **FastAcq** side-bezel button and select **On.**
9. Press the **Waveform Display** lower-bezel button.
10. Turn Multipurpose **a** clockwise to adjust persist time to ∞ **s** (infinite).

This step will ensure that all events captured will remain displayed on the oscilloscope. After several seconds you will notice that erroneous patterns in dark blue will begin filling the display. The digital phosphor display with color intensity grading shows the history of the signal's activity by using color to identify areas of the signal that occur more frequently, providing a visual display of just how often anomalies occur.

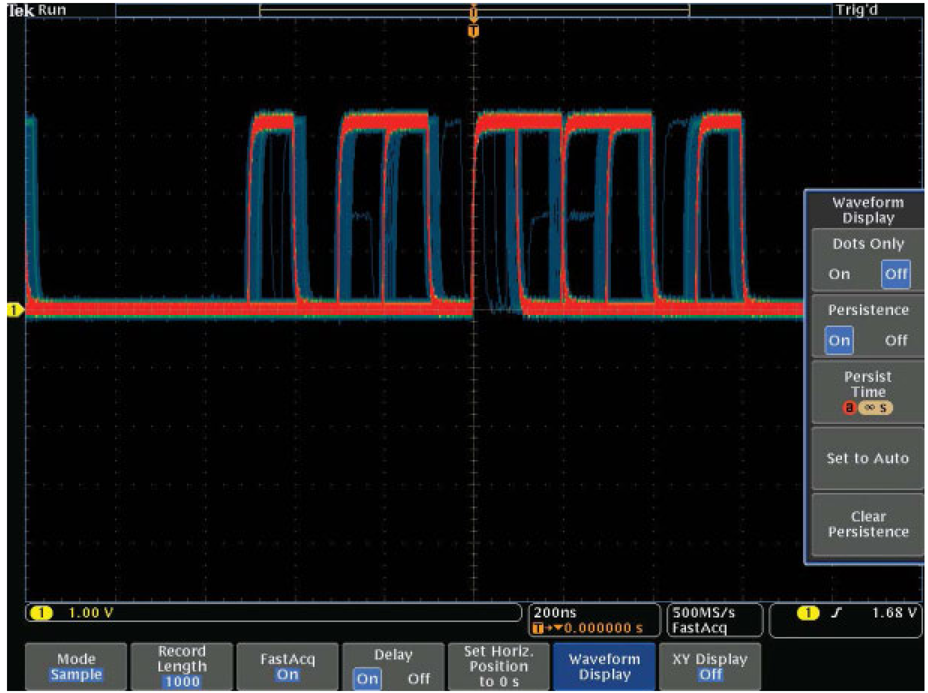


Figure 5.

Now we see an erroneous runt in the signal. To capture it, follow the steps below.

11. Press **Set to Auto** the side-bezel button to turn off infinite persistence.
12. Press trigger **Menu,** select **Type Edge** lower-bezel button, use Multipurpose **a** to scroll down to **Runt.**
13. Press the **Thresholds** lower-bezel button, adjust High to approximately **2.00 V** using Multipurpose **a**, and adjust Low to about **1.00 V** using Multipurpose **b.**
14. Press the **Mode** lower-bezel button and press the **Normal** side-bezel button.
15. Press the **Menu Off** button twice to remove the menus. You should be triggering on the runt signal.

Figure 6.

Exercise 2

Wave Inspector® Navigation and Automated Search

Trying to find one particular event, such as a spike on your signal or a runt pulse, in a long waveform record can be difficult. For example, a 20 Mpoint record length on the MDO4000C is equal to over 20,000 oscilloscope screens worth of data! To make it easier to find what you are looking for, the MDO4000C Series has a special feature called Wave Inspector which provides tools for quickly moving through long records including an automated search function.

The following steps will explore the use of waveform navigation and search tools that greatly simplify finding events of interest.

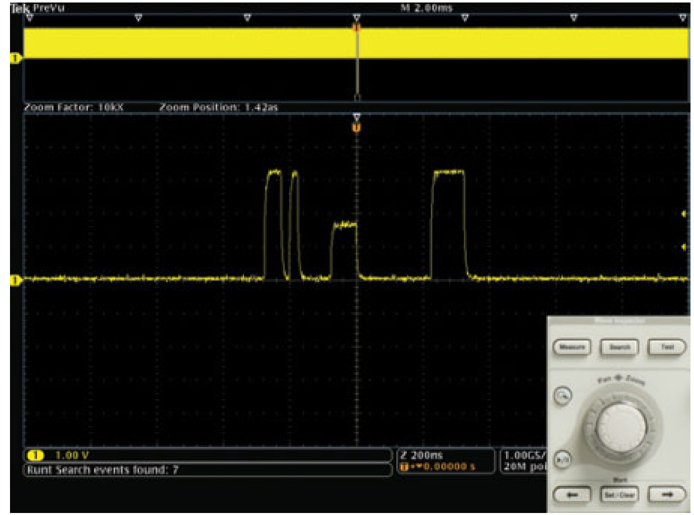


Figure 7.

1. Connect the channel 1 probe tip to the FREQ_ANOMALY (Frequent Anomalies) signal on the demonstration board. Connect the ground lead of the probe to the GND point.
2. Press the front panel **Default Setup** button to set the oscilloscope to a known state. Press **Autoset.**
3. Press trigger **Menu,** select **Type Edge** lower-bezel button, use Multipurpose **a** to scroll down to **Runt.**
4. Press the **Thresholds** lower-bezel button, adjust High to approximately **2.00 V** using Multipurpose **a**, and adjust Low to about **1.00 V** using Multipurpose **b.**

Now you are triggering on a runt.

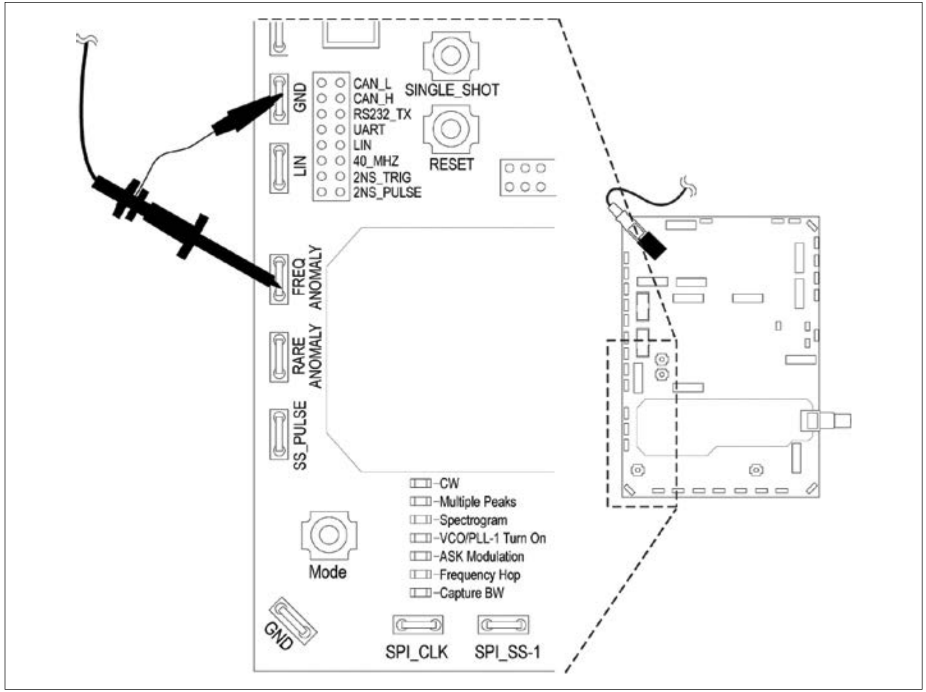


Figure 8.

Capturing the signal with sufficient detail is critical to successful debugging. For example, if you are interested in how frequent the runt signal occurs, you can acquire a long time window with a long record length and search for runt signals.

5. To increase the record length, press **Acquire,** select the **Record Length** lower-bezel button, then select **20 Mpoints** using Multipurpose **a.**
6. Press the **Menu Off** button to remove the menus.
7. Turn the Horizontal **Scale** control to select **2.00 ms/div.**
8. Press the front panel **Single** button to make an acquisition.

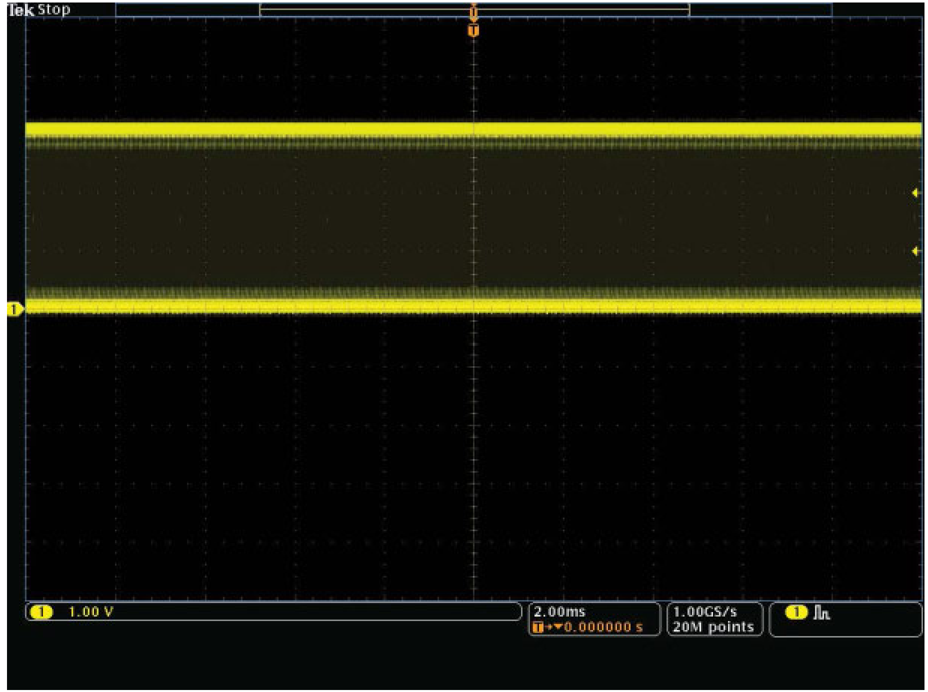


Figure 9.

9. Press the front panel **Search** button.
10. Press the **Search** lower-bezel button.
11. Press the **Copy Trigger Settings To Search** side-bezel button.

Now all runts in the acquisition that meet this trigger specification are marked with a hollow white triangle at the top of the display. Notice the number of search events shown in the lower left corner is three.

Figure 10.

It is very difficult to see much signal detail in this display. If we zoom in on the waveform, the details become visible.

12. Press the **Menu Off** button to remove the menus.
13. Turn the inner Wave Inspector control and notice how the upper window of the display shows the context while the lower window shows the zoomed details.
14. Turn the outer, spring-loaded Wave Inspector control to pan right and left through the acquired waveform. The further you turn the control, the faster the panning.
15. You can also navigate to one of the marks using the ← and → arrow buttons.

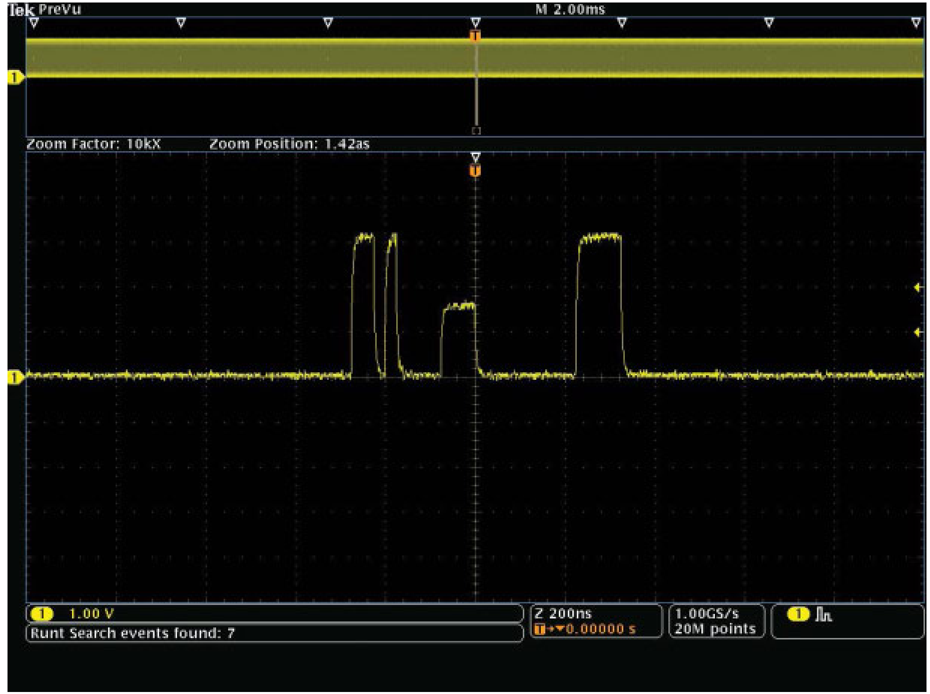


Figure 11.

