Finding Hidden Problems Using Deep-Memory Oscilloscopes

What should you do when everything looks right but something is still wrong?

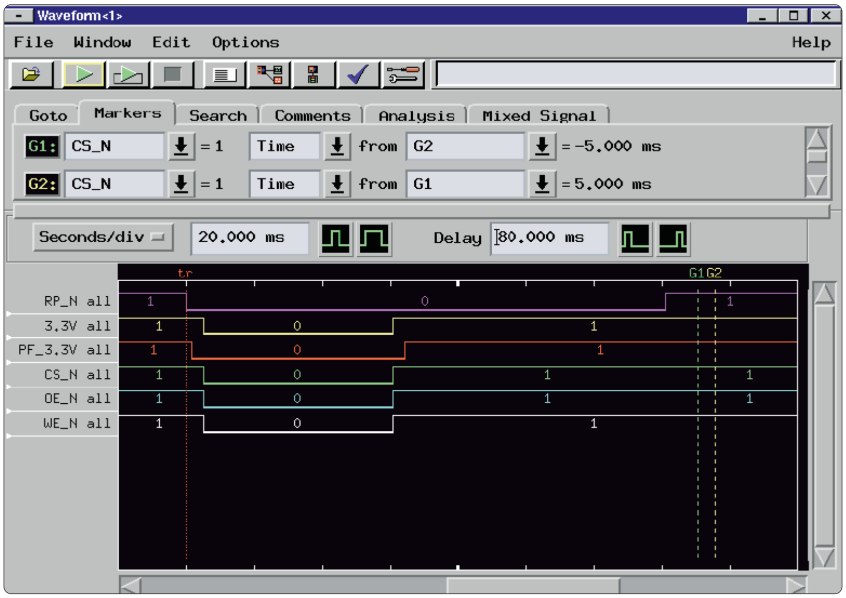
Profile of Mark Andresen, IBM

Every engineer knows the feeling: As far as you can see, everything is working properly—the right signals are getting to the right places at the right times, the firmware is doing what it's supposed to do, and everything else seems to be in order—and yet the system still doesn't function properly. This situation can drag on for days or weeks, putting product launches and production schedules in jeopardy while you continue to search for clues.

IBM's Server Group recently encountered such a scenario. One of the company's PCI interface card products was mysteriously failing on the production line, but the problem affected only some units and not others.

Starting the Investigation

Of course, any time there is danger of stopping a production line, it's a major financial issue and customer satisfaction concern. The initial investigation narrowed the problem to cards using flash memory modules from one particular vendor; identical cards using flash memory modules from three other vendors worked perfectly.



G1: CS_N = 1 Time from G2 = -5.000 ms

G2: CS_N = 1 Time from G1 = 5.000 ms

Seconds/div 20.000 ms

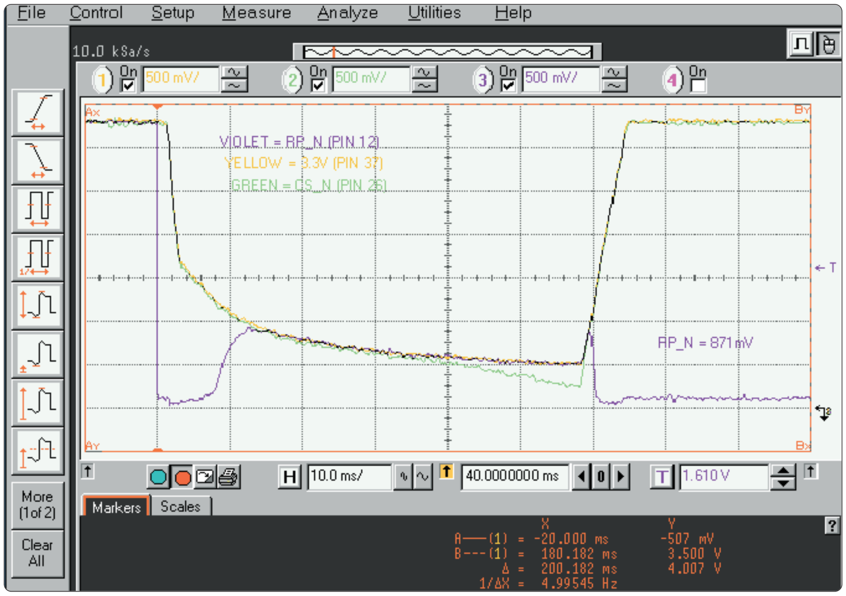
Delay 80.000 ms

Figure 1. The flash memory module was receiving the correct control signals and should have been generating valid data after the reset signal (RP_N) went inactive, but its outputs were still in tri-state mode and there was no apparent chip-select activity in the expected area (outlined by the display markers).

