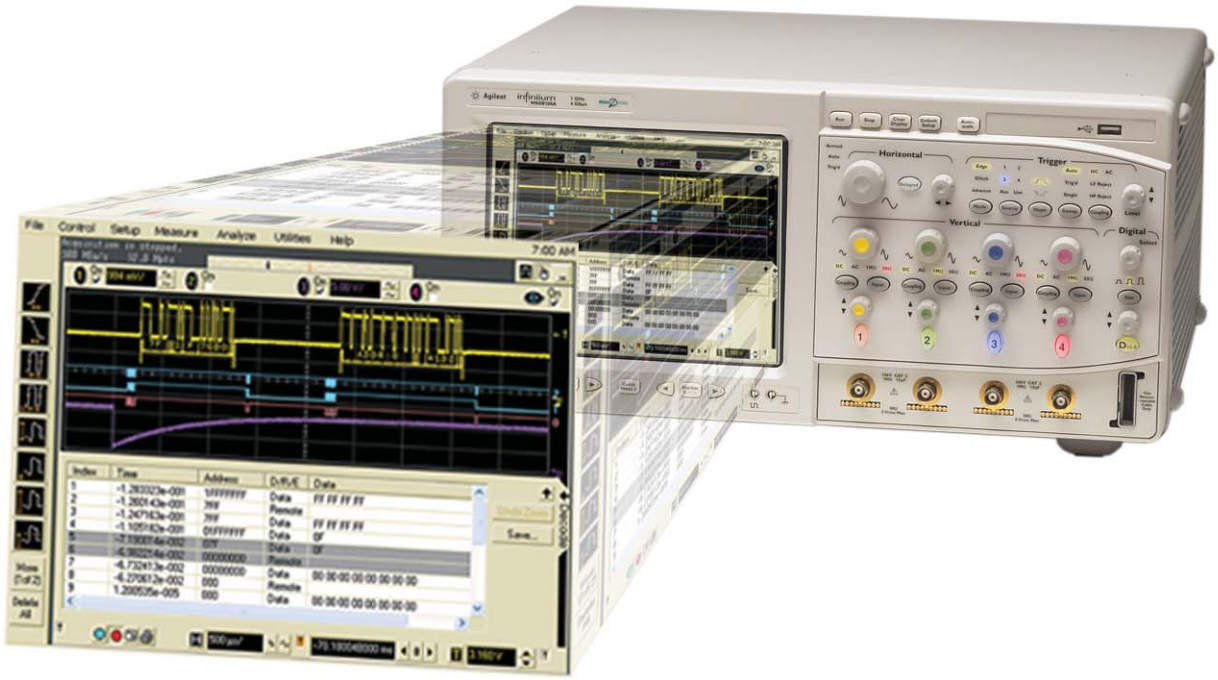
N5402A Automotive Serial Data Analysis Software for Infiniium 8000 Series Oscilloscopes

Data Sheet



Agilent Technologies

Features

- **Protocol decode of the CAN and FlexRay serial buses**
- **Extensive search capability of CAN and FlexRay frames**
- **FlexRay jitter and eye-diagram measurements with automatic mask testing**
- **FlexRay mask failure analysis using eye unfolding**

The event-driven CAN (Controller Area Network) serial bus has become the backbone for communication among many separate controllers, sensors, actuators, and ECUs located throughout automotive and industrial designs. The time-triggered FlexRay serial bus is gaining rapid adoption for more safety-critical and drive-by-wire applications where higher baud rates and a deterministic architecture are required.

Software engineers typically use dedicated protocol analyzers for higher-level abstract observation of the data layer information of these buses – but without seeing the physical/signal layer characteristics. Hardware engineers often use traditional oscilloscopes to view the physical layer characteristics of automotive serial bus signals, but without being able to easily decipher protocol level information.

The Agilent Technologies N5402A Automotive Serial Data Analysis software allows engineers to view both the protocol layer information and physical layer signal characteristics inside a single instrument – the Infiniium oscilloscope.

CAN and FlexRay protocol decode analysis

The N5402A's Automotive analysis software package extends Infiniium's ease-of-use advantages to serial data analysis. The dialog box makes the setup process to perform CAN and FlexRay serial decode easy. CAN analysis supports CAN 2.0A and CAN 2.0B compliant messages with user-selectable standard data rates from 10 kHz to 1 MHz. In addition, CAN analysis supports single-ended probing on CAN_H or CAN_L, or differential probing across both CAN_H and CAN_L with the signal type selection box as shown in Figure 1.

