Mixed Analog and Digital Signal Debug and Analysis Using a Mixed-Signal Oscilloscope

Wireless LAN Example Application

Application Note 1418

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Introduction

Many of today's designs include microprocessors and digital signal processors (DSPs) that combine analog signals with digital content. Debugging a mixed-signal design often includes correlating important handshaking activity while simultaneously verifying the analog components of the system. The digital signals in a design can be very fast, while the analog signals tend to be much slower. Viewing and analyzing the many signals of interest within a microprocessor or DSP-based embedded design can be difficult or impossible using a conventional 2- or 4-channel digital storage oscilloscope (DSO). The increased complexity and faster digital speeds of clock rates and edge times require oscilloscopes with more channels and higher bandwidths.

In addition, if you want to view and analyze the fast digital and slower analog signals at the same time with high resolution, you need an oscilloscope that has deep memory. With deep memory, you can capture a longer amount of time, but unless the measurement device is very responsive, it can be difficult to find the portion of the signal you are interested in. Many of today's designs include modulated signals and long serial streams, so it is important to be able to find the area of interest quickly and easily. For complex designs, easy triggering also is important.

Designers of microcontroller- and DSP-based embedded systems have been solving problems and debugging their designs using mixed-signal oscilloscopes (MSOs) since 1996, when Agilent Technologies first introduced the instruments. Anticipating the increased complexity and faster speeds of today's mixed-signal designs, Agilent designed new and improved MSOs. These MSOs have up to 20 analog and digital channels, up to 1 GHz bandwidth, improved digital timing performance and usability, as well as MegaZoom deep memory with record lengths as long as 16 MB.

Debugging a 32-bit Mixed-Signal Application

The MSO makes it possible to use a single instrument to view lower-frequency analog signals and simultaneously correlate them with the higher-speed digital components in your system design. This ability makes the MSO a critical debugging tool. There are many applications for using a mixed-signal oscilloscope, including time correlating true analog signals with digital control signals or analyzing the analog characteristics of high-speed signals in a digital system. No matter what your application is, an MSO makes analyzing and debugging your mixed analog and digital designs easier than ever before.

To illustrate the MSO's value as a debugging tool, this application note takes you through an example using an Agilent Infiniium 54832D MSO to debug a mixed analog and digital 32-bit wireless local area network (LAN) application. Of course, this is just one of many possible applications where an MSO is an ideal tool.

Debugging a 32-bit mixed-signal wireless LAN application

For our example mixed-signal application, we will explore an 802.11a wireless LAN access point as shown in figure 1. Essentially, this system takes data from a wireless laptop, demodulates the signal down to baseband, and then converts the signal to a wireline signal onto a LAN.

There are two main parts of this design that communicate through a PCMCIA interface. From the antenna of the access point, there is an RF processor that demodulates the transmitted signal to a baseband processor. From there, the baseband processor decodes the OFDM (orthogonal frequency domain modulation) signal and sends the data to an embedded system that then sends the data out to the LAN. This mixed-signal system contains a 32-bit power PC embedded processor with a 100 MHz SDRAM and a simple LAN controller bus that communicates with the processor to send data out to the network.

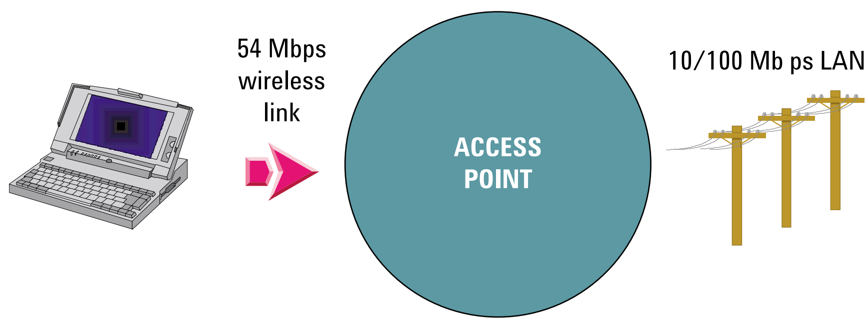

Figure 1. A wireless LAN access point is a mixed-signal design with analog, digital, and embedded processor elements.