The logic analyzer screen in **figure 1** shows key control signals for the flash module during the startup sequence. By the time the active-low reset signal (RP_N) is pulled high (roughly 110 ms into the sequence), the 3.3-V power signal is active and confirmed by the voltage supervisor signal (PF_3.3V). At this point, the memory module should have received a chip-select pulse (CS_N) and begun generating valid data, but its outputs were still in tri-state mode and the expected chip-select activity was not evident.

To study the problem in more detail, the entire startup sequence needed to be captured with enough resolution to find fast-moving signals. A key part of the challenge was to determine whether the problem was analog (a signal integrity problem) or digital (a result of incorrect commands or hardware timing malfunctions) in nature.

Examining the problem was a classic example of the memory-depth-versus-resolution tradeoff in both scopes and logic analyzers. To capture all the relevant activity in the startup sequence, a very slow timebase setting was used on the analyzer. Of course, the slower the timebase setting, the lower the resolution, so the expected chip-select activity actually could have been taking place unbeknownst to the analyzer.



```
                X                    Y
A——(1) = -20.000 ms          -507 mV
B---(1) =  180.182 ms         3.500 V
      Δ =  200.182 ms         4.007 V
   1/ΔX =  4.99545 Hz
```

Figure 2. With a standard high-speed scope, the analog behavior of the signals became apparent, but the chip-select activity expected after RP_N went high was not evident.

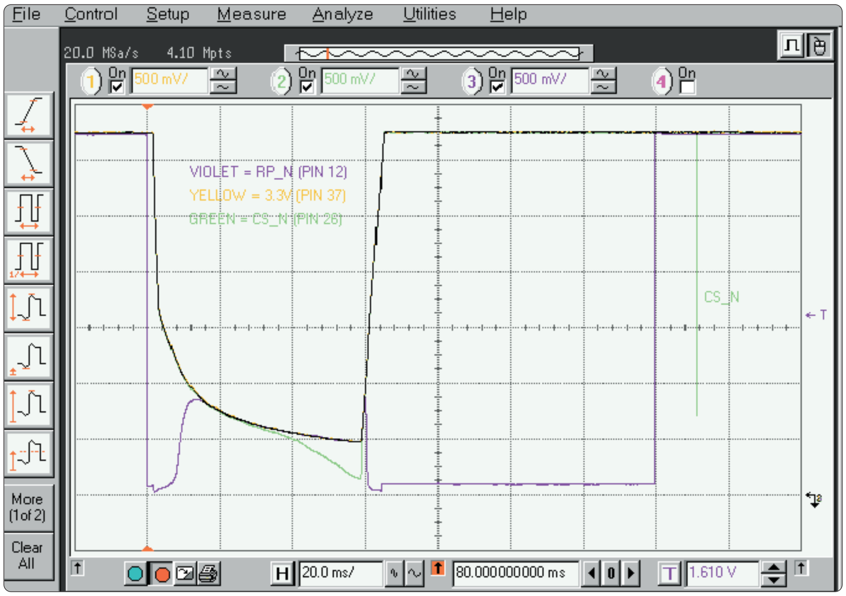


Figure 3. A high-resolution deep memory waveform capture uncovered chip-select activity (CS_N) shortly after the chip reset signal (RP_N) went inactive high, narrowing the source of the problem to the memory module itself.

Next, a high-speed, conventional-memory scope was hooked up **(figure 2)**, but because the scope didn't have memory deep enough to capture the entire 160-ms reset-read cycle with sufficient resolution, the problem couldn't be isolated with this approach either.