FlexRay analysis supports user-selectable standard data rates of 2.5 Mbps, 5.0 Mbps, and 10 Mbps. Using the FlexRay setup dialog box shown in Figure 2, you can quickly set up the scope to capture and decode FlexRay frames after entering your system's baud rate and synchronous cycle time. If you then click **Autoset and Trigger On Cycle TSS**, the scope will automatically select the optimum sample rate, memory depth, clock recovery method, and triggering to repetitively capture an entire FlexRay cycle while triggering on one unique Transmission Start Sequence (TSS) event.

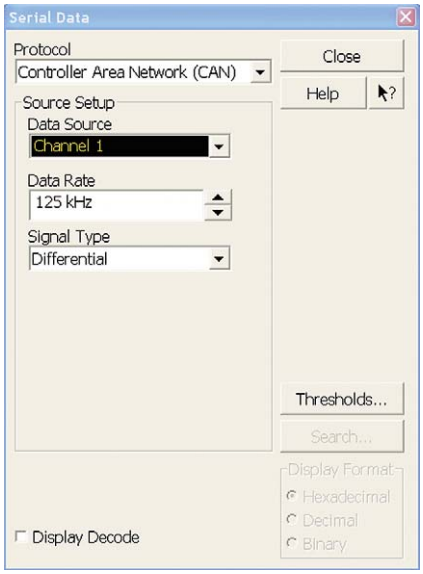


Figure 1. Setup dialog box for CAN analysis

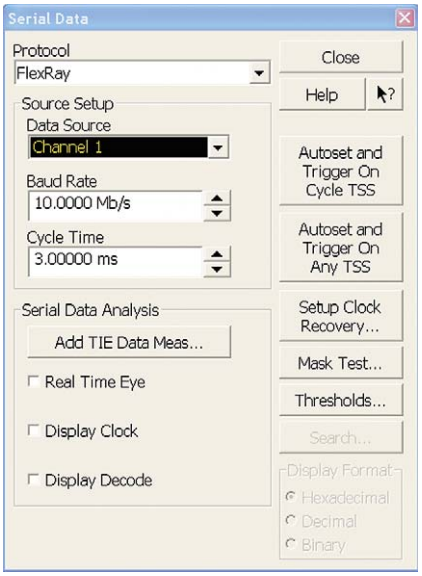


Figure 2. Setup dialog box for FlexRay analysis

Listing window with automatic click and zoom

CAN and FlexRay decode analysis features a time-correlated decode trace with tic marks, as well as a listing window view with automatic click and zoom capability. When either CAN or FlexRay decode analysis has been turned on, a sliding tab is available to either show or hide a protocol decode list of all frames that have been captured in an acquisition including the index number and time stamp value of each frame. For CAN signals, the window also shows the Data/Remote/Error frame type, ID, and data content of each CAN packet in the list. For FlexRay signals, the window shows the frame ID, cycle number, and the payload.

With the listing window, you can easily scroll through all decoded serial packets in an acquisition to find particular events of interest in the transmission. The listing window can be in full-screen to see more decoded packets at one time, or in half-screen to see the listing window along with the captured waveforms as shown in Figures 3 and 4.

To enable easy correlation between the listing window and waveform display, the listing window highlights those serial packets that are currently being viewed in the waveform display. For instance, if you are viewing five serial packets in the waveform display, the listing window will highlight those five serial packet items in the list. The listing window also features an automatic click and zoom capability so that once a particular packet of interest is found in the list, you can click on it to have the scope automatically zoom into that packet for more detailed waveform analysis.

The data in the listing window can be saved to a .csv or .txt file for off-line analysis or documentation purposes.