Exercise 3

Decoding, Triggering and Searching Serial Buses

Tired of having to visually inspect serial data streams to determine if each bit is a 1 or a 0? Tired of having to start, stop, and then manually combine bits into bytes to determine hex values? The MDO4000C Series can automatically decode and trigger on packet-level content, such as the start of a packet, specific addresses, specific data content, and unique identifiers on popular serial interfaces, such as I²C, SPI, CAN, LIN, FlexRay, USB2.0, RS-232, RS-422, RS-485, UART, Audio, MIL-STD-1553, and Ethernet. The MDO4000C Series also provides a Bus Display view of the individual signals that make up the bus, such as clock, data, and chip enable. This Bus Display view makes it easy for you to identify where packets begin and end, and to identify sub-packet components, such as address, data, identifiers, CRC and so on.

This exercise demonstrates the ability of the MDO4000C Series to help you debug I²C circuits.

Note: Serial Bus Analysis modules are available for purchase. For demonstration purposes all application modules and options are enabled in MDO4000C demo units.

Figure 12.

Note: You can find more serial bus demonstrations in MDO4000C built-in demos. Press the front panel **Utility** button. Press then **Utility Page** lower-bezel button. Select **Demo** using Multipurpose **a.** More serial bus demos are under **Serial Bus** group.

1. Connect the channel 1 probe's ground lead to a point labeled GND on the demonstration board. Connect the probe tip to the I2C_CLK test point on the demonstration board.
2. Connect the channel 2 probe's ground lead to a point labeled GND on the demonstration board. Connect the probe tip to the I2C_DATA test point on the demonstration board.
3. Press the front-panel **Default Setup** button.
4. Press the front-panel channel **2** button to turn on channel 2.

   Press the **RESET** button on the demo board if there is no signal on the screen.

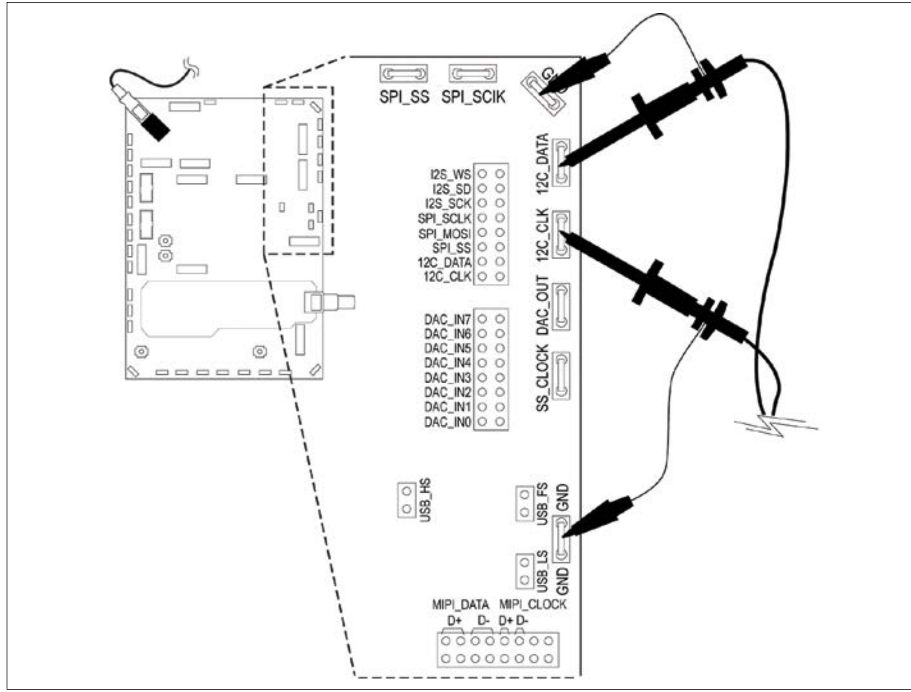


Figure 13.

5. Turn the front-panel channel 1 and channel 2 Vertical **Scale** controls to set both channel 1 and channel 2 to **2.0 V/div.**
6. Turn the channel 1 and channel 2 Vertical **Position** controls to position channel 1 in the upper half of the screen and channel 2 in the lower half.
7. Turn the front-panel Horizontal **Scale** control to set the horizontal scale to **20.0µs/div.**

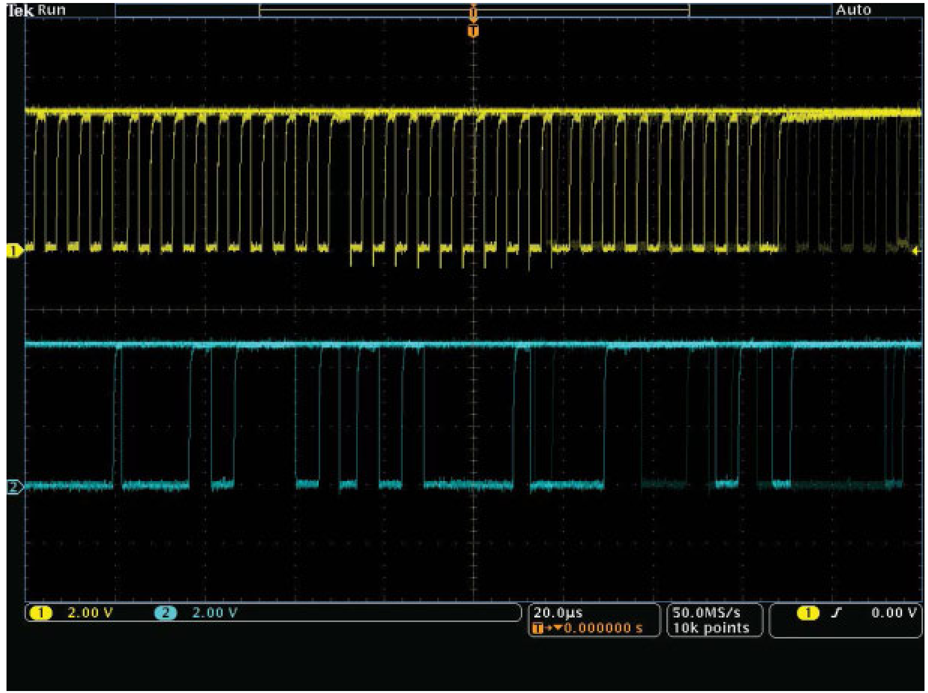


Figure 14.

8. Press the **B1** Bus front-panel button.
9. Press the **Bus B1** lower-bezel button and turn Multipurpose **a** to select **I2C.**
10. Press the **Define Inputs** lower-bezel button.
11. In the side menu, confirm that the SCLK Input is set to channel 1 and that the SDA Input is set to channel 2.

Figure 15.

12. Press the **Thresholds** lower-bezel button.
13. Turn multipurpose **a** and **b** to set the thresholds at about the midpoint of each waveform. You could also use the presets for common logic family voltages from the **Choose Preset** side menu.
14. Press the front-panel **Menu Off** button once to remove the side menu.
15. Press the front-panel **Single** button to acquire a single acquisition.

Now the scope automatically decodes I²C bus. The decode bus may be different from what you see here.

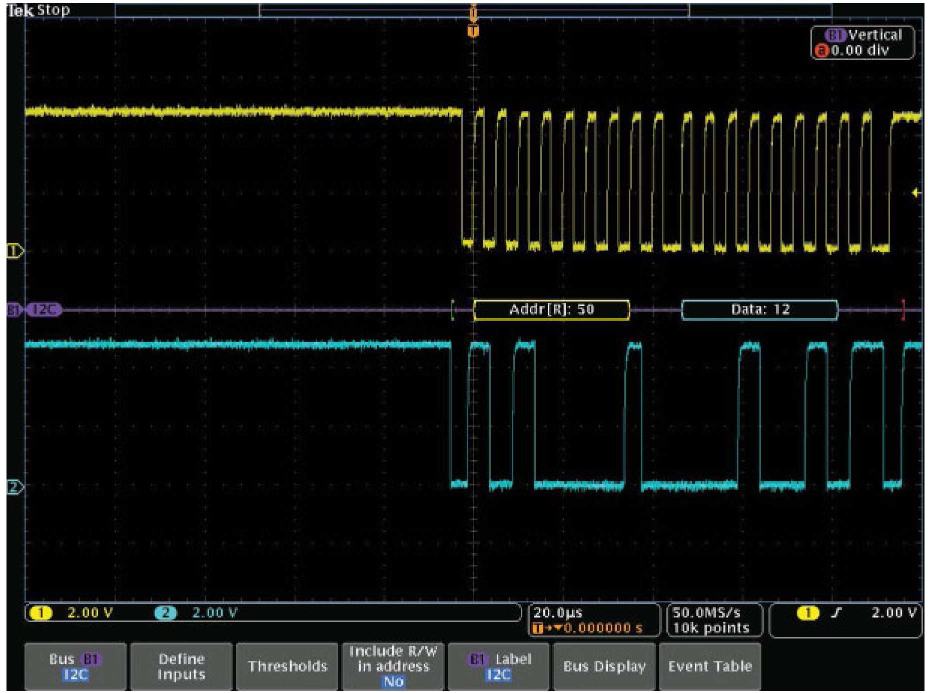


Figure 16.

When debugging a system, you often want to capture the state of some key signals when a certain event occurs. One key event may be the transmission of specific data over the I^2C bus.

The MDO4000C Series Oscilloscope triggers on:

- Start
- Repeat Start
- Stop
- Missing Acknowledgements
- Address
- Data
- Address & Data

To trigger on a specific address, follow these steps:

16. Press the front-panel Trigger **Menu** button.
17. Press the **Type** lower-bezel button and turn Multipurpose **a** to select **Bus**.
18. Press the **Trigger On** lower-bezel button.

Notice the list of trigger choices. The key is that you can trigger on all the important components of an I^2C packet. Prior to this, you had to hope that the acquisition you were making contained the data of interest. Now you can guarantee it by specifying the trigger condition.

19. Turn Multipurpose **a** to select **Address.**
20. Press the **Address** lower-bezel button.
21. The **Address** side-bezel button should already be selected.
22. Turn Multipurpose **a** and **b** to enter a hex address of **50.**
    - Turn Multipurpose **a** clockwise to the first ‘X’ under Hex
    - Turn Multipurpose **b** clockwise to show the digit ‘5’.
    - Turn Multipurpose **a** clockwise to move the cursor to the next ‘X’
    - Turn Multipurpose **b** clockwise to show the ‘0’ digit

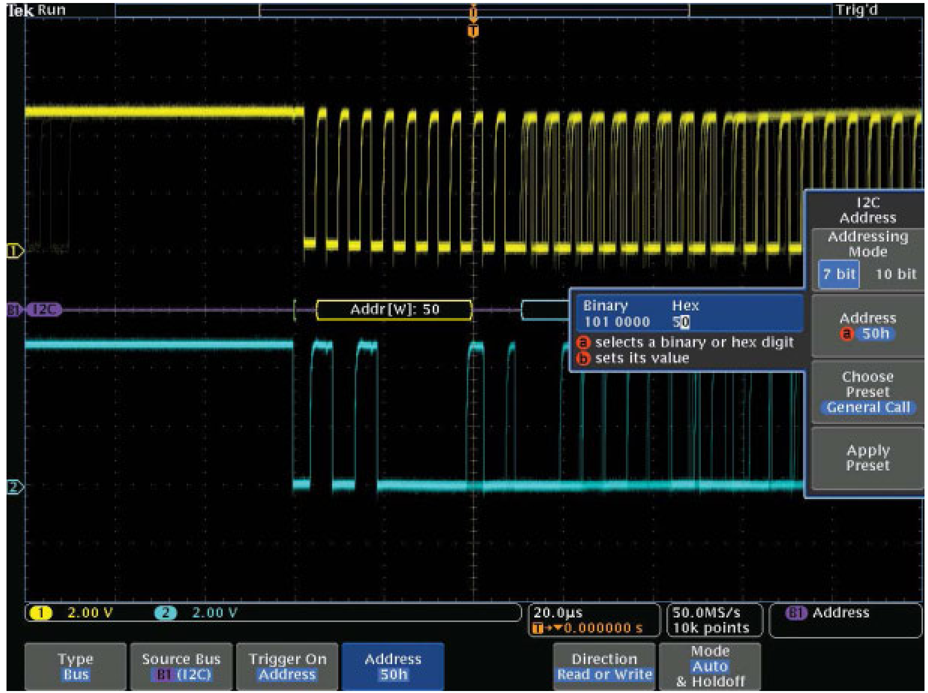


Figure 17.

23. Press the **Direction** lower-bezel button.
24. Select the **Write** side-bezel button.
25. Press **Single** to make an acquisition.
26. Press **Menu Off** once.

Notice that the oscilloscope now triggers on writes to address 50.

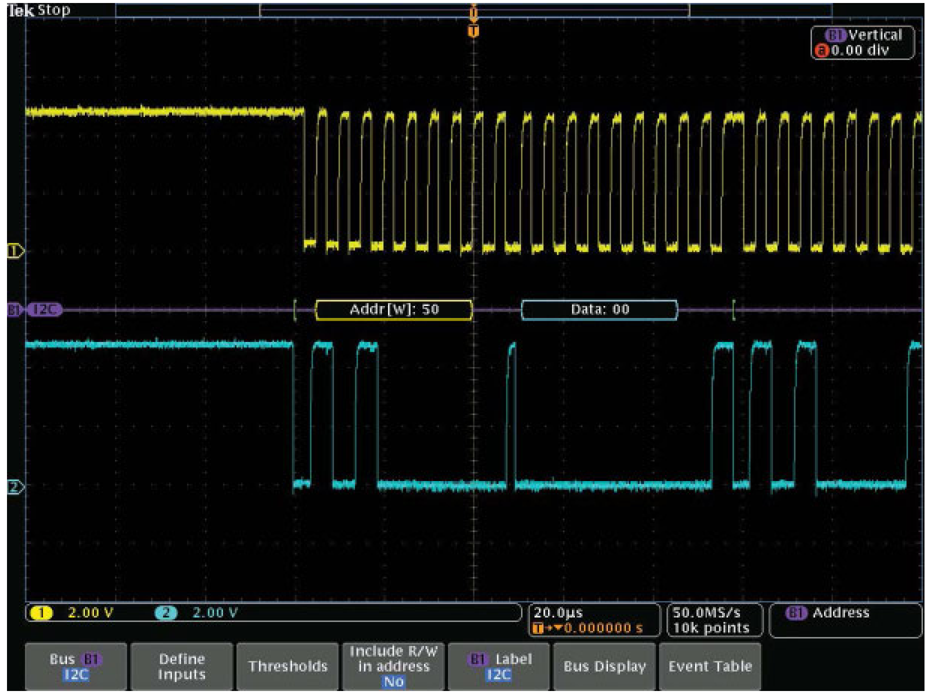


Figure 18.