The access point is a fairly small device, with two PC boards folded on top of one another. Figure 2 shows how the boards look when they are unfolded. The entire system is bidirectional, but in this example we will look at a transmission from the computer to the network.

This example application is a classic mixed-signal system. There are analog, digital, and embedded processor and DSP components, and the MSO is the perfect tool for looking at mixed-signal types and speeds from these elements simultaneously.

Viewing analog and digital signals simultaneously

Figure 3 shows the MSO probe connections to the analog and digital signals of an access point PC board. For our demonstration, we connected the access point to a LAN, where it then sent information to a laptop PC with a wireless LAN card installed. We executed a refresh command of the laptop's Web browser. We then captured the resulting packet of information on the MSO.

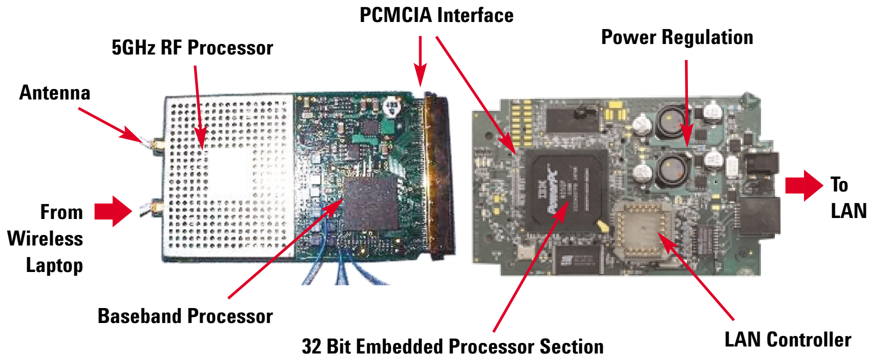

Figure 2. 802.11a 54-Mbps access point with boards unfolded.

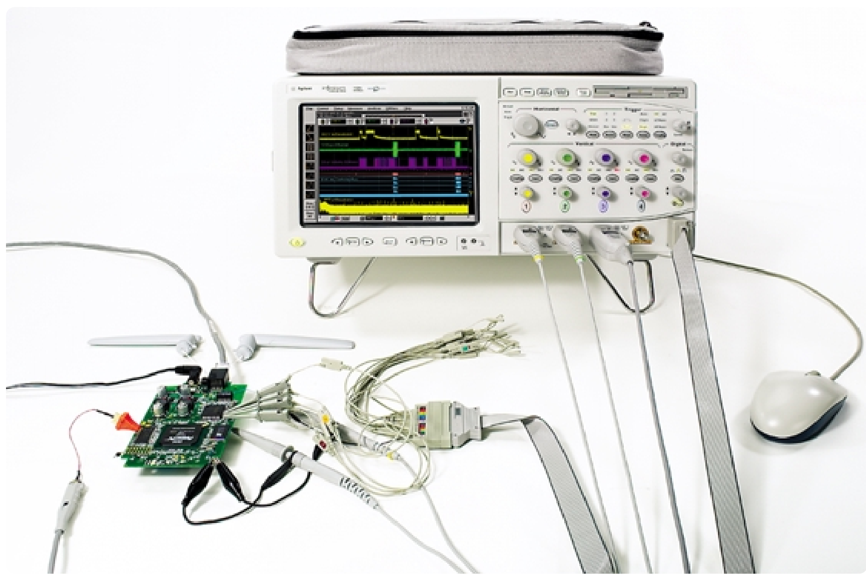

Figure 3. Using an Infiniium 54832D MSO to probe the analog and digital signals of a wireless LAN access point.