Finding the Problem

Finally, Agilent's Infiniium oscilloscope with MegaZoom deep memory uncovered the problem. As **figure 3** shows, the CPU was in fact generating chip-select activity (CS_N)

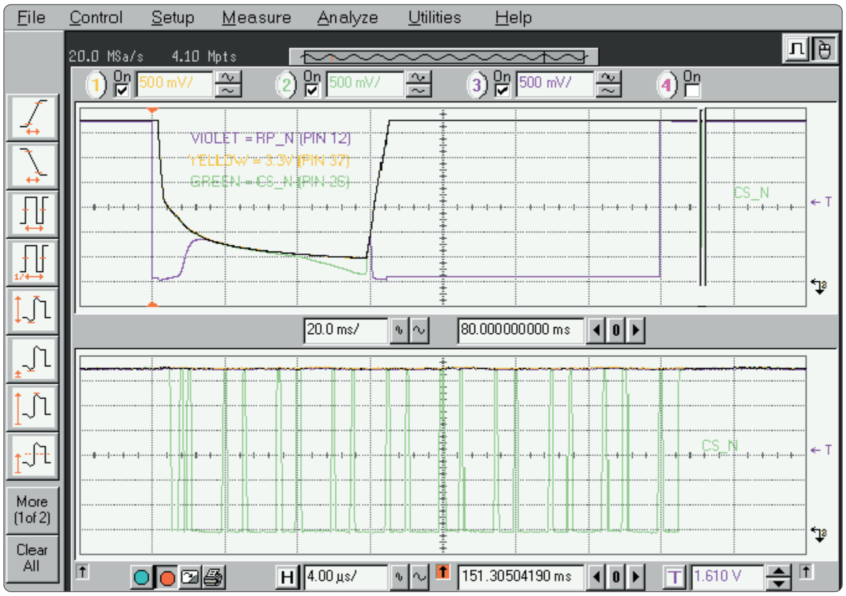


Figure 4. Zooming in on the captured data with 5000X magnification revealed nearly two dozen individual chip-select commands.

shortly after the reset signal (RP_N) went inactive high, confirming that the memory module was getting the right commands at the right time. This led to the next question: Why wasn't the memory responding?

Because deep memory captured much more data than was actually shown onscreen, zooming in for a closer look at the chip-select activity was as simple as telling the scope where to look and increasing the resolution setting. The upper trace of **figure 4** shows the scope zoomed in tightly around the CS_N spike. The lower trace shows the resolution changed from 20 ms/div to 4 µs/div. It was now obvious that not only was the chip-select line getting pulsed, the CPU was pinging the memory module nearly two dozen times trying to get it to respond. This flurry of chip-select activity from the CPU with no resulting data from the memory module clearly indicated that the module was hung up.

The problem seemed to be caused by the memory module, so next the voltage profile of the chip-select signal was examined earlier in the reset sequence. Due to design considerations elsewhere in the system, the power supply level dropped to 1.1 V for a period of roughly 20 ms. Although the chip's specifications did not prohibit this situation, the chip got stuck in an indeterminate state whenever this happened and could not be recovered

```
                X              Y
A——(1) =  64.727074 ms   -507.0 mV
B---(1) =  159.999803 ms   6.0000 V
      Δ =  95.272729 ms   6.5070 V
  1/ΔX =  10.4961830 Hz
```

Figure 5. With a temporary capacitor added to prevent the 3.3 V from dropping into a range that sent the memory module into an indeterminate state, the module began generating valid data.

through another reset cycle (RP_N going low) even when active for over 60 ms with 3.3 V in specification. The problem was solved temporarily by adding a capacitor that prevented the supply line from dropping into this range, thereby allowing the part to reset correctly **(figure 5)**.

Discussions with the part vendor confirmed that this was a known (but not communicated) problem with the flash chip. If the supply voltage dropped into the 1.1 V to 1.2 V range and not all the way to 0.0 V, the part would not initialize correctly. The deep-memory scope displayed a more-accurate voltage profile, which the memory vendor was able to use to analyze the part's performance more closely. Fortunately, IBM had been obtaining memory modules from three other suppliers, so they simply discontinued using the faulty part without making any circuit changes.