In addition to seeing decoded packet data on the bus waveform itself, you can view all captured packets in a tabular view much like you would see in a software listing. Packets are time stamped and listed consecutively with columns for each component (Address, Data, etc.).

To view an event table:

27. Turn the front-panel Horizontal **Scale** control to set the horizontal scale to **20.0 ms/div** to capture more data.
28. Set the record length to 1M points or higher to capture more details of the signal. To change the record length, press **Acquire,** press the **Record Length** lower-bezel button, and then select **1Mpoints.**
29. Press **Single.**
30. Press the **B1** Bus button.
31. Press the **Event Table** lower-bezel button.
32. Press the **Event Table On** side-bezel button.
33. Scroll through table with Multipurpose **a.**

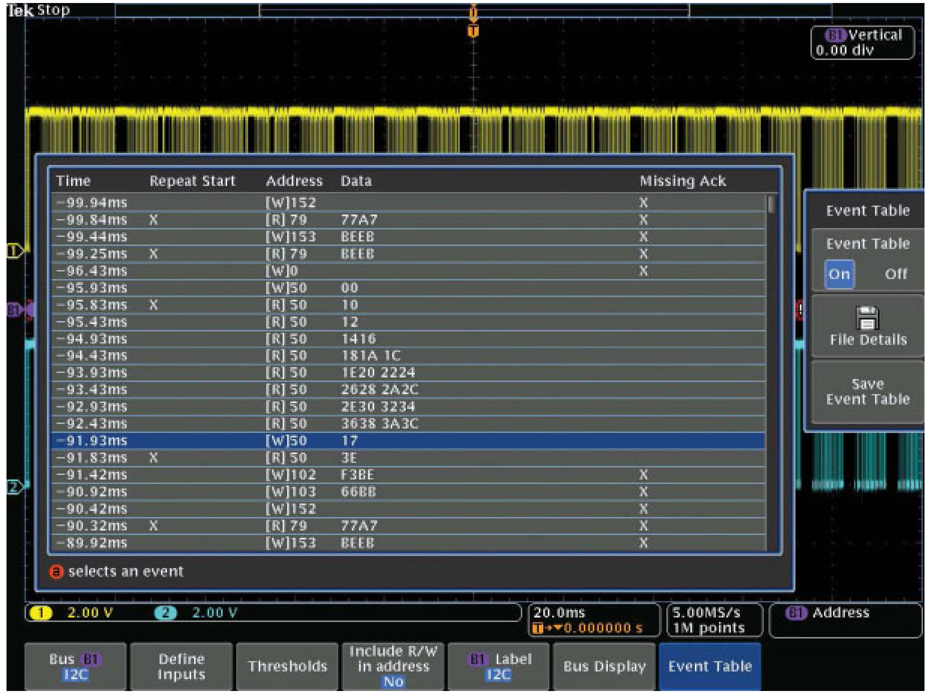


Figure 19.

You can also search for specific values or packets. To search for data value hex 17:

34. Press the **Search** front panel button.
35. Press the **Search** lower-bezel button and turn on search by pressing the **Search On** side-bezel button.
36. Define the search type by pressing the **Search Type** lower-bezel button and selecting **Bus.**
37. Define the search criteria by pressing the **Search For** lower-bezel button, selecting **Data,** and pressing the **Data** lower-bezel button.
38. Press the **Data** side-bezel button and set hex data to **17h**.

The oscilloscope automatically finds all occurrences in the acquisition that meet the search criteria and marks each event with a hollow white triangle at the top of the display. Notice the number of search events in the lower left corner. Wave Inspector automated searches save you time and give you confidence that all events have been found.

Now you can use the Wave Inspector controls to zoom in and manually navigate among the marks to examine the signal details.

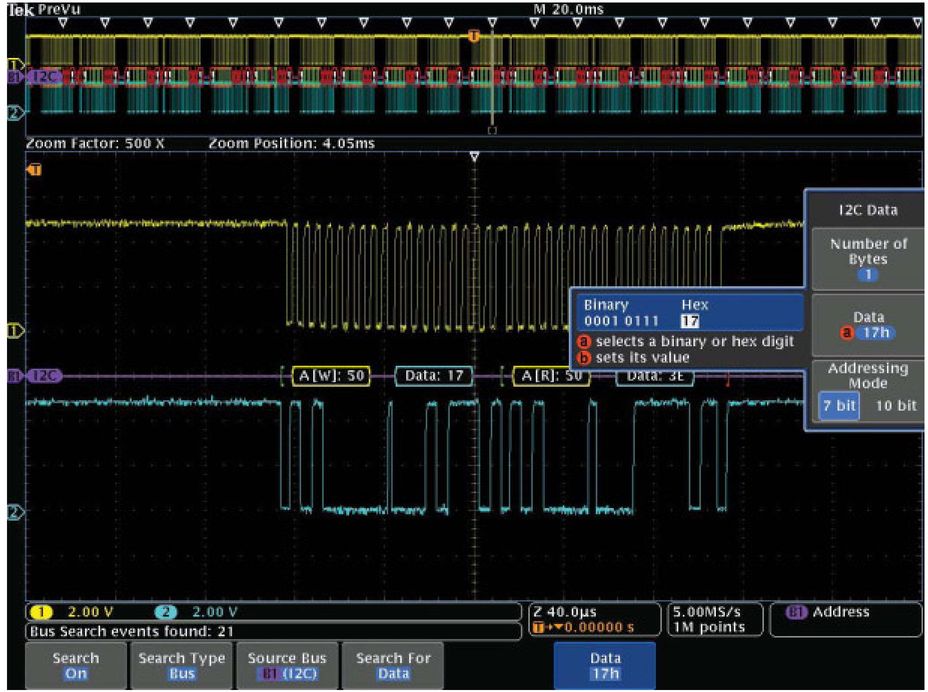


Figure 20.

Exercise 4

Acquiring Analog and Digital signals of a D/A Converter

Most embedded systems contain a mix of analog and digital circuitry. MDO4000C Series oscilloscope with its Mixed Signal Oscilloscope capability enables the acquisition of analog and digital signals and displays them time correlated on the display, providing insight into your complete system operation. Automated measurements work on both analog and digital channel data making it easy to learn even more about your signal behavior. And because everything is automatically time correlated, cursor measurements work across analog and digital channels. The digital channel monitor shows activity on digital channels at a glance without having to turn them on.

This exercise demonstrates how this oscilloscope can be used to simultaneously view analog and digital signals by probing both sides of a simple D/A convertor.

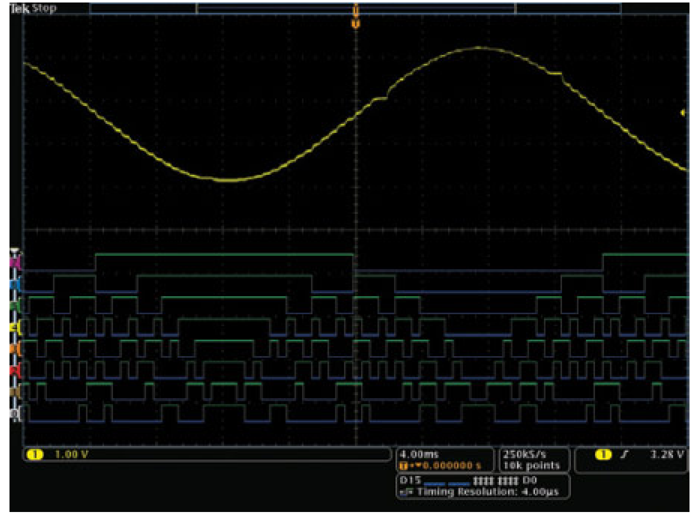


Figure 21.

Note: You could purchase the MDO4MSO instrument option to add 16 digital channels to your MDO4000C, which includes the P6616 digital probe and accessories. For demonstration purposes, many application modules and options are enabled in MDO4000C demo units.

1. Connect Channel 1 to the DAC_OUT signal on the demonstration board. Connect the probe's ground lead to a point labeled GND on the demonstration board.
2. Connect the P6616 Logic Probe to the front-panel Logic Probe connector below the oscilloscope display.

Note: Firmly insert the connector into the probe port on the front of the oscilloscope until you hear an audible 'click'. Test that you cannot remove the probe without pressing the buttons on the sides of the connector.

3. Connect Group 1 of P6616 digital probe to J1002 header labeled DAC_IN_0 through DAC_IN_7 on the demonstration board.

Note: Make sure to connect the signal side of the probe header, with the color-coded channel labels, to the signal side of the connector and the ground side of the probe to the ground side of the connector.

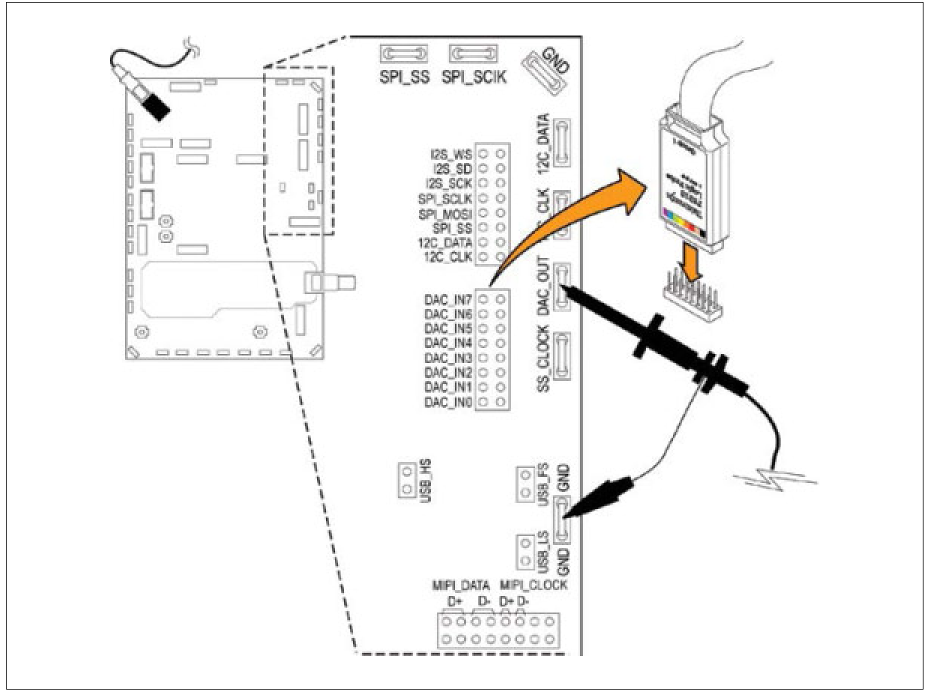


Figure 22.

4. Press the front-panel **Default Setup** button.
5. Change the Horizontal **Scale** to **4.00ms/div.**
6. Set the trigger level to 50% of Ch1 by pressing the trigger **Level** control.
7. Adjust the Vertical **Position** to place the signal in the middle of the upper half of the display.
8. Press the trigger **Menu** front panel button.
9. Press the **Coupling DC** lower-bezel button. Select the **HF Reject** side-bezel button to reject high frequency components of the signal.

Figure 23.

10. Press the blue **D15-D0** front-panel button and the **D15-D0 On/Off** lower-bezel button.
11. Press the **Turn On D7-D0** side-bezel button to display channels D0 through D7.
12. Press the **Monitor** lower-bezel button to turn on the digital channel Monitor.
13. Press **Single** to make an acquisition.
14. Press the **B1** Bus front-panel button.
15. Press the **Define Inputs** lower-bezel button.
16. Use the Multipurpose **a** control to set the Number of Data Bits to **8.**
17. Press the **Menu Off** button once.
18. Use the Multipurpose **a** control to position the parallel bus waveform on the display.
19. Use the front-panel Wave Inspector controls to zoom in and examine the signal details.