The signals being measured by the analog channels of the MSO are the output of the baseband processor, the Ethernet signal out, and one data bit of the fast SDRAM bus. In this example, the SDRAM has edge speeds of up to 1 nanosecond. This edge speed requires an oscilloscope with a 1 GHz bandwidth to accurately measure and display the signals. The signals measured by the MSO's digital channels include one direction of a full-duplex 4-bit bus that runs between the PowerPC and the LAN controller and also a clock signal.

There are 16 digital channels available on the MSO, but for this application, we chose to view only five of the digital channels. Figure 4 shows an acquisition of a single packet of information being sent through the access point as described above. The baseband, Ethernet, and SDRAM signals are acquired on three of the MSO's analog channels while the LAN controller bus signals, shown in blue, are acquired on the digital channels. The red trace between the analog signals and the blue digital signals is a digital bus or a collection of digital channels presented as one waveform on the display. You also can see a 2 Mpt FFT computation of the baseband signal at the bottom of the MSO display. These signals were all acquired *in one acquisition on one instrument* and screen.

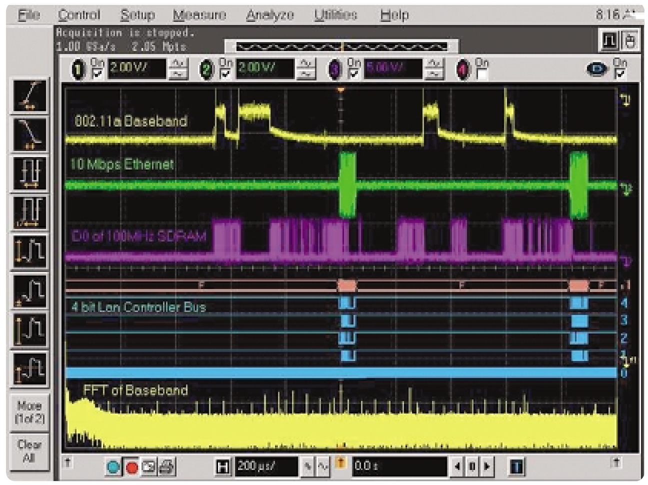

Figure 4. An MSO allows you to time correlate analog, digital, and spectral information all in one instrument.

Finding a debug method to capture and analyze all of this data on one acquisition traditionally has been a headache for most designers. You would normally have to get the device under test into the same state to measure all of the signals. Then you would have to move probes around, trigger multiple times, store waveforms on the display, and then find a way to correlate all this activity.

An MSO allows you to capture, display and measure all of this information simultaneously. It is easy to use and has all the functionality of a DSO, but has added digital channels and triggering capabilities. It simplifies the debug process by allowing you to see more channels and more time at once. An MSO replaces today's DSOs, and as you can see from the screen in figure 4, an MSO is the perfect tool for easily and efficiently analyzing mixed-signal applications.

Isolating the right information

In this example, there could be a packet error in the transmitted signal, so you may want to isolate a packet to see the interactions occurring in the system. On the wired Ethernet line is a sync burst that indicates the start of the transmission onto the LAN. A 1010 pattern on the data lines of the LAN controller held for a duration of 5 microseconds generates this sync burst at the beginning of every 10 Mbit LAN packet. To isolate this condition, we set the MSO to trigger on the 1010 pattern for a duration of 5 microseconds. Figure 5 displays the 1010 pattern on D1 through D4 of the MSO's digital channels, with DO assigned to the clock.

Because a 54832D MSO has 16 digital timing channels and four analog channels, you can use the digital channels to perform a pattern trigger for a duration of time in order to trigger on a condition, such as a start of packet in this case. In fact, you can trigger across all 20 of the MSO's channels. You can set up the digital channels quickly and easily using the trigger setup dialog box, as shown in figure 6.

These extra digital channels allow you to assign the four analog channels to analyze and measure the other signals of interest in the system. With an ordinary 4-channel DSO, you would use four channels just to generate a trigger, and there would be no channels left for debugging.