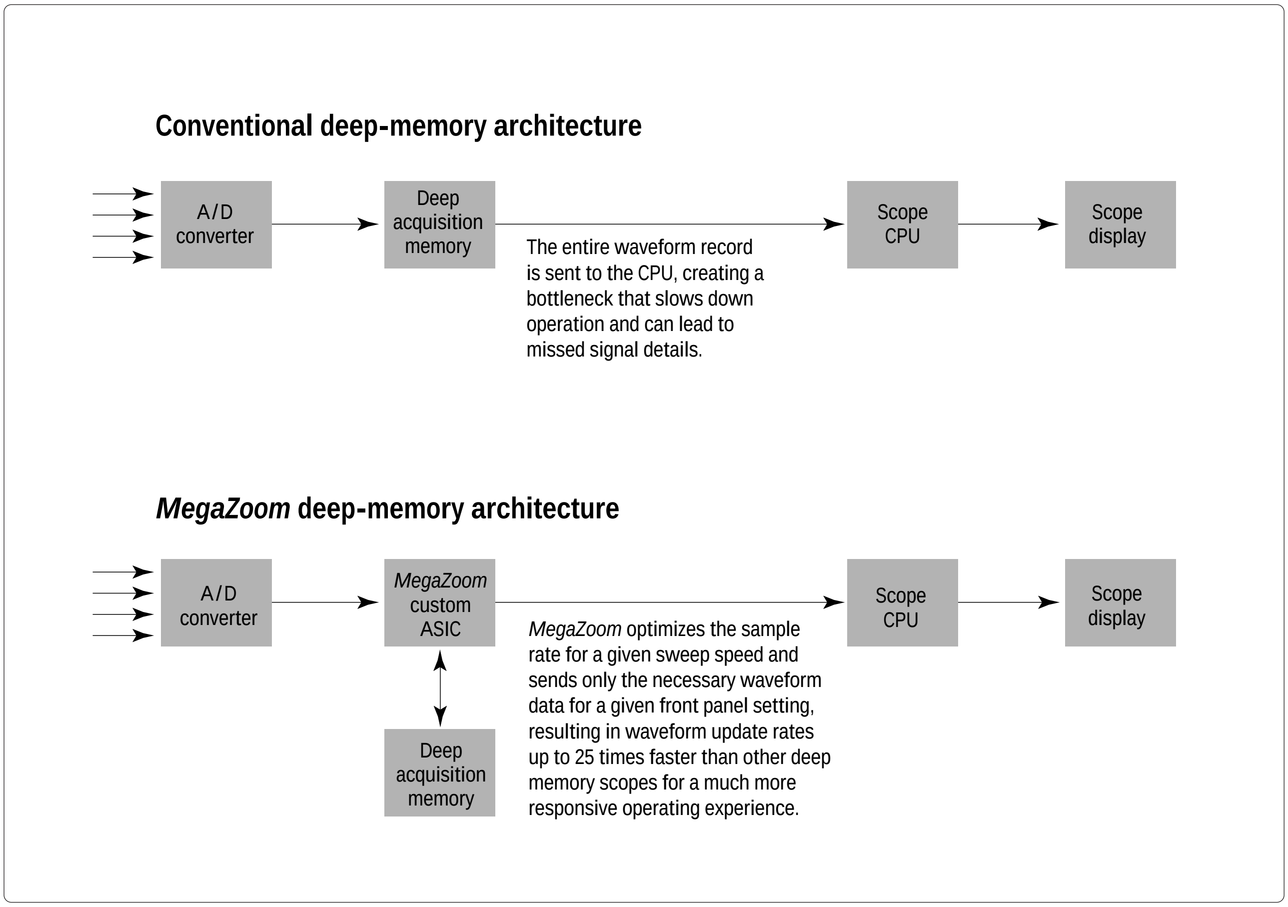


Figure 6. Agilent MegaZoom delivers fast, responsive operation through a custom integrated circuit that optimizes data acquisition and processing.

Applying Deep-Memory Technology to Other Measurement Challenges

The unique capabilities of deep-memory oscilloscopes offer a compelling measurement solution whenever you have high-speed signals interacting with low-speed signals or long data streams, particularly when there are important events spaced far apart in time. In general, deep-memory scopes can be helpful in the following applications:

- examining long serial data streams, including *Bluetooth*™ baseband, USB, CAN, SPI, I2C, Ethernet LAN, and serial HDTV signals
- mixing analog and digital design, including power supplies, motor drives, PLCs, battery-powered devices, embedded processors, ADCs, DACs, and data-acquisition systems
- finding details buried in complex waveforms such as modulated signals and video signals

- capturing and analyzing infrequent and unpredictable events such as glitches, runts, and transients
- substituting for complex triggering (Simply edge-trigger on an event and capture everything associated with it, then pan around and zoom in on the details you want to analyze.)

The usefulness of deep memory has improved considerably in recent years, with fast, responsive displays and transparent operation—eliminating the two biggest frustrations with traditional deep-memory scopes. The new MegaZoom Infiniium oscilloscope from Agilent Technologies features automatic deep memory that allows the maximum sample rate to be available at all times, without requiring users to calculate and then manually set the memory. **Figure 6** shows how MegaZoom scopes deliver this new level of performance.

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Expanded from original article in
Agilent Measurement Solutions
Volume 1. Issue 2

Printed in the USA April 18, 2002
5988-5979EN

Agilent Technologies