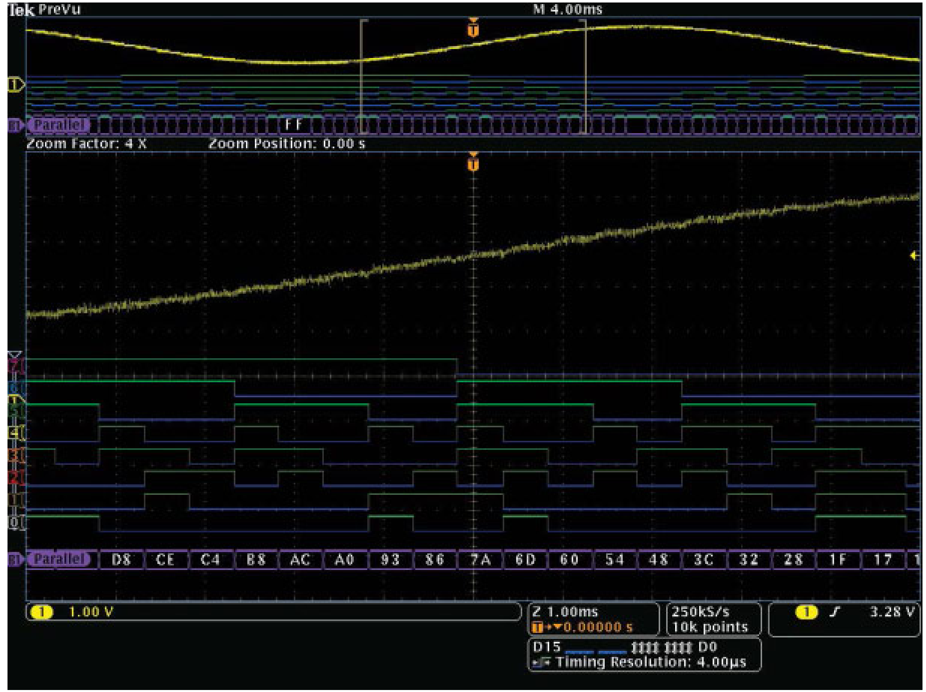


Figure 24.

Exercise 5

Generating Waveforms with the Integrated AFG

Arbitrary function generators (AFG) are useful in a number of applications, including adding noise to signals to test noise immunity in a system, emulating missing components in a design, and sweeping frequencies or modulating signals for characterization in time/frequency domains.

The MDO4000C Series oscilloscope with the 50 MHz integrated AFG can easily replicate signals acquired by the oscilloscope with added noise or other analog characteristics.

The MDO4000C also works in conjunction with ArbExpress PC-based arbitrary waveform editing software to create even more complex waveforms that can be generated by the AFG in the oscilloscope.

This exercise shows how you can capture a waveform on the oscilloscope, transfer it to the arbitrary function generator and replicate it.

Note: You could purchase the MDO4AFG option to enable the AFG functionality. For demonstration purposes MDO4AFG option is enabled in MDO4000C demo units.

1. Connect a BNC cable to Channel 1 and to the AFG OUT connector on the rear of the oscilloscope.
2. Connect a passive probe to Channel 2 on the oscilloscope.
3. Connect the ground lead of the probe to the GND point and the probe tip to the RARE_ANOMALY signal on the demonstration board.
4. Press the **Default Setup** front-panel button.
5. Press the Channel **1** front-panel button twice to turn off channel 1 and press the Channel **2** front-panel button to turn on channel 2.
6. Turn the Horizontal **Scale** control to select **200 ns/div.**
7. Press trigger **Menu,** press the **Type** lower-bezel button, and use Multipurpose **a** to scroll down to **Runt.**
8. Press the **Source 1** lower-bezel button and change the source to Channel **2.**

Figure 25.

9. Press the **Thresholds** lower-bezel button, adjust High to approximately **2.00 V** using Multipurpose **a,** and adjust Low to about **1.00 V** using Multipurpose **b.**
10. Press the **Mode** lower-bezel button. Press the N**ormal** side-bezel button.
11. Press **Single** to take one acquisition.
12. Press the **AFG** front panel button to open the AFG menu.
13. Press the **Waveform Sine** lower-bezel button, and use Multipurpose a to select **Arbitrary.**
14. Press the **Waveform Edit** lower-bezel button.
15. Press the **Load Waveform** lower-bezel button.
16. Press the **OK Load** button to copy the acquired waveform on Channel 2 into the arbitrary edit memory.

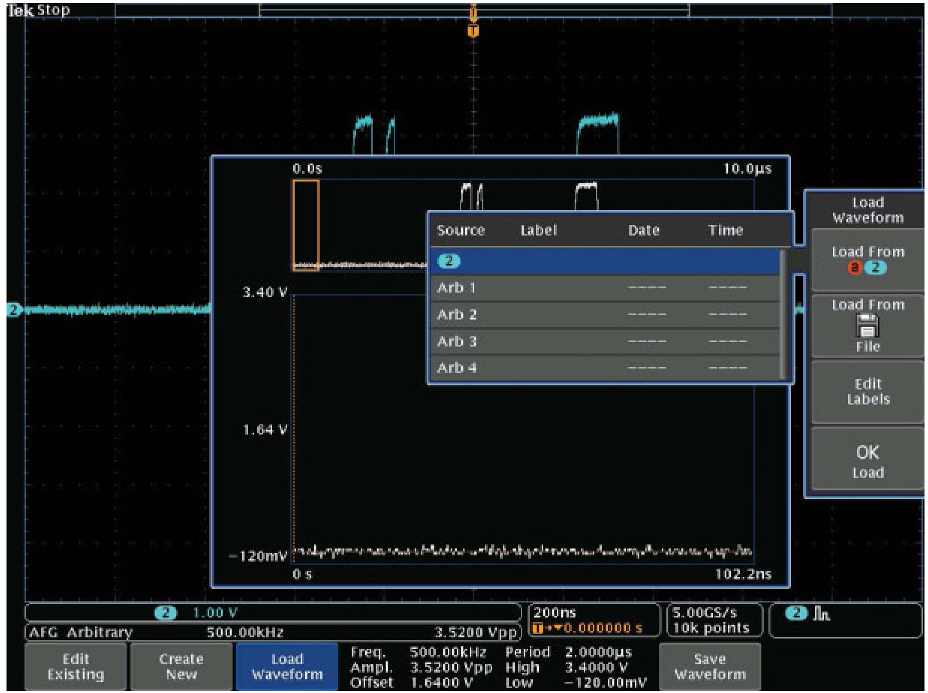


Figure 26.

17. Press the Channel **2** front panel button twice to turn off channel 2 and press the Channel **1** front panel button to turn on channel 1.
18. Press the **Run/Stop** front panel button to start acquiring the output of the AFG.
19. Turn the front-panel channel 1 Vertical **Scale** control to set channel 1 to **1.00 V/div.**
20. Press the Trigger **Menu** front panel button.
21. Press the **Source** lower-bezel button and change the source to Channel **1.**
22. Press the **Thresholds** lower-bezel button, adjust High to approximately **2.00 V** using Multipurpose **a,** and adjust Low to about **1.00 V** using Multipurpose **b.**

Now you are triggered on the runt signal generated by MDO4000C's integrated AFG.

Figure 27.

Exercise 6

Measuring Signals with the Integrated DVM / Frequency Counter

The integrated digital voltmeter (DVM) is free when you register your MDO4000C. It monitors voltage values of critical signals or power rails in your system at a glance without having to connect a separate meter. The oscilloscope offers 4-digit Voltage Measurements for AC+DC RMS, AC RMS, and DC and 5-digit Frequency Measurement through the same probes as the oscilloscope channels. This functionality is decoupled from the scope trigger circuit allowing for uninterrupted measurements that are always available and updating, even when the scope is not running.

This exercise shows how you can measure DC voltage on a signal over time.

1. Connect a BNC cable to Channel 1 and to the AFG output on the rear of the oscilloscope.
2. Press the **Default Setup** front-panel button.
3. Press the **AFG** front panel button to bring up the AFG menu.
4. Select the **Waveform Settings** lower-bezel button to change the Amplitude and Offset of the sine waveform.
5. Use the key pad (or Multipurpose **a** and **b**) and side-bezel buttons to set the AFG output to a **Sine** wave at **100 kHz** Frequency, **1Vp-p** Amplitude, and a **500mV** Offset.
6. Set Horizontal S**cale** to **10µs/div.**
7. Set Ch1 Vertical **Scale** to **200mV/div** and use vertical **Position** to center the waveform on the display.
8. Press the Trigger **Level** control to set the trigger level to 50% of Ch1.

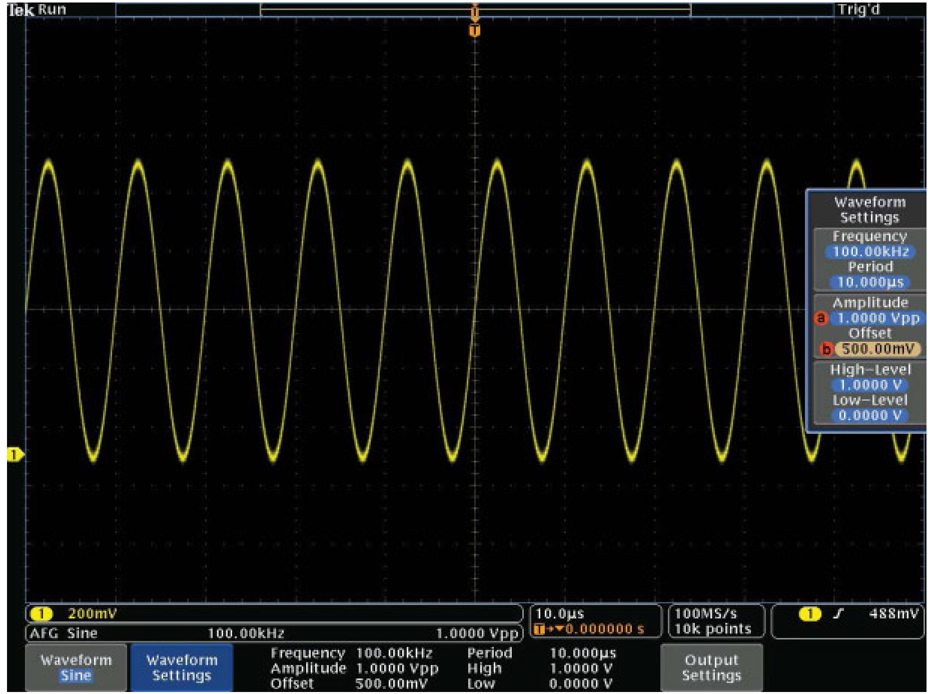


Figure 28.

9. Press the **Measure** front panel button.
10. Press the **DVM** lower-bezel button to turn on the DVM.
11. Use Multipurpose **a** to choose **DC** Full DVM display.
12. Press **Menu Off** to remove all menus.

The easy-to-read display offers you both numeric and graphical representations of the changing measurement values. The readouts at the right side of the display accumulate the minimum, maximum, and average values of the measurement over the entire measurement period. The graphic shows the range of values measured over the previous five second interval.

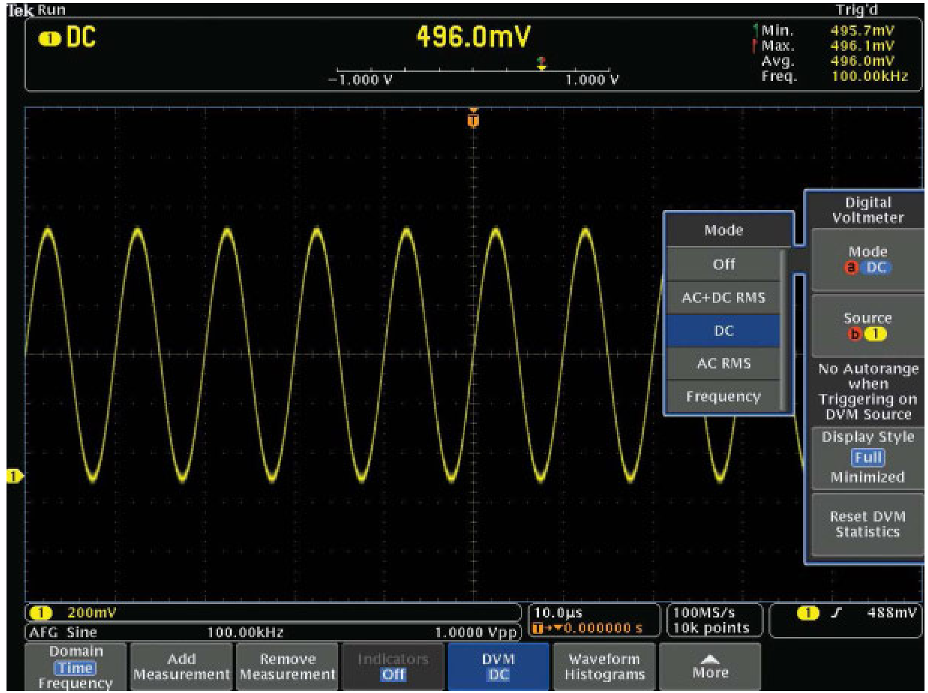


Figure 29.

Exercise 7

Fast and Accurate Spectral Analysis with Integrated Spectrum Analyzer

With the addition of a true RF acquisition system, N-connector, and dedicated spectrum analyzer controls and user interface, any MDO4000C Series product can be equipped with an integrated spectrum analyzer. The MDO4000C's spectrum analyzer offers better RF measurement performance than FFT math operations found on traditional oscilloscopes.

Now you can continue to use your tool of choice – the oscilloscope – for all of your debugging needs, regardless of time or frequency domain. When the need arises to view RF signals, it is far simpler and faster to continue using your tool of choice – the oscilloscope – rather than finding and relearning a spectrum analyzer.

When using the spectrum analyzer by itself, the MDO4000C looks and operates just as a like a stand-alone spectrum analyzer. This exercise shows the automated markers and spectrogram functionality on the MDO4000C.