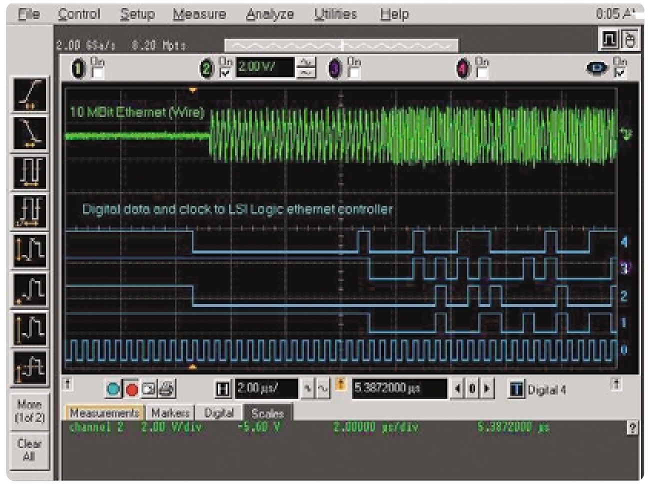

Figure 5. Use the MSO's 16 digital channels for triggering. The MSO is set to trigger on the 1010 pattern for a duration of 5 microseconds. With an ordinary four-channel DSO, the four channels would be used just to generate a trigger and there would be no channels left for debugging.

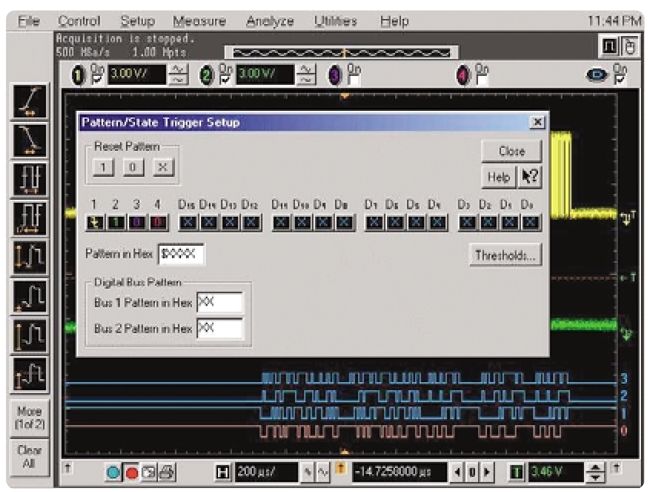

Figure 6. Triggering extends across all 20 channels with easy-to-use dialogs for quick trigger setups. MSOs have two pods of eight digital channels each, with connectors that are compatible with Agilent 16700 Logic Analyzers.

Although it is not shown in this example, you could set up a trigger condition based on the states of the four digital bits. You also could include the clock line and any of the analog signals in the trigger specification to narrow in on a problem. With the Infiniium 54830D Series of MSOs, you can trigger on patterns that are up to 20 channels wide. This is impossible to do with a conventional DSO. The MSO gives you the extra triggering and viewing capabilities that you need to debug your mixed-signal system.

Using bus mode to gain added visibility and insight

In figure 5, the characteristics of the Ethernet signal change at about 1.5 divisions from the right side of the display. This is where the sync burst ends and the real data packet begins. To make it easier to identify the start of packet condition or any other condition of interest, you can configure the display of the digital channels to be in a bus mode to easily identify a digital pattern. Figure 7 displays a bus representing eight digital channels. This screen shows the data coming across the bus as a hex display that is correlated with the Ethernet signal in the system. In this example, the 1010 digital pattern would be identified as 5 hex on the display, allowing you to easily and quickly identify the condition you are searching for.

You can display one or two 8-bit buses and each bus can have from 2 to 16 channels associated with it. You also can display any given digital channel individually, regardless of whether it is already part of one or both buses. The 16 digital timing channels give you not only added triggering capabilities, but also more visibility into what is going on in your design with this easy-to-use bus mode.