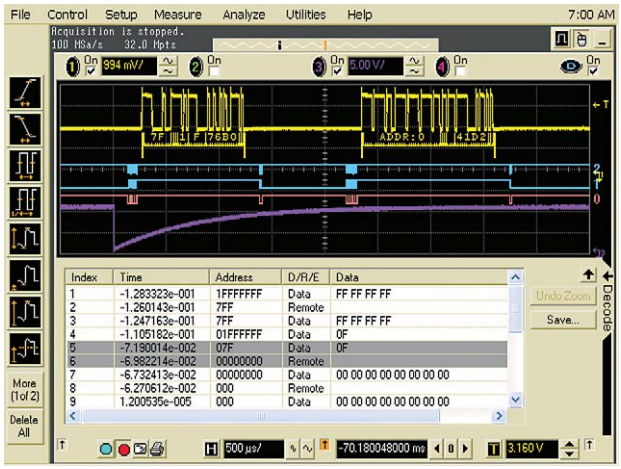


Figure 3. CAN protocol decoding

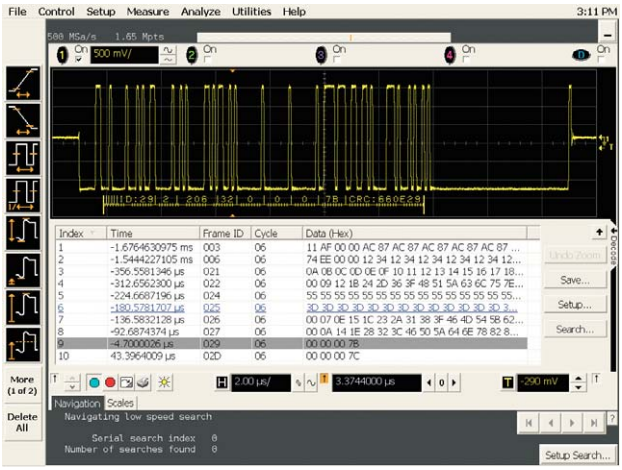


Figure 4. FlexRay protocol decoding

FlexRay eye pattern and jitter analysis

Eye-diagram measurements have traditionally been performed on oscilloscopes by triggering on an explicit clock signal while accumulating multiple/repetitive overlaid waveforms (infinite persistence) of a data signal. However, many of today's serial buses, such as FlexRay, are based on signals with embedded clocks (non-explicit). Creating eye-diagram displays on these types of serial buses requires that the scope be able to extract and recover the clock from real-time acquisitions of the signal. The recovered clock is then used to "slice" the waveform into multiple bit segments (Unit Intervals) that are then overlaid – or folded – into an eye-diagram display.

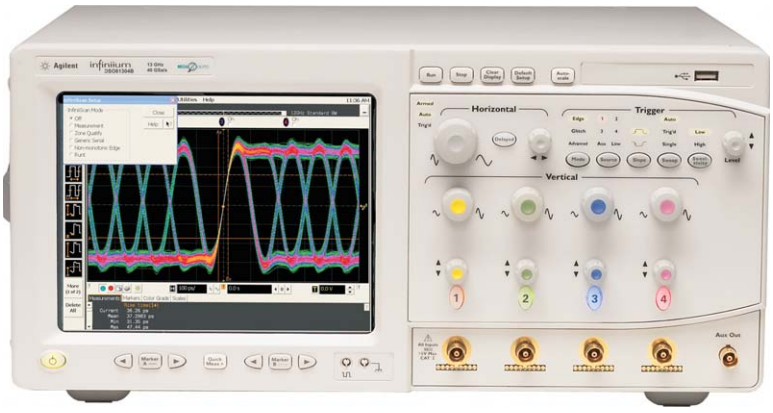


Figure 5. FlexRay eye-diagram and jitter analysis using an Infiniium oscilloscope

With the N5402A option, Agilent's Infiniium Series oscilloscopes can automatically perform real-time eye-diagram measurements along with pass/fail mask testing on the differential FlexRay bus.

For FlexRay real-time eye measurements, there are a variety of clock recovery algorithms to choose from based on clock rates (2.5 Mbps, 5.0 Mbps, and 10 Mbps) and test plane (TP1, TP2, TP3, and TP4). In addition, you can select clock recovery algorithms from a transmitter's or receiver's perspective. When using the receiver clock recovery algorithm, the scope re-synchronizes an ideal/theoretical clock (10 MHz for 10 Mbps FlexRay) to each Byte Start Sequence (BSS) event of every frame. This creates an eye from a receiver's perceptive showing you what the receiver "sees" relative to its clock re-synchronization.

When using one of the FlexRay transmitter clock recovery algorithms, the scope synchronizes an ideal clock to just the first Byte Start Sequence (BSS) event of each frame. Eyes created using this clock recovery algorithm will show what the transmitter sends which may include possible transmitter timebase drift and inaccuracies relative to the ideal clock rate over an entire frame. This method also provides relative timing information of each BSS event within frames.

In addition to specifying bit rates and transmitter or receiver clock recovery, the N5402A's FlexRay clock recovery algorithms also supports filtering the clock recovery on specific frame IDs and cycle number – including base and repetition. This enables the Infiniium oscilloscope to create eye-diagrams based on specific nodes in your synchronous system.

Automatic pass/fail eye mask testing and jitter analysis

Along with creating user-selected real-time eye patterns, the Infiniium oscilloscope also supports automatic pass/fail mask testing on FlexRay differential waveforms as shown in Figure 6. When a specific mask test is selected, the scope pre-sets display scaling, sample rate, memory depth and clock recovery algorithm – and then applies the selected industry standard mask for comparison. Any failures of the mask are then highlighted in red within the mask region.

When using FlexRay mask testing, the scope runs continuously until a failure is detected. This can be very useful for running overnight tests to look for extremely infrequent and random failures.

In addition to pass/fail mask testing, the Infiniium also automatically performs a Time Interval Error (TIE) measurement on each data signal edge crossing relative to the FlexRay recovered clock. This provides a statistical measurement of the jitter in your system.

