

## Oscilloscope Measurement Tools to Help Debug Automotive Serial Buses Faster

*Our thanks to Agilent for allowing us to reprint the following article.*

### Introduction

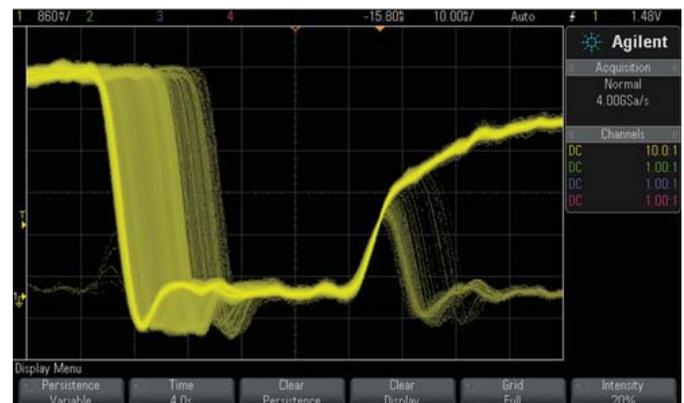
The primary reason engineers use oscilloscopes to debug and characterize automotive serial buses, such as CAN, LIN, and FlexRay, is because of an oscilloscope's inherent ability to characterize the analog quality of these signals. Performing analog characterization using an oscilloscope is often referred to as "physical layer" measurements. Serial bus protocol analyzers are optimized at performing measurements at the "application layer". Instruments such as these are focused on providing trace flow of data at a higher abstraction level — but at the cost of providing little or no physical layer measurement capability. A scope is not a replacement for a serial bus protocol analyzer, but neither is a serial bus protocol analyzer a replacement for a scope. Engineers working on automotive serial bus applications typically have both.

Although there are many oscilloscopes on the market today from multiple vendors that offer automotive-focused options, Agilent's InfiniiVision Series oscilloscopes offer some unique measurement capabilities (only available in Agilent scopes) for debugging and characterizing the physical layer of automotive serial buses including:

- Fastest oscilloscope waveform update rates
- Only oscilloscopes with hardware-based decoding for CAN, LIN, and FlexRay
- Only oscilloscopes with CAN and FlexRay eye-diagram mask testing
- Only oscilloscopes with a dual-bus time-interleaved protocol lister
- Only oscilloscopes with a real-time frame counter with bus utilization
- Only oscilloscopes with segmented memory acquisition with frame decoding in a lister display
- Only battery-operated oscilloscopes with automotive options
- Only oscilloscopes with FlexRay physical layer conformance test software and with complete test reporting

- Lowest price oscilloscopes with CAN, LIN, and FlexRay options

### Fastest Oscilloscope Waveform Update Rate



**Figure 1: An update rate of 1,000,000 waveforms/sec easily captures infrequent glitches and jitter that other scopes miss.**

With Agilent's exclusive MegaZoom IV technology, the 3000 X-Series oscilloscopes can update waveforms as fast as 1,000,000 waveforms per second. Even when capturing long waveforms while using the scope's automatic deep acquisition memory — which is often required for automotive serial bus applications — Agilent's InfiniiVision Series oscilloscopes remain responsive. A responsive scope not only enhances the usability of the instrument, but it also enhances the scope's probability of capturing elusive events that may be problematic in an automotive design as shown in Figure 1. When using deep memory on other vendor's oscilloscopes, waveform update rates can be extremely slow. Not only does this make the scope difficult to use, but this also decreases the scope's probability of finding the infrequent glitch.

To learn more about oscilloscope waveform update rates, download Agilent's application note titled, "Evaluating Oscilloscopes for Best Waveform Update Rates" listed at the end of this document.

## Only Oscilloscopes with Hardware-based Decoding for CAN, LIN, and FlexRay



Figure 2: Hardware-based decoding captures and displays an infrequent CAN error frame that other scopes miss.