With previous debugging solutions, correlating triggers and signals has been difficult and time consuming. You needed to use multiple instruments to set up a trigger and then find a way to time correlate the instruments. An MSO makes triggering and signal correlation easy. Many designers prefer to use an MSO for debugging their mixed-signal designs because of the viewing capabilities such as bus mode and the ability to trigger across 20 channels.

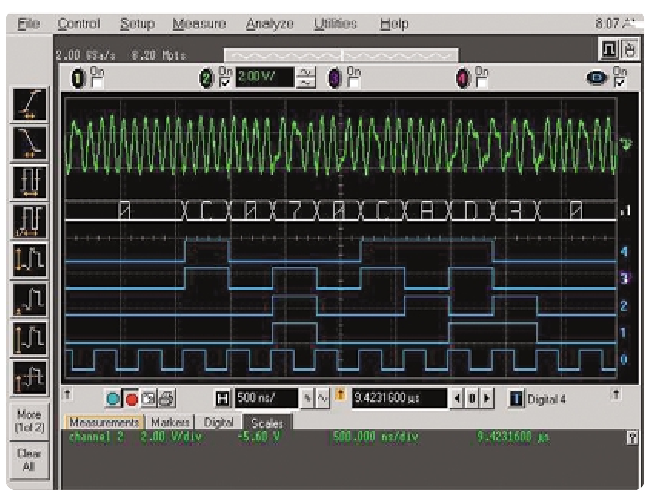

Figure 7. Digital signals can be grouped together by bus and viewed as hex value at every transition.

Capturing long time periods

Why is deep memory important for debugging mixed-signal designs? Because it lets you achieve long capture time *and* high resolution. In this example, you need deep memory to capture a long period of time with high resolution because of the range of signal speeds. Without deep memory, you can achieve either long capture time *or* high resolution, but not both simultaneously. The sample rate of an oscilloscope changes as you slow down the timebase or sweep speed. The scope must reduce its sample rate as the sweep speed is slowed down in order to capture enough time to fill the entire display without running out of memory. Keeping the sample rate as high as possible is critical, because it ensures that your are capturing your signals at full resolution, eliminating aliasing and measurement errors.

Often when you are debugging a complex system, you do not know exactly what the problem is, so you cannot set up the scope to trigger on it. You have to trigger on something more basic, such as an edge, and then look at the captured data to find the problem. This usually requires capturing a long span of time and then zooming in and out on the display, so again long time capture and high resolution are critical. Perhaps most common is the need to correlate high-speed signals, which are often digital, with slower speed ones. In order to measure them both correctly with one acquisition, you need a time span that is long enough to show one or more full periods of the slower signals, and you need the sample resolution to be high enough to show full detail on the fast signals. Deep memory is essential for this ability.

In this example, you can acquire an entire packet of the data in about 500 microseconds of time. At a sweep speed of 200 microseconds per division, you need a minimum of 1 Mbyte of memory to view this packet of information with the sample rate set to 2 GSa/s. You need 1 Mbyte of memory just to capture the most basic transaction. If there are any errors or other transaction complexities, you would need even more memory.

The importance of deep memory in this application is shown in figures 8 and 9. Figure 8 shows an acquisition of the faster SDRAM signal and the slower baseband signal. If you look at the fast SDRAM signal on the purple trace in figure 9, you will see the same acquisition zoomed in by a factor of *200,000 times*. Note that the rise time is about 1.5 nanoseconds and the time scale is 2 nanoseconds per division. In this measurement, the scope is stopped and this analysis is performed on the single original acquisition. Without deep memory sustaining the high sample rate, there would not be nearly enough underlying data to support this amount of zooming.