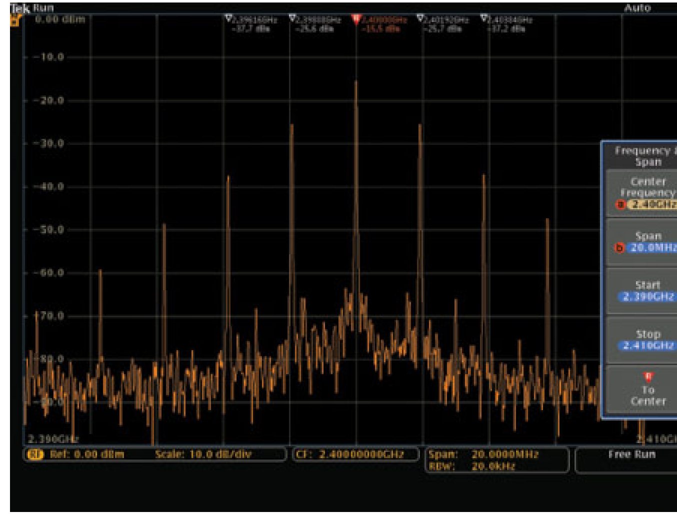


Figure 30.

Note: You could purchase option SA3 to enable the spectrum analyzer with a 3 GHz input range, or option SA6 to enable the spectrum analyzer with a 6GHz input range, on your MDO4000C. For demonstration purposes, the SA6 option is enabled in MDO4000C demo units.

A. Spectral Peak Identification

Identifying peaks in your spectrum is one of the first steps to understanding the behavior of your design. Whether you are using the basic marker functions or analyzing noise density or phase noise, easy-to-use tools are critical for saving time.

Simply define threshold and excursion values to automatically mark all peaks that meet your criteria. Or use manual markers to investigate any non-peak areas of the spectrum.

This exercise demonstrates how the frequency and amplitude of peaks in the spectrum are quickly identified with automatic peak markers.

1. Attach an N-to-BNC adapter to the RF input on the oscilloscope.
2. Connect a BNC cable to the adapter.
3. Connect the other end of the cable to the RF Out (BNC) connector on the demonstration board.
4. Press the **Mode** button on the MDO Demonstration board until the Multiple Peaks LED is lit.
5. Press the **Default Setup** front-panel button.

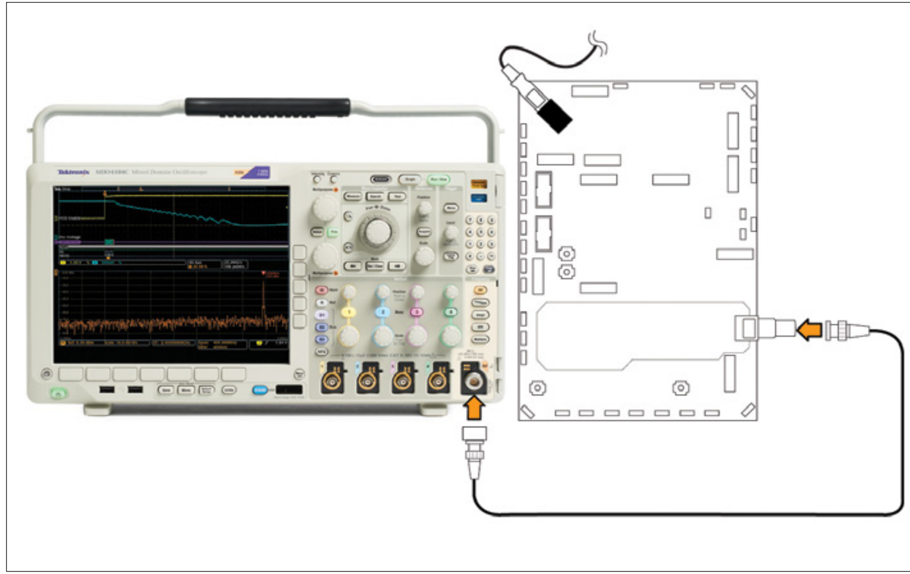


Figure 31.

6. Press the channel **1** front panel-button twice to turn off channel 1.
7. Press the **RF** front panel button to turn on the RF channel.
8. Press the **Freq/Span** front-panel button under the spectrum analyzer controls.
9. Use Multipurpose **a** or the 10-digit keypad to set the Center Frequency to **2.4 GHz.**
10. Use Multipurpose **b** to set the Span to **20 MHz.**
11. Press the **Markers** front-panel button.
12. Use Multipurpose **a** to set number of Peak Markers to **11**.
13. Press the **Threshold** side-bezel button and use Multipurpose **a** to set threshold to **-70.0 dBm.**

Notice that peaks meeting the criteria are indicated with Absolute Frequency and Amplitude Readouts. The highest-amplitude peak is the Reference Marker and is shown in red.

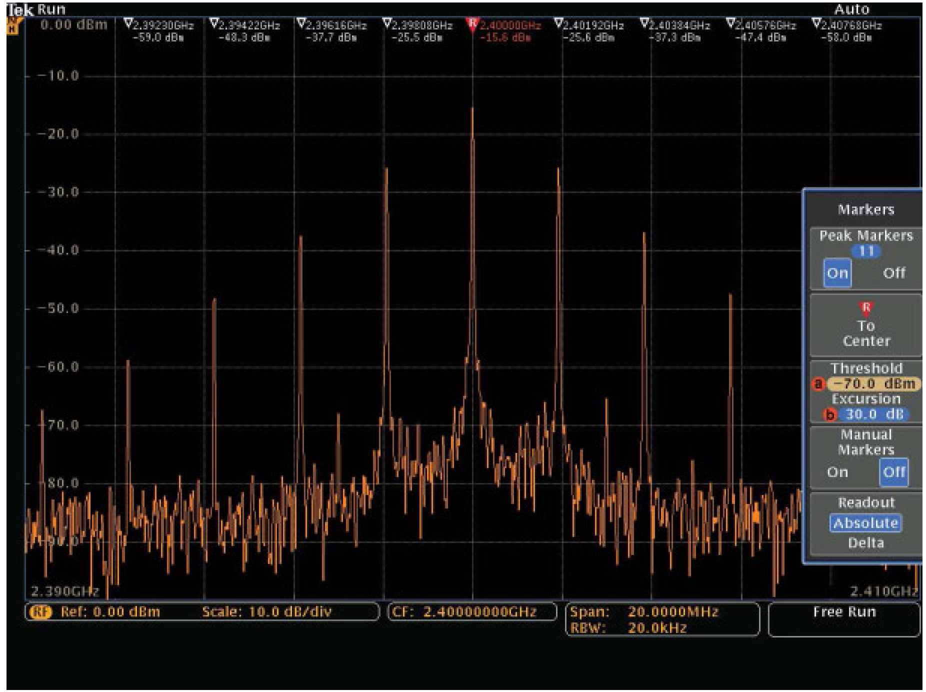


Figure 32.

14. Press the **Readout** side-bezel button to select **Delta.**

Notice peak readouts are now relative to the Reference Marker (the red triangle).

15. Press the **Manual Markers** side-bezel button.

Notice the Ref Marker can now be moved anywhere via manual markers and the second marker allows you to investigate non-peak areas of the spectrum.

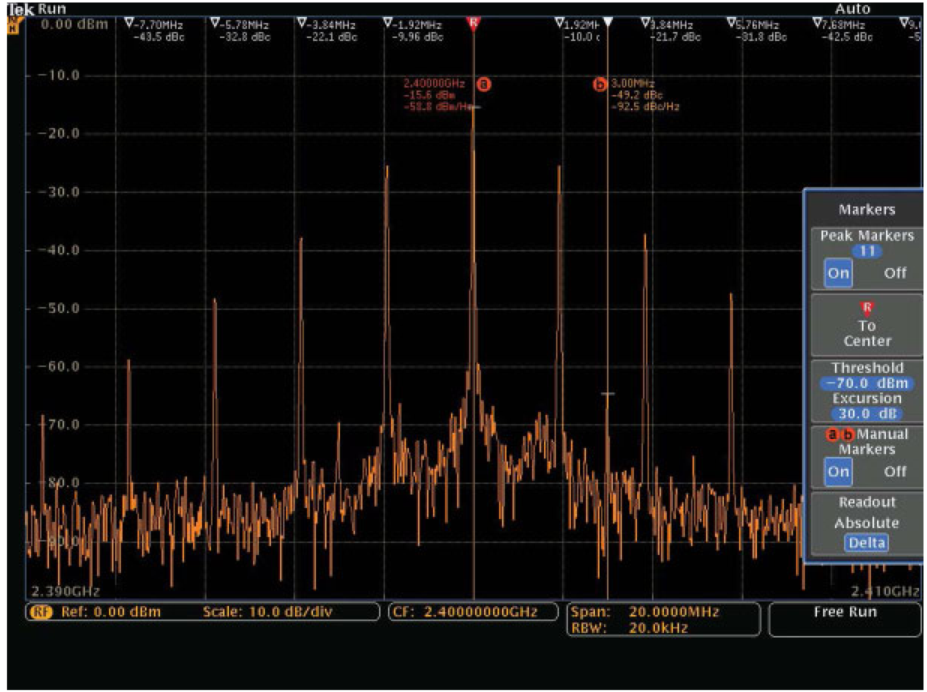


Figure 33.

B. Spectrogram Demonstration

Spectrograms are useful for monitoring slowly-changing RF events, and for identifying low amplitude signals that are too subtle for the eye to catch. The spectrogram display provides an intuitive color map showing how the signal varies over time. You can even go back and compare previously acquired data.

You can monitor portions of the signal (triggered) or look at a wider range of signals (free run). For many designs, spectrum analysis begins with signal visualization and the spectrogram makes this task even easier.

This exercise demonstrates how the oscilloscope spectrogram shows what is happening in the spectrum over time, and shows how to look at the Spectrum Slices using the Multipurpose a control.

1. Follow step 1 to 3 in the previous exercise to connect the RF channel to the demonstration board.
2. Press the **Mode** button on the Demonstration board until the Spectrogram LED is lit.
3. Press the **Default Setup** front-panel button.
4. Press the channel **1** front panel-button twice to turn off channel 1.
5. Press the **RF** front panel button to turn on RF channel.
6. Press the **Freq/Span** front-panel button.
7. Press the **R to Center** side-bezel button to set the Center Frequency to the frequency of the reference marker.
8. Use Multipurpose **b** to set span to **10 MHz.**
9. Press the **Ampl** front-panel button.
10. Using the Multipurpose **a** control, set the Ref Level to **-10.0 dBm.**

Notice that the amplitudes and frequencies of the spectral peaks are moving over time.

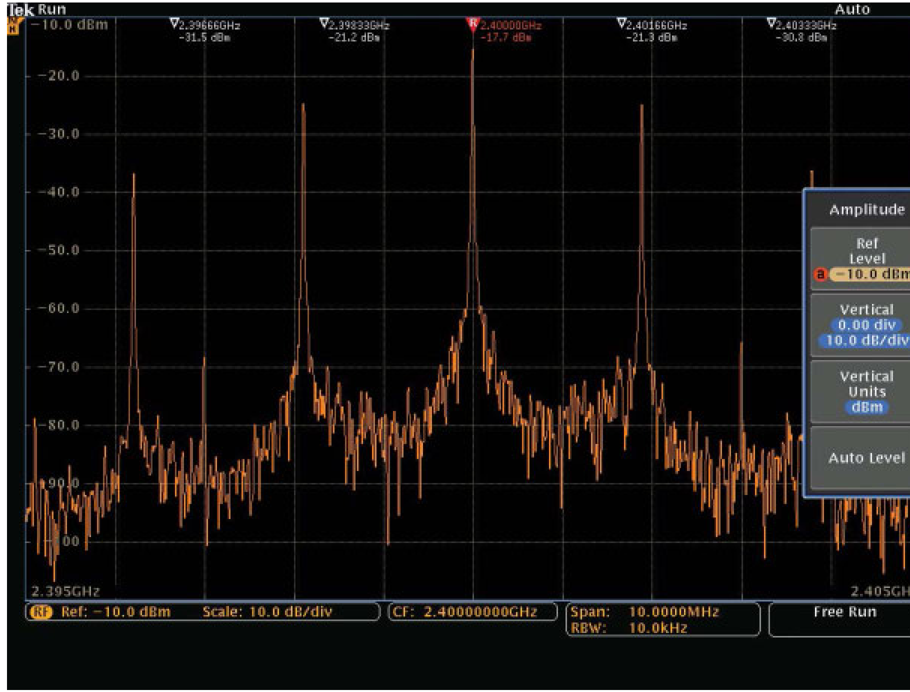


Figure 34.

11. Press the **RF** front panel button to turn on the RF menu.
12. Press the **Spectrogram** lower-bezel button.
13. Press the **Display On** side-bezel button to turn on the spectrogram.

A Spectrogram shows how the spectrum changes over time. The x-axis is frequency, the y-axis is time. A Spectrogram is created by taking each spectrum and flipping it up on its edge so that it's one pixel row tall and then using color to indicate amplitude. Hotter colors (red, yellow) indicate higher amplitudes while colder colors (blue, green) indicate lower amplitudes.