With the addition of Infiniium's EZJIT jitter analysis software option, jitter can be displayed in various formats including TIE trend, histogram, and spectral views as shown in Figure 7.

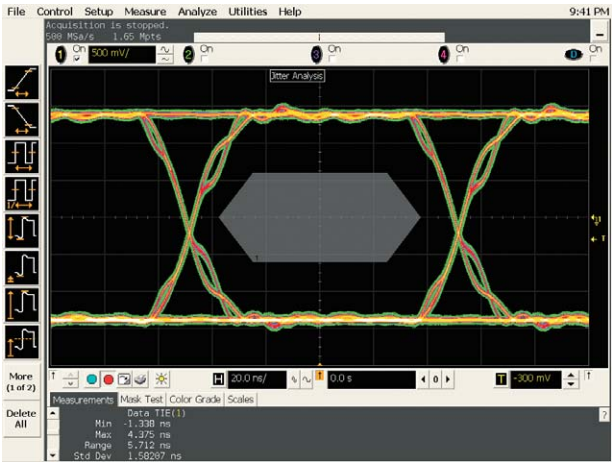


Figure 6. FlexRay mask test using a TP1 mask



Figure 7. Performing jitter analysis on FlexRay signals is easy with Agilent EZJIT jitter analysis software

Analyzing mask failures

After running a “stop-on-failure” FlexRay mask test, you can then easily “unfold” the eye pattern waveform to restore the last captured real-time waveform to reveal the location of each mask violation.

Figure 8 shows a TP1 FlexRay mask test using a receiver clock recovery algorithm. This test uncovered a severe and infrequent timing problem in our system. The timing error occurred after acquiring over 7,000 FlexRay cycles (3 ms cycle time), and after capturing and measuring edge timing of over 14,000,000 unit intervals (100 ns bit intervals) in a 10 Mbps synchronous FlexRay system. Total test time was approximately 1 hour and 45 minutes before capturing the first mask violation.

When the FlexRay eye pattern is unfolded and protocol decoding is turned on, we can see that the first failure occurred during static frame ID:6 as shown in Figure 9. Note the highlighted red waveform segment near the center of the display indicating the real-time location of the timing violation relative to the beginning of the frame.

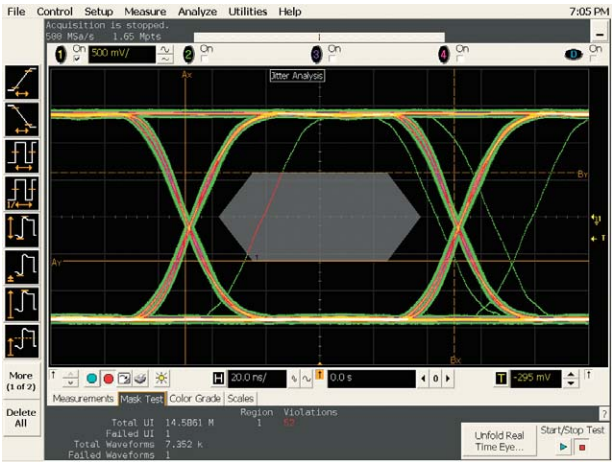


Figure 8. FlexRay eye mask failure

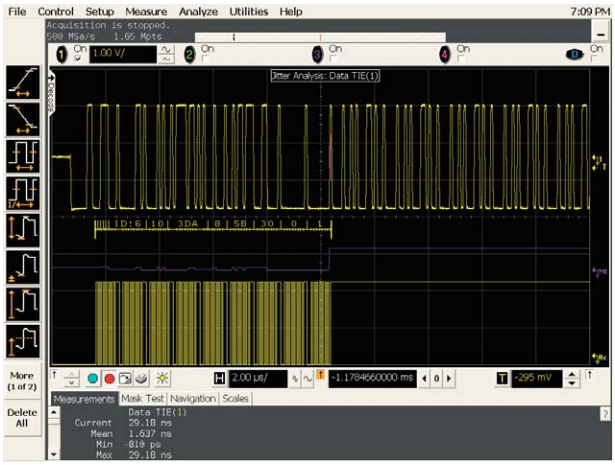


Figure 9. Unfolding the eye reveals that a timing failure occurred during static frame #6

Analyzing mask failures

With the scope's timebase expanded around this unfolded mask failure as shown in Figure 10, we can quickly measure the timing of this errant pulse relative to the recovered clock (bottom yellow trace). It initially appeared that the rising edge of the 8th bit of the 9th byte of frame ID:6 (2nd pulse displayed) occurred approximately 30 ns late. Note that the binary decode indicates that this payload byte has a value of 0000 0001.