The MSO’s MegaZoom deep memory automatically adjusts the memory depth so that as you change the time per division, the scope always samples with the maximum sample rate and memory depth available. Also, MSOs come standard with 2 Mbytes of deep memory per channel that allows you to capture slower signals and still see the details on fast signals all in one acquisition. The MSO automatically keeps the sample rate at its maximum setting based on the memory depth so that you can see the big picture and then zoom in on the details without having to trigger twice.

Traditionally, deep-memory scopes have had slow update rates, and they respond sluggishly to user inputs. This is not true for MSOs with MegaZoom deep memory. MegaZoom deep memory responds instantly to your changes, even with the deepest records, up to 16 MBytes. This instant response is enabled by a custom architecture that captures data into acquisition memory and rapidly post-processes the data in the hardware for display and measurements. This architecture makes it possible to provide the waveform update rate and front panel responsiveness you need to get your job done more easily.

In order to make the 1.5 nanosecond measurement accurately, you need a high-fidelity active probe such as the Agilent 1156A. The 1156A probe features very low input capacitance and properly damped tip resistance that enable it to make very unobtrusive and high-fidelity measurements.

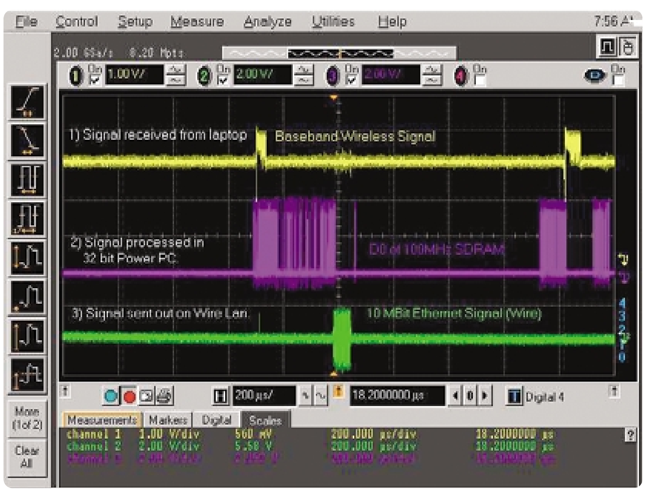

Figure 8. With an MSO, you can view a mix of signals. MegaZoom Deep memory lets you capture slow signals and then zoom in on the details fast without having to trigger twice.

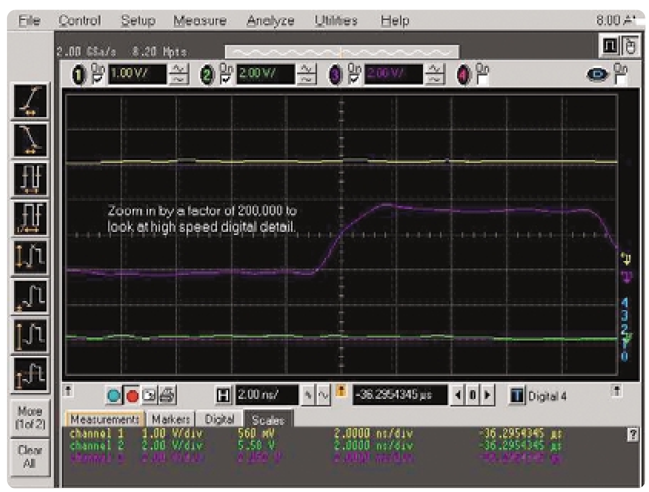

Figure 9. This screen shows the same acquisition shown in figure 8 zoomed in by 200,000 times! MegaZoom Deep memory sustains a high sample rate so you can zoom in to see the details and make accurate measurements.

Frequency domain measurements and analysis

Looking at the baseband signal in figure 10, we see the time view along with bit 0 of the SDRAM bus. Because this comes from the wireless signal, it is valuable to also look at it in the frequency domain. You can make FFT measurements with an MSO, just like you can with a DSO.