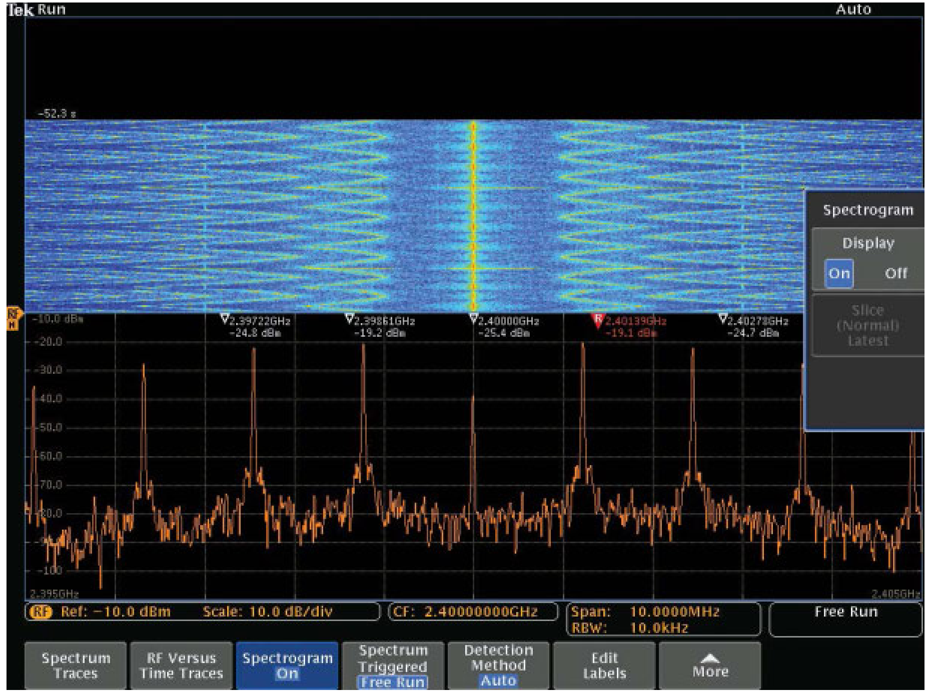


Figure 35.

14. Press the **Run/Stop** front panel button to stop acquiring.
15. Turn the Multipurpose **a** control to scroll through Spectrum Slices.

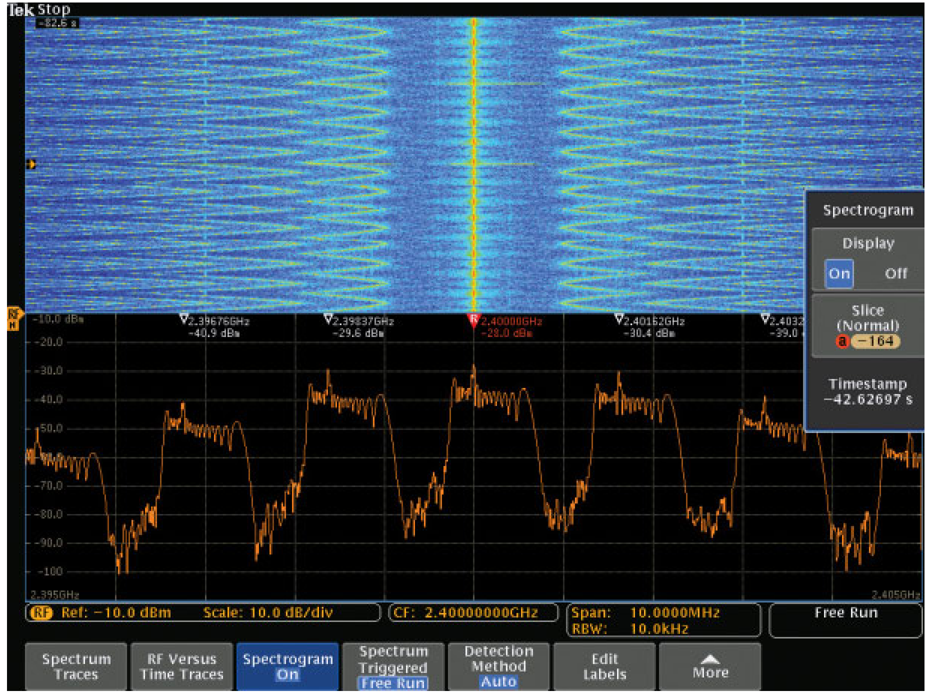


Figure 36.

Exercise 8

Mixed Domain Analysis: Viewing Complete System Activity

The MDO4000C Series can be used as an oscilloscope, or a spectrum analyzer, or combined to capture synchronized analog, digital, and RF signals. The power of the MDO4000C Series goes beyond simply observing the frequency domain as you would on a spectrum analyzer. The real power is in its ability to correlate events in the frequency domain with the time domain phenomena that caused them.

Debugging EMI or modern wireless-enabled designs often requires investigation of more than just the RF signal. Understanding timing relationships between the RF and other analog, digital, or bus signals in the device under test is critical but incredibly difficult with multiple stand-alone pieces of test equipment that weren't designed for the task.

Figure 37.

This demo shows the MDO4000C Series' unique ability to use a single trigger event to synchronize and display time-correlated analog, digital and RF signals, and to view the RF Spectrum at any point in time within the acquisition to see how it changes over time or with device state.

1. Connect Channel 1 probe tip to the VCO-1 Enable signal on the demo board. Connect the probe's ground lead to a point labeled GND on the demo board.
2. Connect Channel 2 probe tip to the PLL-1 Voltage signal on the demo board. Connect the probe's ground lead to a point labeled GND on the demo board.
3. Connect digital probe D0 to SPI_CLK, D1 to SPI_SS-1, and D2 to SPI_MOSI signals on the demo board.
4. Attach an N-to-BNC adapter to the RF input on the oscilloscope.
5. Connect a BNC cable to the adapter.
6. Connect the other end of the cable to the RF Out (BNC) connector on the demonstration board.
7. Press the **Mode** button on the MDO Demo board until the VCO/PLL-1 LED is lit.
8. Press the **Default Setup** front-panel button.

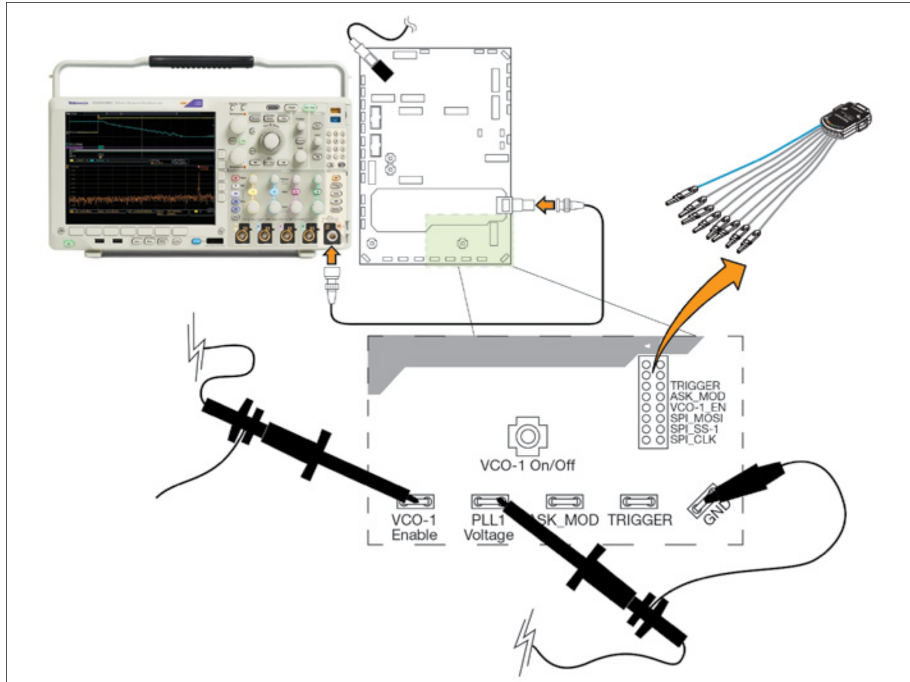


Figure 38.

9. Press the **Utility** front panel-button.
10. Press the **Utility Page** lower-bezel button and select D**emo** using Multipurpose **a.**
11. Press the **Spectrum Analyzer** lower-bezel button and the **VCO/PLL Turn On** side-bezel button.
12. Press the **Recall Demo Setup** side-bezel button.
13. Press the **Menu Off** front-panel button.
14. Press the **Single** front-panel button to arm the scope for an acquisition.
15. Press the VCO-1 Enabled button on the demo board. The LED next to the button should turn off.
16. Press the VCO-1 Enabled button again. The LED next to the button should light and the scope should acquire data.
17. Turn the outer ring of the front-panel Wave Inspector control counter-clockwise to move the Spectrum Time indicator (orange bar) to the left of the VCO Enable signal's rising edge. The frequency-domain display shows that the oscillator is not generating an RF signal prior to the VCO being enabled.

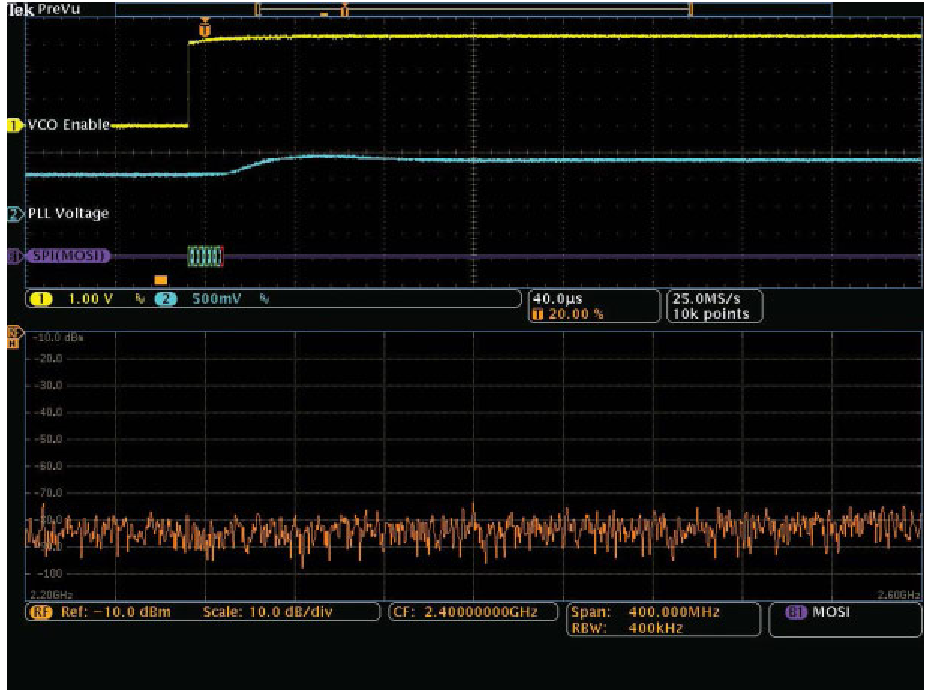


Figure 39.

18. Turn the outer ring of the front-panel Wave Inspector control clockwise to move the Spectrum Time indicator (orange bar) through the acquisition until the Spectrum Time indicator is near the right side of the display.

What's happening?

- The VCO (voltage controlled oscillator) is enabled when channel 1 goes high.
- Next a command on the SPI bus tells the VCO/PLL (phase-locked loop) circuit the desired frequency, which in this case is 2.4 GHz.
- Once the SPI command has been transmitted, the VCO/PLL circuit begins tuning to the desired frequency.
- In this screenshot, a single acquisition of the entire turn-on event has been made by triggering on the SPI serial bus command indicating the setting of the desired 2.4 GHz frequency.

With the MDO4000C Series, you can easily correlate frequency domain events with relevant time domain control signals, enabling you to quickly and easily make critical timing measurements such as time to stability of a VCO/PLL circuit.

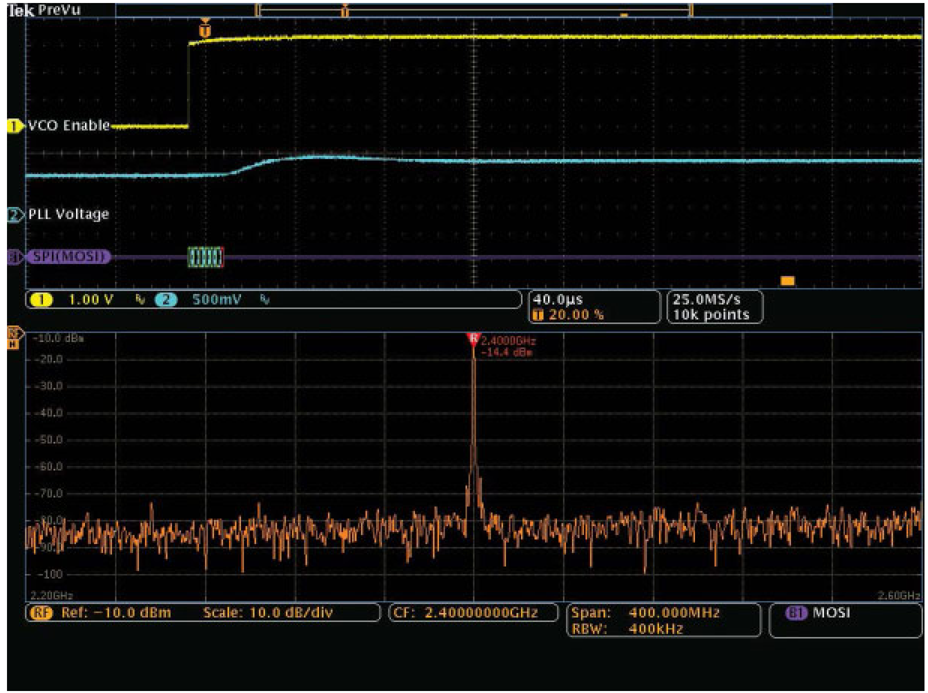


Figure 40.