Agilent's InfiniiVision Series oscilloscopes are the only oscilloscopes on the market today that utilize hardware-based decoding of the CAN, LIN, and FlexRay serial buses. Hardware-based decoding provides a virtual real-time update of the decode trace, and doesn't degrade the scope's waveform update rate (up to 1,000,000 waveforms per second). This enhances the scope's probability of capturing and displaying infrequent serial bus communication errors, such as error frames or CRC errors as shown in Figure 2. All other vendor's scopes utilize software-based decoding. Not only does using deep memory slow down the scope's update rate, but using serial bus decoding further degrades update rates. Turning on more advanced functions in other vendor's scopes (more memory, more decoding, more measurements, etc.) can significantly degrade usability; making it more difficult to debug an automotive system.

## Only Oscilloscopes with CAN and FlexRay Eye-diagram Mask Testing

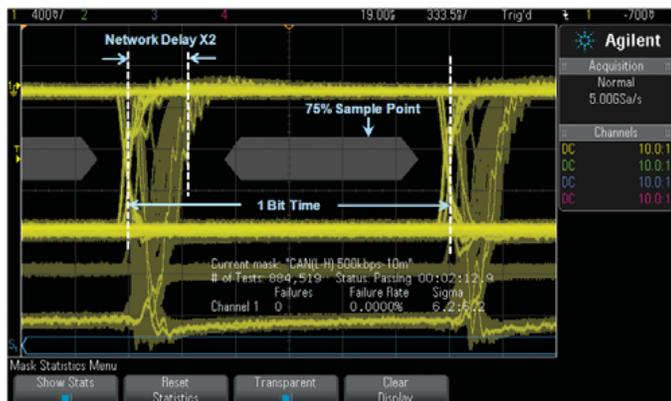


Figure 3: CAN eye-diagram mask testing shows amplitude variations and timing uncertainties, including network propagation delays, from all frames and all bits.

The "workhorse" bus in all of today's automobiles is the differential CAN bus. Agilent's 3000 X-Series oscilloscopes are the only scopes on the market today that can perform pass/fail CAN eye-diagram measurements on the CAN bus.

An oscilloscope eye-diagram provides a composite measure of the overall quality of the physical layer in one simple measurement. All recessive and dominant bits of the differential CAN bus are overlaid to show worst-case amplitude and worst-case timing of all bits from all frames as shown in Figure 3. The CAN eye-diagram measurement on Agilent's 3000 X-Series not only shows amplitude variations of frames transmitted from various nodes in the system, but it also clearly shows network propagation delays during the arbitration and acknowledgement phases of frames.

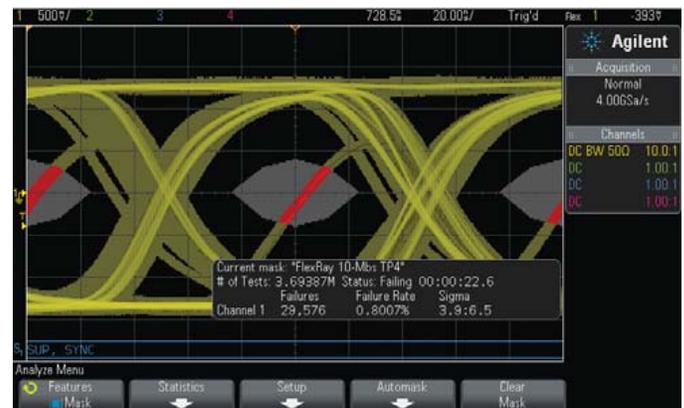


Figure 4: FlexRay eye-diagram mask test shows significant physical layer issues when probed at the input of a particular FlexRay receiver.

In addition to CAN eye-diagram mask testing, Agilent's InfiniiVision Series oscilloscopes can also perform eye-diagram mask testing on the higher-speed differential FlexRay bus. Figure 4 shows an example of "TP4" eye-diagram mask test at the input of a FlexRay receiver. In this measurement example, we can see significant edge jitter, slow rising and falling edges, and a shifted bit that intersects the pass/fail mask causing mask test failures.

To learn more about eye-diagram testing on differential automotive buses, download Agilent's application notes titled, "CAN Eye-diagram Mask Testing" and "FlexRay Eye-diagram Mask Testing" listed at the end of this document.