Figure 11 shows the FFT of the baseband signal. The MSO performs an FFT of all the data on the screen. This allows you to zoom in and out on the portion of the time record that has the frequency content of interest. It also makes it easy to compare the spectral content of different regions of the time-domain signal. In this case, most of the energy is located in the leftmost division of the FFT. You can see how the energy spans a broad, relatively even frequency range.

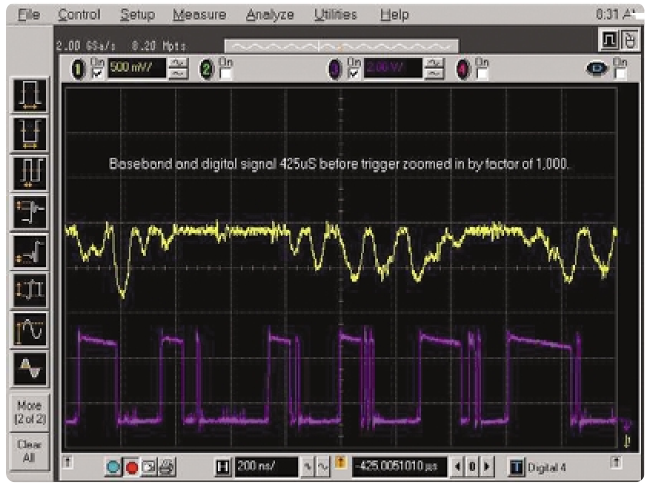

Figure 10. Because the baseband signal comes from the wireless signal, it also is valuable to look at it in the frequency domain by performing an FFT.

Figure 11. FFT of the Baseband Signal. Most of the energy is located in the leftmost division of the FFT.

Figure 12 shows the beginning of the baseband transmission. In the first horizontal division of the FFT, instead of a broad, somewhat uniform distribution of frequency content, there are some distinct spectral lines. These lines indicate that the beginning of the baseband packet has a sync period just as the wireline side does. However, it is easier to see this event in the frequency domain.

There are also some noise spikes on the FFT in figure 12. These spikes could be caused by an unintended coupling in the system. In this access point, there is a high-power line driver on the wireline side in close proximity to a sensitive RF receiver on the wireless side that may be causing a coupling problem.

Figure 12. Looking back further in time to the beginning of the baseband transmission, we see noise spikes on the FFT. Some noise spikes are most-likely caused by unintended coupling in the system.

Time correlate analog, digital, and spectral information

Using the MSO's digital channels can help you gain more detailed insight into the possibility of coupling. Figure 13 shows the digital bus turned back on and the time delay moved back to very near the original trigger point. In the live display and debug of this application, moving the horizontal delay back and forth showed that the noise spikes on the FFT measurement changed in magnitude based on which data was present on the LAN signal shown by the hex readouts of the bus mode.

The next step in your analysis would be to identify the data sequence that correlates to the highest levels of noise on the FFT display and further analyze that condition. For example, you could alter the PowerPC programming to repeatedly send out the corresponding data sequence attributed to the noise spikes. From there, you would then look more carefully at the FFT with a spectrum analyzer to determine the root causes of the coupling.

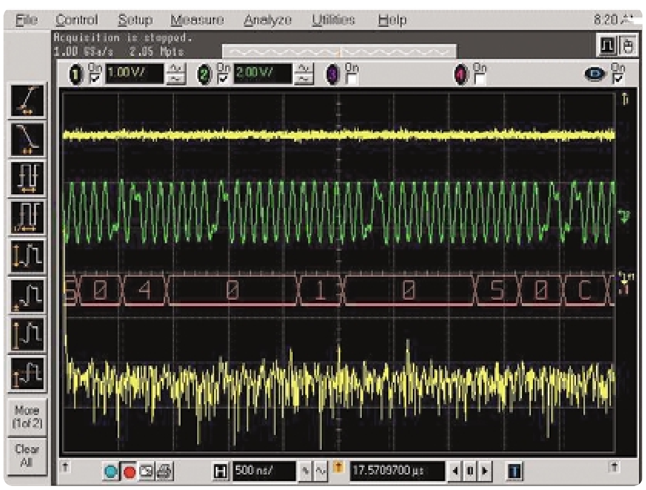

Figure 13. Using the MSO's digital channels can help you gain further insight into the possibility of coupling. Moving the horizontal delay back and forth showed that the noise spikes on the FFT changed in magnitude based on which data was present on the LAN signal according to the hex readouts of the digital bus.