After further analysis, we determined that this errant pulse that generated the mask violation wasn't supposed to be the 8th bit of this byte. This pulse was actually the next BSS pulse which should precede the 10th byte of the frame. But it occurred approximately 85 ns early and slid into the 9th byte, which was supposed to be a null byte (0000 0000). In an ideal 10 Mbps FlexRay system, BSS events occur exactly 1 µs apart. This timing violation has produced what appears to be a coding error in our FlexRay system.

Using the scope's automatic parametric measurements we also determined that the width of the errant BSS pulse was just 90 ns. The ideal width of BSS pulses following a "0" is 100 ns for 10 Mbps FlexRay systems. Visually compare the width of the two BSS pulses shown in Figure 10. The Infiniium's FlexRay eye mask test and unfolding capability has revealed a severe systematic and infrequent timing problem in our FlexRay design.



Figure 10. Timing measurements on the errant FlexRay pulse reveals that a BSS pulse occurred nearly one bit period early

Mask files

Included in the N5402A automotive serial data analysis software are 48 FlexRay mask test files. Automatic mask testing can be easily executed using these files within the appropriate automotive serial data analysis menu. Table 1 summarizes the default mask and setup parameters for each of these mask test files. Mask test parameters and default GP-IB commands can be easily modified using a standard text editor.

Table 1. FlexRay mask files

Mask file name	Baud rate	Test plane[1]	Clock recovery method[1]	Observation window	Test time
FlexRay 10M TP1-receiver-1cycle.msk	10 Mbps	TP1	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 10M TP2-receiver-1cycle.msk	10 Mbps	TP2	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 10M TP3-receiver-1cycle.msk	10 Mbps	TP3	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 10M TP4-receiver-1cycle.msk	10 Mbps	TP4	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 10M TP1-transmitter-1cycle.msk	10 Mbps	TP1	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 10M TP2-transmitter-1cycle.msk	10 Mbps	TP2	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 10M TP3-transmitter-1cycle.msk	10 Mbps	TP3	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 10M TP4-transmitter-1cycle.msk	10 Mbps	TP4	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 10M TP1-receiver-95bits.msk	10 Mbps	TP1	10 MHz sync'd to every BSS	9.5 µs[3]	Stop-on-failure
FlexRay 10M TP2-receiver-95bits.msk	10 Mbps	TP2	10 MHz sync'd to every BSS	9.5 µs[3]	Stop-on-failure
FlexRay 10M TP3-receiver-95bits.msk	10 Mbps	TP3	10 MHz sync'd to every BSS	9.5 µs[3]	Stop-on-failure
FlexRay 10M TP4-receiver-95bits.msk	10 Mbps	TP4	10 MHz sync'd to every BSS	9.5 µs[3]	Stop-on-failure
FlexRay 10M TP1-transmitter-95bits.msk	10 Mbps	TP1	10 MHz sync'd to 1st BSS in frame	9.5 µs[3]	Stop-on-failure
FlexRay 10M TP2-transmitter-95bits.msk	10 Mbps	TP2	10 MHz sync'd to 1st BSS in frame	9.5 µs[3]	Stop-on-failure
FlexRay 10M TP3-transmitter-95bits.msk	10 Mbps	TP3	10 MHz sync'd to 1st BSS in frame	9.5 µs[3]	Stop-on-failure
FlexRay 10M TP4-transmitter-95bits.msk	10 Mbps	TP4	10 MHz sync'd to 1st BSS in frame	9.5 µs[3]	Stop-on-failure

1. It should be noted that masks and clock recovery methods have not been fully defined within the FlexRay physical layer test specification for testing multi-node synchronous FlexRay systems as of Agilent's release of the N5402A automotive serial data analysis software option.
2. Oscilloscope sample rate and memory depth have been pre-selected to capture a default cycle time of 3 ms. Instructions are included within each mask file on how to easily modify the acquisition time to match your synchronous FlexRay system cycle time using a standard text editor.
3. Testing for an observation window of 9.5 µs on 10 Mbps FlexRay signals is in compliance with the physical layer conformance test specification, version 2.1, revision A, paragraph 5.1.4.6. A 9.5 µs observation window translates into 95 bits for slower baud rate FlexRay systems resulting in observation windows/acquisition times of 19 µs for 5.0 Mbps systems and 38 µs for 2.5 Mbps systems.