## Only Oscilloscopes with a Dual-bus Time-interleaved Protocol Lister Display

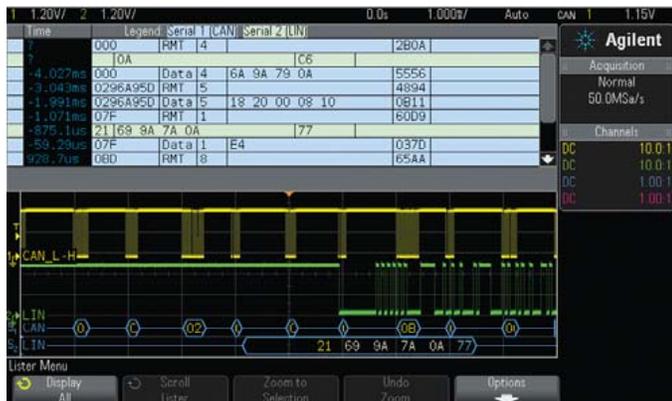


Figure 5: Dual time-interleaved lister display makes it easier to track data through CAN-to-LIN gateways.

Most oscilloscopes on the market today with serial bus options can display decoded data in two formats. One format shows one or more decode traces time-correlated to the captured waveform. This decode trace is primarily useful when the scope's timebase is setup to view a single frame. On Agilent's InfiniiVision Series oscilloscopes, these time-correlated decode traces is always shown near the bottom of the scope's display (below the waveforms). The second decode format is what Agilent calls the "lister" display. The lister display shows a tabular list of decoded data with columns that are clearly labeled based on the fields for the specific protocol.

Today's automobiles utilize multiple buses for control and monitoring including the CAN, LIN, and FlexRay buses. Data within these buses sometimes needs to be passed from one bus to another. Automotive vendors use chips known as "gateways" to interchange data between buses. Agilent's 3000 X-Series scopes are the only oscilloscopes on the market today that can display time-interleaved decoded data from two buses in the same lister table as shown in Figure 5. In this example, the LIN bus frames are shown in green while the CAN bus frames are shown in blue. The time-interleaved lister display makes it easy to trace data that is perhaps passed from one bus to another. Other scopes on the market can either display one table only, or two tables side-by-side. But even when two tables are displayed side-by-side, it can be very difficult to trace the data transfers between the buses.

## Only Oscilloscopes with a Real-time Frame Counter with Bus Utilization

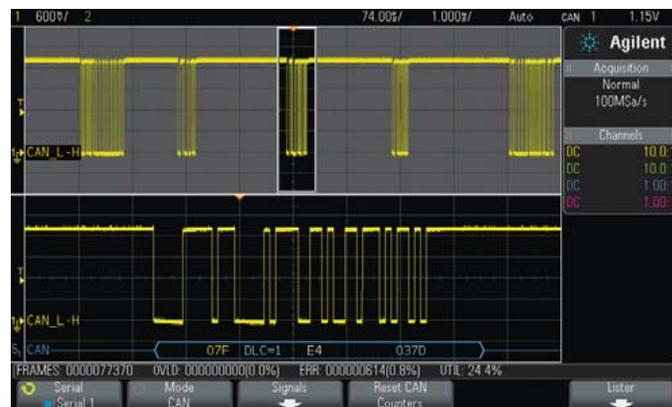


Figure 6: Real-time frame counter and bus utilization measurement helps characterize CAN and FlexRay systems.

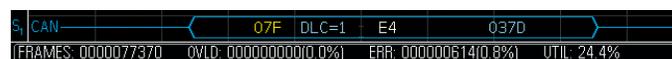
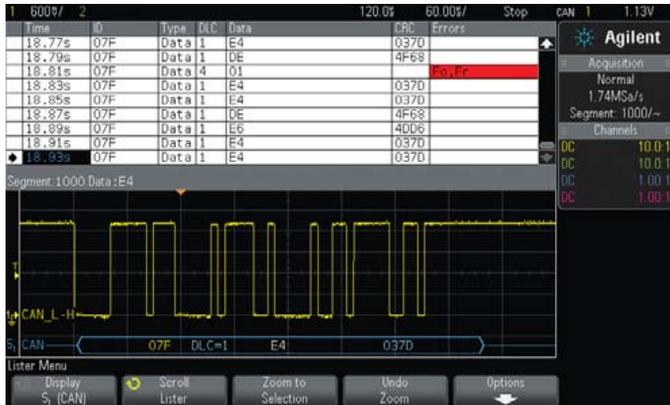