Exercise 9

Quickly Characterize Time-Varying RF Events

Characterizing and correlating time-varying RF events with analog signals can be difficult and time-consuming. With the MDO4000C Series, you can easily monitor system behavior with easy-to-use signal visualization tools.

The MDO4000C series provides support for three RF time domain traces that are derived from the underlying I and Q data of the spectrum analyzer input including:

- RF Amplitude vs. Time
- RF Frequency vs. Time
- RF Phase vs. Time

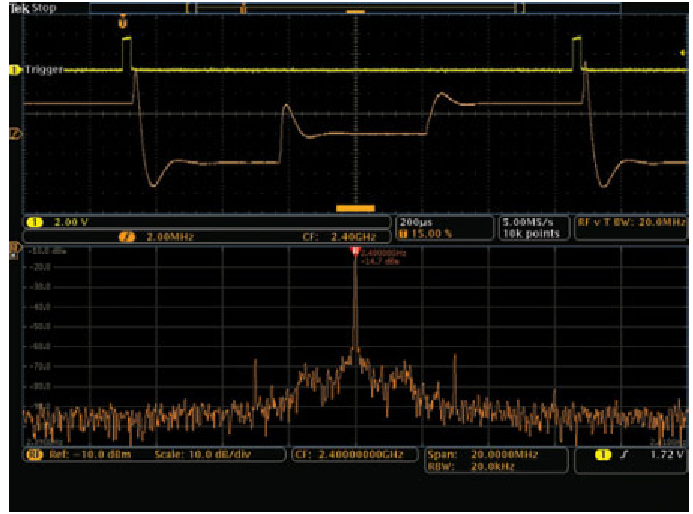


Figure 41.

This demo illustrates how to use the RF vs Time traces to quickly characterize time-varying events of a frequency-hopping signal (such as how long it takes to settle to a new frequency).

1. Connect Channel 1 to the TRIGGER signal on the demo board. Connect the probe's ground lead to a point labeled GND on the demo board.
2. Attach an N-to-BNC adapter to the RF input on the oscilloscope.
3. Connect a BNC cable to the adapter.
4. Connect the other end of the cable to the RF Out (BNC) connector on the demonstration board.
5. Press the **Mode** button on the MDO Demo board until the Frequency Hop LED is lit.
6. Press the **Default Setup** front-panel button.

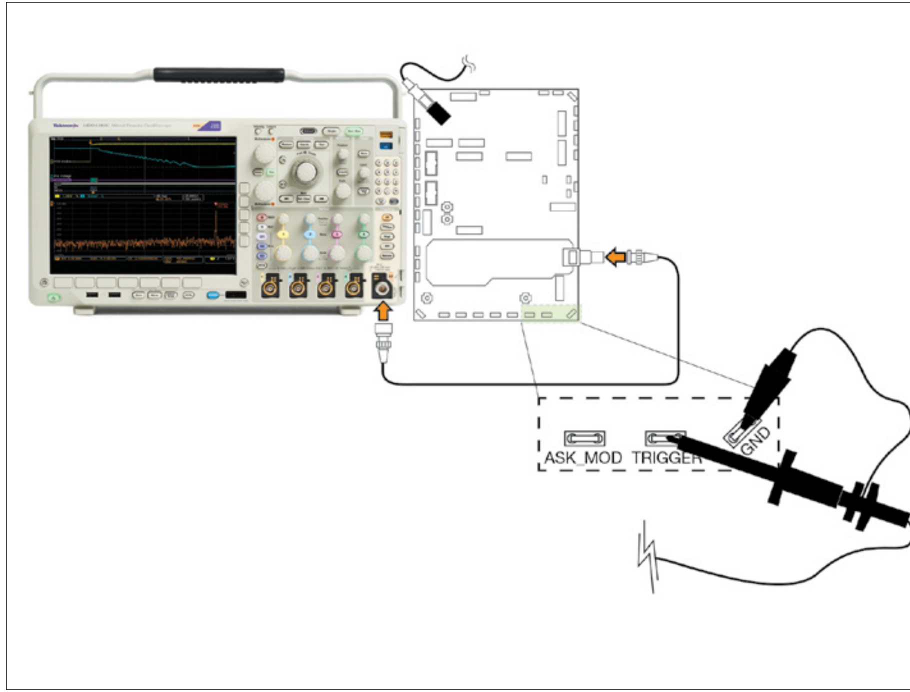


Figure 42.

7. Press the **Utility** front panel-button.
8. Press the **Utility Page** lower-bezel button and select **Demo** using Multipurpose **a.**
9. Press the **Spectrum Analyzer** lower-bezel button, the **–more-** side-bezel button, and the **Frequency Hop** side-bezel button.
10. Press the **Recall Demo Setup** side-bezel button.
11. Press the **Menu Off** front-panel button.
12. Press the **Single** front-panel button to acquire a single acquisition.
13. Turn the outer ring of the front-panel Wave Inspector control counter-clockwise to move the Spectrum Time indicator (orange bar) a couple of divisions to the left of the center of the display. As you move the Spectrum Time indicator, notice how the frequency versus time trace in the upper half of the display corresponds to the spectrum in the lower half of the display.

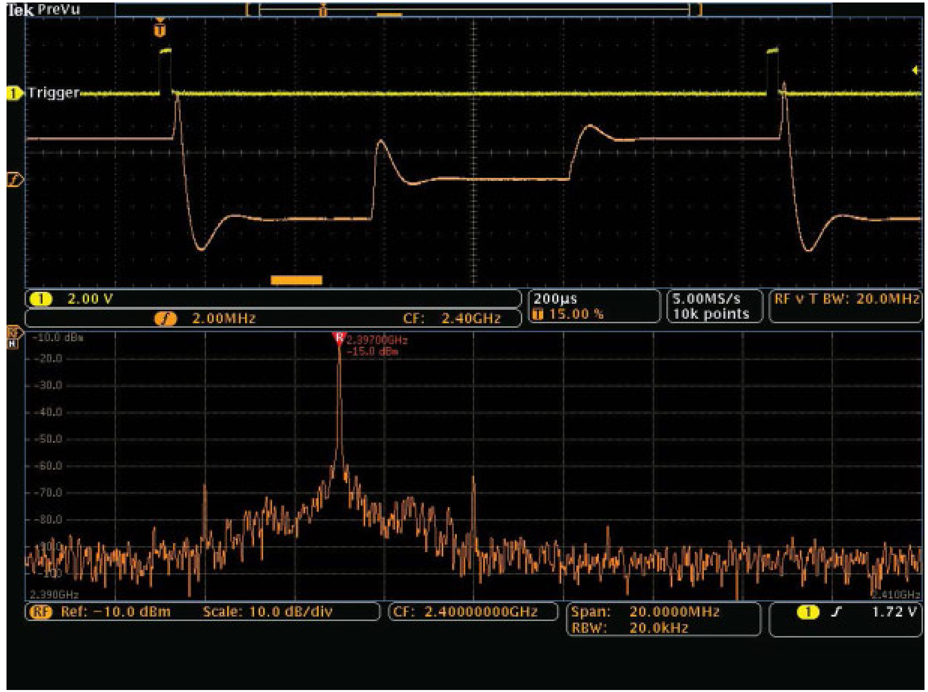


Figure 43.

14. Use the outer ring of the front-panel Wave Inspector control to move the Spectrum Time indicator (orange bar) through the acquisition to see how the spectrum changes with the Frequency Modulation.
15. Position the Spectrum Time indicator a couple of divisions to the right of the center of the display.

What's happening?

The Trigger signal on Channel 1 is a digital control signal that initiates the frequency hopping cycle. The VCO frequency is set to about 2.397 GHz, then increased to 2.400 GHz, and finally increased to about 2.403 GHz.

But notice that, between these stable frequency settings, the MDO4000C allows you to examine the time-domain undershoot and overshoot in the frequency versus time display, and the corresponding frequency-domain displays where the RF energy is smeared across the spectrum.

Note that you can quickly characterize time varying RF events (such as how long it takes to settle to a new frequency or how much overshoot/undershoot there is during a transition) with RF vs. time traces.

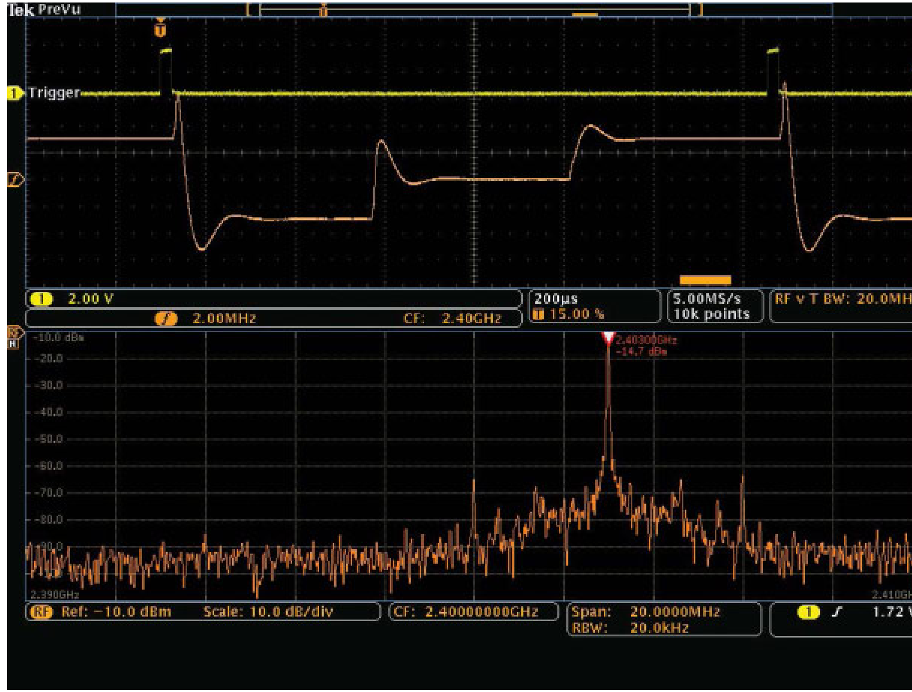


Figure 44.

Exercise 10

Capturing Wideband Signals

RF standards continue to evolve to wider bandwidths. In addition, many modern wireless devices transmit and receive over multiple bands. Traditional spectrum analyzers do not have the capture bandwidth necessary to debug these systems.

With the MDO4000C Series, you can see the whole spectrum of interest at any point in time with the up to 3 GHz ultra-wide capture bandwidth (approximately 100 times wider than the 10-40 MHz capture bandwidths of traditional spectrum analyzers).

Note: Combined with SignalVu-PC, the MDO4000C offers industry's widest bandwidth vector signal analyzer providing advanced modulation analysis.

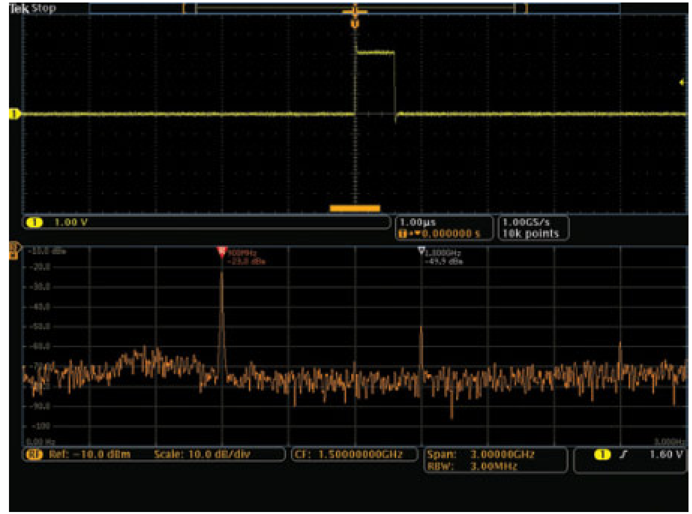


Figure 45.

This demo shows you the power of the MDO4000C's exceptionally wide capture bandwidth (up to 3 GHz) by capturing an RF device's transition from 900 MHz to 2.4 GHz in a single acquisition.

1. Connect the probe on Channel 1 to the TRIGGER signal on the demo board. Connect the probe's ground lead to a point labeled GND on the demo board.
2. Attach an N-to-BNC adapter to the RF input on the oscilloscope.
3. Connect a BNC cable to the adapter.
4. Connect the other end of the cable to the RF Out (BNC) connector on the demonstration board.
5. Press the **Mode** button on the MDO Demo board until the Capture BW LED is lit.
6. Press the **Default Setup** front-panel button.