Mask files

Table 1. FlexRay mask files *(continued)*

Mask file name	Baud rate	Test plane[1]	Clock recovery method[1]	Observation window	Test time
FlexRay 5M TP1-receiver-1cycle.msk	5 Mbps	TP1	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 5M TP2-receiver-1cycle.msk	5 Mbps	TP2	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 5M TP3-receiver-1cycle.msk	5 Mbps	TP3	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 5M TP4-receiver-1cycle.msk	5 Mbps	TP4	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 5M TP1-transmitter-1cycle.msk	5 Mbps	TP1	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 5M TP2-transmitter-1cycle.msk	5 Mbps	TP2	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 5M TP3-transmitter-1cycle.msk	5 Mbps	TP3	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 5M TP4-transmitter-1cycle.msk	5 Mbps	TP4	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 5M TP1-receiver-95bits.msk	5 Mbps	TP1	10 MHz sync'd to every BSS	19 µs[3]	Stop-on-failure
FlexRay 5M TP2-receiver-95bits.msk	5 Mbps	TP2	10 MHz sync'd to every BSS	19 µs[3]	Stop-on-failure
FlexRay 5M TP3-receiver-95bits.msk	5 Mbps	TP3	10 MHz sync'd to every BSS	19 µs[3]	Stop-on-failure
FlexRay 5M TP4-receiver-95bits.msk	5 Mbps	TP4	10 MHz sync'd to every BSS	19 µs[3]	Stop-on-failure
FlexRay 5M TP1-transmitter-95bits.msk	5 Mbps	TP1	10 MHz sync'd to 1st BSS in frame	19 µs[3]	Stop-on-failure
FlexRay 5M TP2-transmitter-95bits.msk	5 Mbps	TP2	10 MHz sync'd to 1st BSS in frame	19 µs[3]	Stop-on-failure
FlexRay 5M TP3-transmitter-95bits.msk	5 Mbps	TP3	10 MHz sync'd to 1st BSS in frame	19 µs[3]	Stop-on-failure
FlexRay 5M TP4-transmitter-95bits.msk	5 Mbps	TP4	10 MHz sync'd to 1st BSS in frame	19 µs[3]	Stop-on-failure

1. It should be noted that masks and clock recovery methods have not been fully defined within the FlexRay physical layer test specification for testing multi-node synchronous FlexRay systems as of Agilent's release of the N5402A automotive serial data analysis software option.
2. Oscilloscope sample rate and memory depth have been pre-selected to capture a default cycle time of 3 ms. Instructions are included within each mask file on how to easily modify the acquisition time to match your synchronous FlexRay system cycle time using a standard text editor.
3. Testing for an observation window of 9.5 µs on 10 Mbps FlexRay signals is in compliance with the physical layer conformance test specification, version 2.1, revision A, paragraph 5.1.4.6. A 9.5 µs observation window translates into 95 bits for slower baud rate FlexRay systems resulting in observation windows/acquisition times of 19 µs for 5.0 Mbps systems and 38 µs for 2.5 Mbps systems.

Mask files

Table 1. FlexRay mask files *(continued)*

Mask file name	Baud rate	Test plane[1]	Clock recovery method[1]	Observation window	Test time
FlexRay 2.5M TP1-receiver-1cycle.msk	2.5 Mbps	TP1	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 2.5M TP2-receiver-1cycle.msk	2.5 Mbps	TP2	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 2.5M TP3-receiver-1cycle.msk	2.5 Mbps	TP3	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 2.5M TP4-receiver-1cycle.msk	2.5 Mbps	TP4	10 MHz sync'd to every BSS	1 cycle[2]	Stop-on-failure
FlexRay 2.5M TP1-transmitter-1cycle.msk	2.5 Mbps	TP1	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 2.5M TP2-transmitter-1cycle.msk	2.5 Mbps	TP2	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 2.5M TP3-transmitter-1cycle.msk	2.5 Mbps	TP3	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 2.5M TP4-transmitter-1cycle.msk	2.5 Mbps	TP4	10 MHz sync'd to 1st BSS in frame	1 cycle[2]	Stop-on-failure
FlexRay 2.5M TP1-receiver-95bits.msk	2.5 Mbps	TP1	10 MHz sync'd to every BSS	38 µs[3]	Stop-on-failure
FlexRay 2.5M TP2-receiver-95bits.msk	2.5 Mbps	TP2	10 MHz sync'd to every BSS	38 µs[3]	Stop-on-failure
FlexRay 2.5M TP3-receiver-95bits.msk	2.5 Mbps	TP3	10 MHz sync'd to every BSS	38 µs[3]	Stop-on-failure
FlexRay 2.5M TP4-receiver-95bits.msk	2.5 Mbps	TP4	10 MHz sync'd to every BSS	38 µs[3]	Stop-on-failure
FlexRay 2.5M TP1-transmitter-95bits.msk	2.5 Mbps	TP1	10 MHz sync'd to 1st BSS in frame	38 µs[3]	Stop-on-failure
FlexRay 2.5M TP2-transmitter-95bits.msk	2.5 Mbps	TP2	10 MHz sync'd to 1st BSS in frame	38 µs[3]	Stop-on-failure
FlexRay 2.5M TP3-transmitter-95bits.msk	2.5 Mbps	TP3	10 MHz sync'd to 1st BSS in frame	38 µs[3]	Stop-on-failure
FlexRay 2.5M TP4-transmitter-95bits.msk	2.5 Mbps	TP4	10 MHz sync'd to 1st BSS in frame	38 µs[3]	Stop-on-failure