Figure 6a: Expanded view of the real-time frame counter

For CAN and FlexRay applications, Agilent's InfiniiVision Series oscilloscopes are the only oscilloscopes on the market today that can count the number detected frames in real-time (no dead-time), including all frames, error frames (CAN), overload frames (CAN), sync frames (FlexRay), and null frames (FlexRay). These frame counters run all the time, even when the scope's acquisition has been stopped as shown in Figure 6, as well as the expanded view of the real-time frame counter shown in Figure 6a. Note that there is no oscilloscope dead-time involved in this measurement.

Also important for characterizing CAN systems is a measure of bus utilization, or "bus load", in percent. This basically measures frame time relative to total time. If "bus load" gets too high in a CAN network, this will increase the probability of bus contention and errors. It also means that lower priority messages may have a more difficult time gaining access to the bus.

## Only Oscilloscopes with Segmented Memory Acquisition with Frame Decoding in a Lister Display



**Figure 7: Segmented memory acquisition with automatic decoding selectively captures 1000 consecutive occurrences of CAN frame ID: 07F with precise time-tagging between each frame**

Automotive engineers often need to capture multiple and consecutive — yet selective — frames of serial data. For example, capture each consecutive occurrence of CAN frame ID: 07F, without capturing everything in between. Without segmented memory acquisition, the alternative is to use a scope with extremely deep memory, and then wade through all that memory after capturing a very long record that includes all frames (not just selective frames). This can be costly, slow, and difficult.

Using Agilent’s InfiniiVision Series oscilloscopes, engineers can set up the scope to capture up to 2000 segments (frames) with precise time-tagging between each frame, and then review them individually with automatic decoding (time-correlated decode trace AND lister) as shown in Figure 7. For this measurement example of capturing consecutive occurrences of just frame 07F, it makes it much easier to measure the time between occurrences of this particular frame, and also allows you to track the data within this particular frame each time it is transmitted.

Although segmented memory acquisition is also available on some other vendor’s oscilloscopes, Agilent’s implementation of segmented memory acquisition in the InfiniiVision Series oscilloscope not only automatically decodes frames, but is also the only scope that displays decoded frames from segmented acquisitions in the protocol lister display.

To learn more about segmented memory applications, download Agilent’s application note titled, “Segmented Memory for Serial Bus Applications” listed at the end of this document.

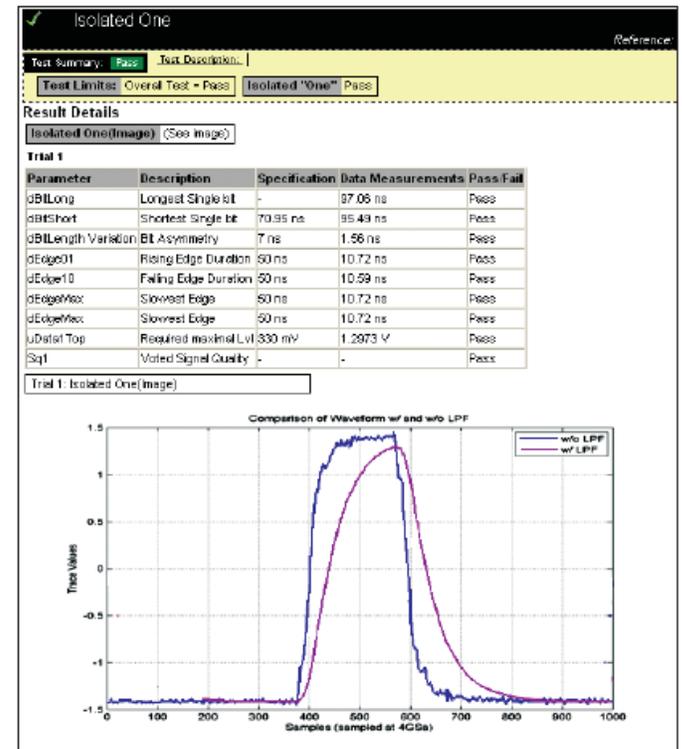
## Only Battery-Operated Oscilloscopes with Automotive Options