Which Agilent MSO is Right for Your Application?

Figure 14. Agilent offers a family of mixed-signal oscilloscopes to meet your design needs.

The MSO's combination of digital channels, analog channels, ease of triggering, and bus display modes make it a great tool for tracking down problems quickly and easily as shown in our wireless LAN example application. MSOs come with different performance specifications and channel counts to meet the needs of engineers working in a wide range of applications that involve both analog and digital signals.

Model	Analog Bandwidth	Channels	Maximum Sample Rate	Maximum Standard Memory
54621D	60 MHz	2 analog + 16 digital	200 MSa/s	4 MB
54622D	100 MHz	2 analog + 16 digital	200 MSa/s	4 MB
54641D	350 MHz	2 analog + 16 digital	2 GSa/s	8 MB
54642D	500 MHz	2 analog + 16 digital	2 GSa/s	8 MB
54830D	600 MHz	2 analog + 16 digital	4 GSa/s	4 MB
54831D	600 MHz	4 analog + 16 digital	4 GSa/s	4 MB
54832D	1 GHz	4 analog + 16 digital	4 GSa/s	4 MB

Summary

This application note showed many of the benefits of an MSO for debugging and analyzing a typical mixed-signal system that included slower analog signals with faster digital signals. An MSO provides all the functionality of a traditional DSO plus much more. These oscilloscopes seamlessly integrate up to 20 channels, display long acquisition times with unparalleled resolution, and respond instantly to user inputs even on the deepest record lengths. These features along with the integrated digital and analog channel triggering capabilities are what differentiate an MSO from other oscilloscopes (DSOs) available today.

This example application demonstrated how an MSO makes debugging and analyzing mixed signal applications easier because of the following features and benefits:

- An MSO simplifies the debug process with up to 20 channels to easily see more time at once.
- Triggering and signal correlation is automatic and easy with triggering across all 20 channels.
- Easy-to-use bus mode display on the digital channels gives added visibility and insight.
- MegaZoom deep memory automatically keeps the sample rate high so that you can see the big picture and then zoom-in on the details without having to trigger twice.
- Easy time correlation of analog, digital and spectral information on one instrument.

Many engineers find MSOs easier and more efficient to use than any other test instrument they've used before. When you troubleshoot a microprocessor- or DSP-based design, an MSO will help you get the job done in less time, with less hassle, giving you more time to figure out the real problems in your system.

Glossary

802.11a 5 GHz wireless LAN protocol transmitting at 54Mbps

Access point A hardware device that acts as a communication hub for users of a wireless device to connect to a wired LAN

Baseband Information carried on a single unmultiplexed signal channel on the transmission medium

DSO Digital storage oscilloscope

DSP Digital signal processor

FFT Fast Fourier transform; an algorithm used to transform time domain data into frequency domain

LAN Local area network

MSO Mixed-signal oscilloscope

OFDM Orthogonal frequency domain modulation

PCMCIA A PCMCIA card is a credit card-size memory or I/O device that connects to a personal computer, usually a notebook or laptop computer

SDRAM SDRAM (synchronous DRAM) is a generic name for various kinds of dynamic random access memory (DRAM)

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Latin America:
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(fax) (305) 269 7599

Taiwan:
(tel) 0800 047 866
(fax) 0800 286 331

Other Asia Pacific Countries:
(tel) (65) 6375 8100
(fax) (65) 6836 0252
Email: tm_asia@agilent.com

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