1. It should be noted that masks and clock recovery methods have not been fully defined within the FlexRay physical layer test specification for testing multi-node synchronous FlexRay systems as of Agilent's release of the N5402A automotive serial data analysis software option.
2. Oscilloscope sample rate and memory depth have been pre-selected to capture a default cycle time of 3 ms. Instructions are included within each mask file on how to easily modify the acquisition time to match your synchronous FlexRay system cycle time using a standard text editor.
3. Testing for an observation window of 9.5 µs on 10 Mbps FlexRay signals is in compliance with the physical layer conformance test specification, version 2.1, revision A, paragraph 5.1.4.6. A 9.5 µs observation window translates into 95 bits for slower baud rate FlexRay systems resulting in observation windows/acquisition times of 19 µs for 5.0 Mbps systems and 38 µs for 2.5 Mbps systems.

Probe automotive signals with precision – even in environmental chambers

Signal integrity measurements on automotive differential signals such as CAN and FlexRay require differential active probing. Agilent offers a range of differential active probes for various bandwidths and dynamic range applications. For the most accurate measurements in automotive embedded systems, Agilent recommends the 1130 Series InfiniiMax active probes for either single-ended or differential applications. This family of active probes comes with a variety of interchangeable, passive probe heads for various probing use-models including browsing, solder-in, and socketed applications (see Figure 11).

Automotive embedded designs must be tested under simulated extreme conditions in environmental chambers. These extreme conditions may include testing ECUs and differential serial buses, at temperatures exceeding 100 °C. Unfortunately, the active circuitry in today's typical active probes cannot tolerate temperatures exceeding 150 °C. However, with the unique electrical and physical architecture of the 1130 Series InfiniiMax active probes, the Extreme Temperature Cable Extension Kit (N5450A) can be used to extend and displace the probe's active amplifier to be outside of an environmental chamber (see Figure 12). With this configuration, InfiniiMax' passive probe heads can be connected to test points within the chamber with temperatures ranging from –55 °C to +155 °C.



Figure 11. Agilent 1130 Series differential active probes with interchangeable passive probe heads



Figure 12. The Extreme Temperature Cable Extension Kit (N5450A) allows differential active probing within environmental chambers at extreme temperatures.

Easily make automotive mixed-signal measurements

Today's automotive designs include a combination of analog, digital, and serial bus signals. The automotive embedded designer often needs to time-correlate signal activity across analog sensors, serial communication, and digital control and I/O signals within ECUs. Agilent Infiniium 8000 Series Mixed Signal Oscilloscopes (MSOs) are the perfect fit for verifying and debugging these types of designs. Agilent MSOs that support automotive serial bus applications provide four channels of analog acquisition and up to sixteen channels of logic signal acquisition, as shown in Figure 13.