**Figure 8: The Agilent 6000 Series oscilloscope with battery and automotive bus options.**

Automotive systems must often be tested in the “field”, and sometimes under real driving situations. Agilent’s 6000 Series oscilloscope shown in Figure 8 is the only scope on the market today that comes with a battery option AND serial bus options that are common in the automotive industry.

## Only Oscilloscopes with FlexRay Physical Layer Conformance Test Software and with Complete Test Reporting



**Figure 9: Test report from Agilent’s 7000B FlexRay Physical Layer Conformance Test software package.**

The FlexRay option on the Agilent 7000B Series oscilloscope comes standard with the FlexRay Physical Layer Conformance Test software package that runs on a PC connected to the scope. This is the oscilloscope industry's most comprehensive FlexRay Physical Layer test package with complete test reporting as shown in Figure 9.

To learn more about FlexRay physical layer conformance testing, download the "FlexRay Analysis Option for 7000 Series Oscilloscopes" data sheet listed at the end of this document.

### Lowest Price Oscilloscopes with CAN, LIN, and FlexRay Options



Figure 10: Agilent's DSOX3012A oscilloscope.

Agilent's 3000 X-Series oscilloscopes are the lowest priced scopes on the market today that provide serial

### Related Literature

Publication Title	Publication Type	Publication Number
<i>Agilent InfiniiVision 3000 X-Series Oscilloscopes</i>	Data sheet	5990-6619EN
<i>Agilent InfiniiVision 7000 Series Oscilloscopes</i>	Data sheet	5990-4769EN
<i>Serial Bus Applications for InfiniiVision 3000 X-Series Oscilloscopes</i>	Data sheet	5990-6677EN
<i>FlexRay Analysis Option for 7000B Series Oscilloscopes</i>	Data sheet	5989-9635EN
<i>Evaluating Oscilloscopes for Best Waveform Update Rates</i>	Application Note	5989-7885EN
<i>CAN Eye-diagram Mask Testing</i>	Application Note	5991-0484EN
<i>FlexRay Eye-diagram Mask Testing</i>	Application Note	5990-4923EN
<i>Segmented Memory for Serial Bus Applications</i>	Application Note	5990-5817EN

To download these documents, insert the publication number in the URL: <http://cp.literature.agilent.com/litweb/pdf/xxxx-xxxxEN.pdf>

bus triggering and decoding for the CAN, LIN, and FlexRay buses. Customers can purchase a two channel, 100-MHz bandwidth DSOX3012A (shown in Figure 10) with the DSOX3AUTO CAN/LIN trigger and decode option for approximately US\$3600. For an additional US\$1500, the scope can also be equipped with the FlexRay option (DSOX3FLEX). No other vendor's scopes on the market today can come close to this entry-level price-point while supporting all of these automotive serial bus options.

To learn more about Agilent's InfiniiVision 3000 X-Series oscilloscopes, download the "InfiniiVision 3000 X-Series Oscilloscopes" data sheet listed at the end of this document.

### Summary

All of today's major oscilloscope vendors offer options for triggering on, decoding, and searching data on the CAN, LIN, and FlexRay serial buses. So you have choice. This document focused on showing you what's unique and different about Agilent's InfiniiVision Series oscilloscopes. Many of the unique capabilities of Agilent's scopes will help you characterize and debug the physical layer of automotive serial faster. To learn more about Agilent's InfiniiVision Series oscilloscopes, refer to the data sheets and application notes listed below. To view short videos focused on automotive applications, go to [www.agilent.com/find/scopes-auto](http://www.agilent.com/find/scopes-auto).