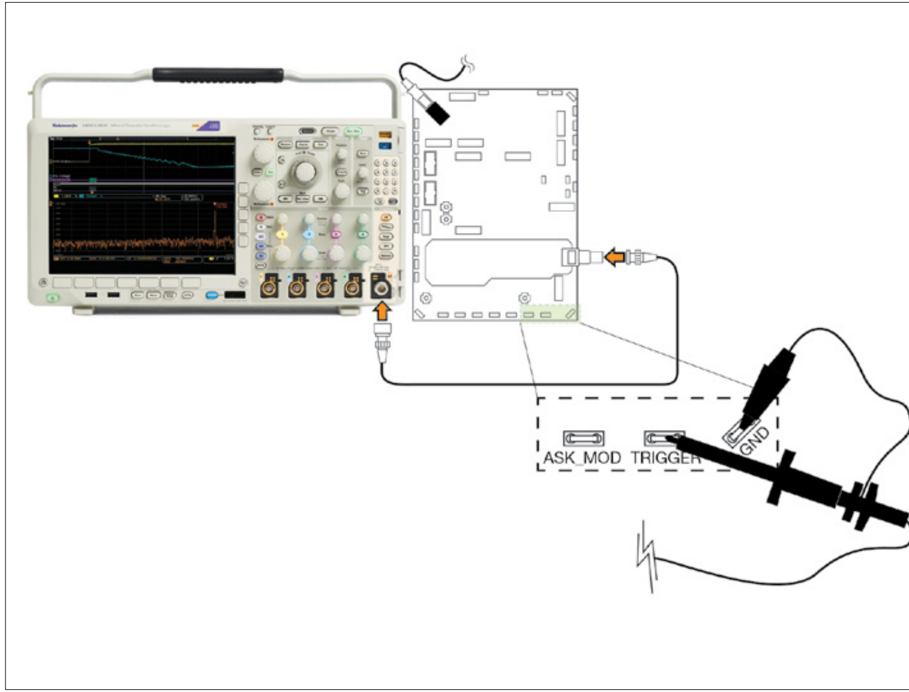


Figure 46.

7. Press the Utility front panel-button.
8. Press **Utility Page** and select **Demo** using Multipurpose **a.**
9. Press the **Spectrum Analyzer** lower-bezel button and the **Capture BW** side-bezel button. If necessary, press the **–more-** side-bezel button to display the second page of the menu.
10. Press the **Recall Demo Setup** side-bezel button.
11. Press the **Menu Off** front-panel button.
12. Press the **Single** front-panel button to acquire single acquisition.

Notice the Span is set to 3 GHz, indicating a 3 GHz capture bandwidth. Also, notice that the frequency-domain display clearly shows a 900 MHz signal (and its harmonics). The device under test is currently communicating to a device in the 900 MHz ISM radio band.

13. Turn the outer ring of the front-panel Wave Inspector control slowly clockwise, positioning the Spectrum Time indicator (orange bar) directly under the pulse on Channel 1. Notice that the 900 MHz signal has been turned off.

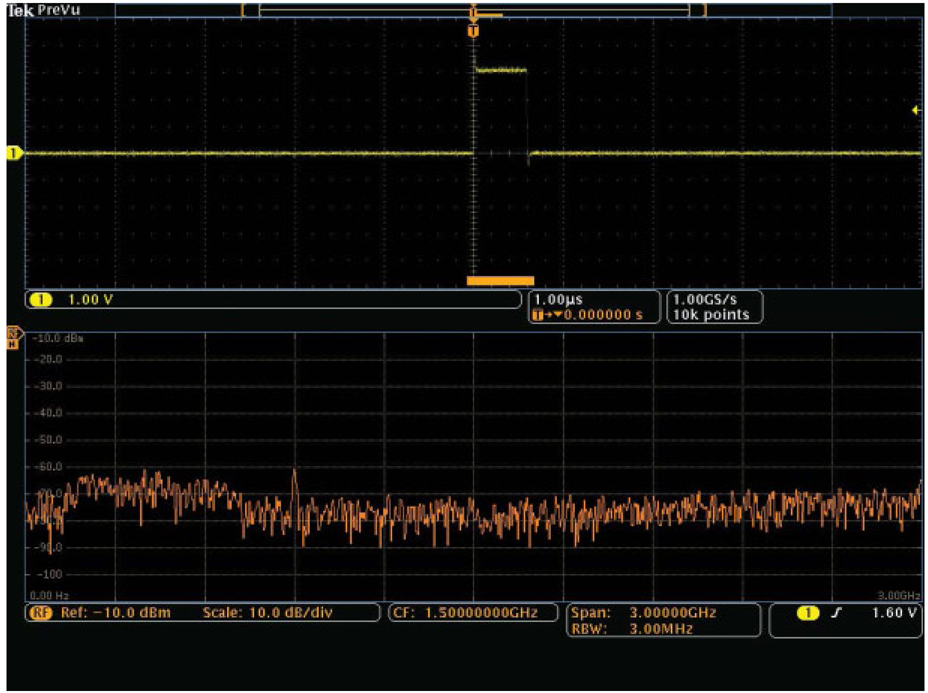


Figure 47.

14. Use the outer ring of the front-panel Wave Inspector control to move the Spectrum Time indicator (orange bar) before and after the pulse on Channel 1.
15. Position the Spectrum Time indicator a couple of divisions to the right of the center of the display.

What's happening?

The pulse seen on channel 1 is a control signal switching the RF output from 900 MHz to 2.4 GHz. We are capturing this transition in a single acquisition! This ability to look across 3 GHz of spectrum and correlate the RF activity to other analog and digital signals is unique to the MDO4000C Series.

In this screen shot, Spectrum Time has been moved to view the spectrum after the trigger event. In the spectrum, the digital control signal (the trigger event) results in the RF output switching from communicating from one device in the 900 MHz ISM radio band to another device in the 2.4 GHz ISM radio band.

Notice that both the 900 MHz and 2.4 GHz ISM radios bands are captured in a single acquisition. A typical spectrum analyzer with capture bandwidth of 10-40 MHz could not capture this wideband, transitory event.

Figure 48.

Locating Signals on Demo Board

The following diagram includes a grid to help you locate signal outputs. To find a particular signal output on the board, look up the connector grid location in the following Signal Descriptions section and use the grid location information to find the signal on the demo board.

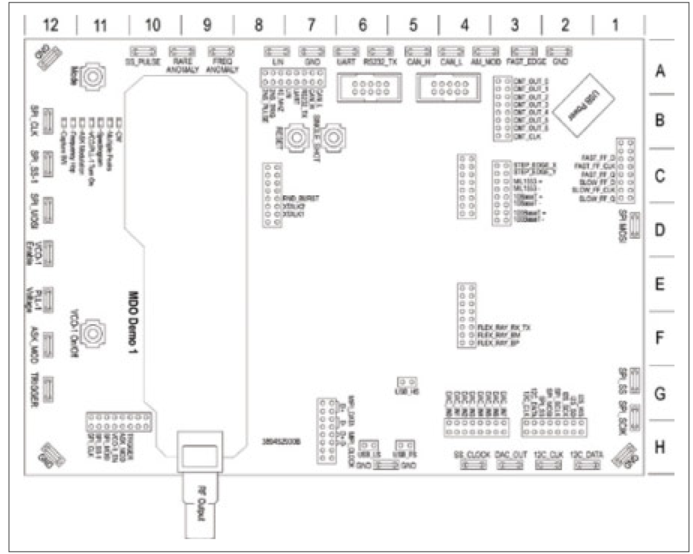


Figure 49.

Capture BW Demo

The RF output connector generates both a 2.4 GHz signal and a 900 MHz signal simultaneously to show the broad frequency capture capability.

The red LED labeled "Capture BW" at grid B12 turns on.

DAC Input, Parallel

Board label: DAC_IN0, DAC_IN1, DAC_IN2, DAC_IN3, DAC_IN4, DAC_IN5, DAC_IN6, DAC_IN7

Grid location: H3, H4

Description: These signals are the input to the DAC. These are also the 8-bit parallel output signals of the port expander in the middle of the mixed signal chain. The sine wave data from the SPI bus is converted to 8 parallel bits to drive the DAC. DAC_IN0 is the LSB. (See Figure 47.)

DAC Output

Board label: DAC_OUT

Grid location: H3

Description: This is the output of the DAC at the end of the mixed signal chain. The DAC is driven from the port expander. The DAC output is a sine wave. Since the output is not filtered, the digitizing levels are present in the output waveform. (See Figure 47.)

The resulting DAC voltage is a sine wave with an amplitude of 0 to 3 volts, and a period of 31 ms.

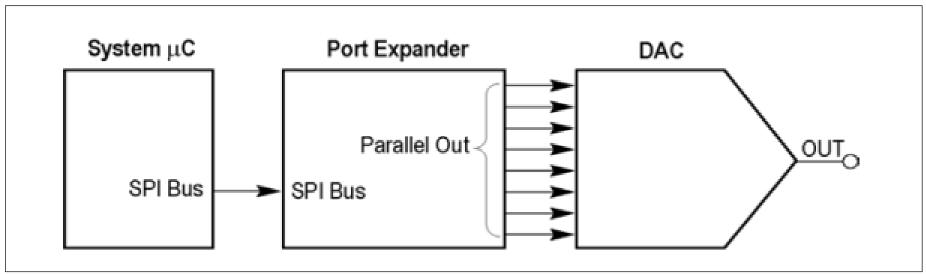


Figure 50. Mixed signal chain block diagram.

Frequent Anomaly

Board label: FREQ_ANOMALY

Grid location: A9

Description: There are two frequently occurring anomalies in this pulse train.

A half height runt signal occurs approximately every 104.8 ms. Use a Runt trigger to isolate the signal.

A 25 ns (narrow) pulse appears approximately every 104.8 ms. Use a Pulse Width trigger to isolate the signal.

The pulse train is a repeating group of three pulses. The three pulses are 100 ns, 200 ns, and 100 ns wide, with a 100 ns low between. The group repeats at a 1.6 μs rate.

The anomaly is a group of four pulses. The four pulses are 100 ns, 50 ns (narrow), 100 ns (runt), and 100 ns wide, with a 100 ns low between, except for a 50 ns low before the runt.

Frequency Hop Demo

The RF output connector generates three frequency steps. These are centered at 2.4 GHz and step up and down 3 MHz from the CF (center frequency). By using the built-in RF Frequency versus Time function of the MDO4000B Series oscilloscopes, you can see the frequency hop represented as a real-time waveform in the time domain.

The red LED labeled “Frequency Hop” at grid B12 turns on.

I^{2}C Bus

Board label: I2C_CLK, I2C_DATA

Grid location: H2, H3

Description: These are the I2C (Inter-IC Communication) bus signals between the μC and a serial EEPROM.

There are several different types of data packets.

The clock rate is a 200 kHz, 0 to 5 volt signal.

Mode Button

Board label: Mode

Grid location: A11

Description: Press this button to choose which of the seven alternative signals to send out of the RF output connector. Your current choice is identified by which of the seven related red LEDs is lighted.

Multiple Peaks Demo

The RF output connector generates an array of frequencies, which are centered around 2.4 GHz, to show the ability of the MDO4000B Series oscilloscopes to dynamically mark each peak in the frequency domain with its exact frequency and amplitude.

The red LED labeled “Multiple Peaks” at grid location B11 turns on.

PLL-1 Voltage

Board label: Voltage

Grid location: E12

Description: This signal is the voltage on the first PLL/VCO in the RF section of the board. It typically operates at 2.4 GHz.

Rare Anomaly

Board label: RARE_ANOM

Grid location: A10

Description: The two less-frequent anomalies in this pulse train can show up on high waveform capture rate oscilloscopes.

A half-height runt signal occurs approximately every 838.8 ms. Use a Runt trigger to isolate the signal.

A 25 ns (narrow) pulse appears in approximately 838.8 ms. Use a Pulse Width trigger to isolate the signal.

The pulse train is a repeating group of three pulses. The three pulses are 100 ns, 200 ns, and 100 ns wide, with a 100 ns low between each pulse. The group repeats at a 1.6 µs rate.

The anomaly is a group of four pulses. The four pulses are 50 ns, 25 ns (narrow), 100 ns (runt), and 100 ns wide, with a 100 ns low between each pulse, except for a 25 ns low before the narrow pulse.

Reset Button

Board label: RESET

Grid location: B7

Description: Press this button to start all generated signals from a common point.

RF Output

Board label: None

Grid location: H9

Description: Use the RF output from this connector in the seven different RF demos controlled by the Mode button. Directly connect this output to the RF input of the MDO4000B Series oscilloscope.

Spectrogram Demo

The RF output connector generates an array of frequencies, which are centered around 2.4 GHz and are both amplitude and frequency modulated, to show the value of the Spectrogram function on slowly changing RF phenomena.

The red LED labeled “Spectrogram” at grid location B11 turns on.

SPI Bus (for RF)

Board label: SPI_CLK, SPI_SS-1, SPI_MOSI-1

Grid location: B12, C12, D12, H11

Description: Description: These are the SPI (Serial Peripheral Interface) serial bus signals. The SPI bus works as follows:

- SCLK rising edge clock

- Active Low SS

- Active High MOSI data

This SPI bus is the control bus for several different parts that control the RF output in the RF based demoes.

Trigger

Board label: TRIGGER

Grid location: G12, H11

Description: This signal acts as a trigger reference for the ASK Modulation, Frequency Hop, and Capture BW demoes. It provides a short positive pulse at the start of the event of interest.

VCO-1 Enable

Board label: VCO-1 Enable

Grid location: E12, H11

Description: This is a digital control signal that transitions from low to high to turn on VCO-1 (2.4 GHz).

VCO-1 On/Off Button

Board label: VCO-1 On/Off

Grid location: F11

Description: Push this button to toggle VCO-1 on or off. Use this in the VCO/PLL demo to turn the VCO off and then back on to capture its start-up sequence.

VCO/PLL Turn On Demo

The RF output connector, VCO-1 Enable loop, and PLL-1 Voltage loop, and the SPI_CLK, SPI_SS_1, and SPI_MOSI_1 square pin connectors generate signals that show the interaction between the control signals and the latency of the RF output turning on and tuning to the desired frequency. Use this mode with the VCO-1 On/Off push button, which toggles the state of the VCO-1 on and off.

The red LED labeled “VCO/PLL-1 Turn On” at grid B11 turns on.

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