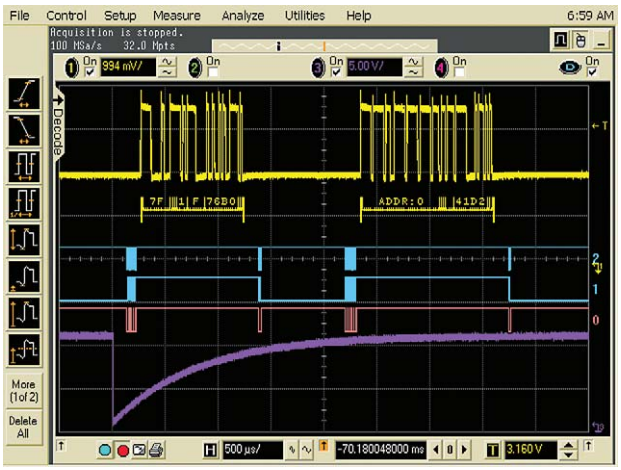


Figure 13. Mixed-signal measurements in automotive system using an MSO

Oscilloscope compatibility

Oscilloscope	Software revision
8000 Series	Requires upgrade to A.05.40 or higher

Ordering information

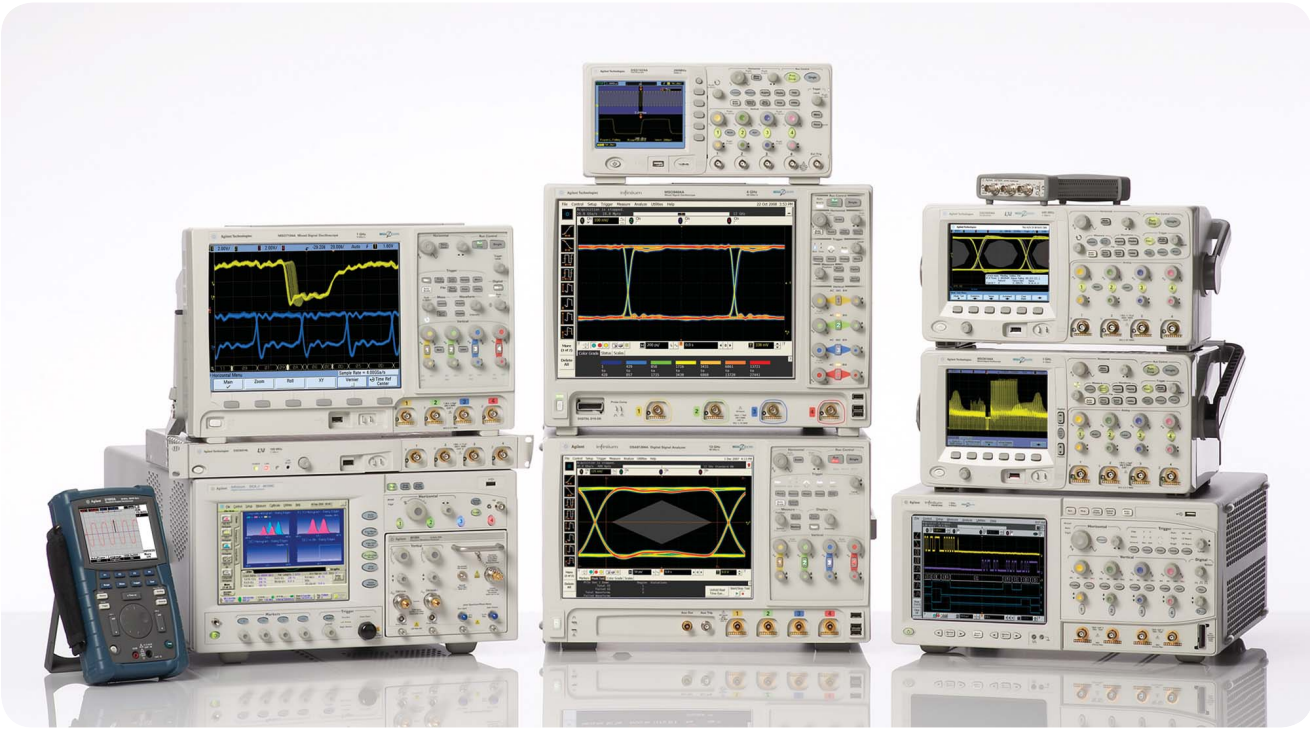
Model	Description
DSO8064A	4-channel 600-MHz DSO
DSO8104A	4-channel, 1-GHz DSO
MSO8064A	4+16-channel, 600-MHz MSO
MSO8104A	4+16-channel, 1-GHz MSO
N5402A (or Option -008)	CAN/FlexRay serial data analysis
1130A	1.5-GHz differential active probe amplifier
E2675A	Differential probe browser kit
N5450A	InfiniiMax Extreme Temperature Cable Extension Kit

Related literature

Publication title	Publication type	Publication number
Infiniium 8000 Series Oscilloscopes	Data Sheet	5989-4271EN
Infiniium Series Oscilloscope Probes, Accessories, and Options	Data Sheet	5968-7141EN
Agilent Technologies EZJIT and EZJIT Plus Jitter Analysis Software for Infiniium Series Oscilloscopes	Data Sheet	5989-0109EN
N5450A InfiniiMax Extreme Temperature Extension Cable	Data Sheet	5989-7542EN
Extending the Range of Agilent InfiniiMax Probes	Application Note	5989-7587EN
Finding Sources of Jitter with Real-Time Jitter Analysis	Application Note	5988-9740EN

Product Web site

For the most up-to-date and complete application and product information, please visit our product Web site at:
www.agilent.com/find/scopes



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Agilent Open simplifies the process of connecting and programming test systems to help engineers design, validate and manufacture electronic products. Agilent offers open connectivity for a broad range of system-ready instruments, open industry software, PC-standard I/O and global support, which are combined to more easily integrate test system development.

LXI

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LXI is the LAN-based successor to GPIB, providing faster, more efficient connectivity. Agilent is a founding member of the LXI consortium.

Windows is a U.S. registered trademark of Microsoft Corporation.

www.agilent.com/find/scopes

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