MIL-STD 1553 Triggering and Hardware-based Decode (Option 553) for Agilent's InfiniiVision Series Oscilloscopes

Data Sheet

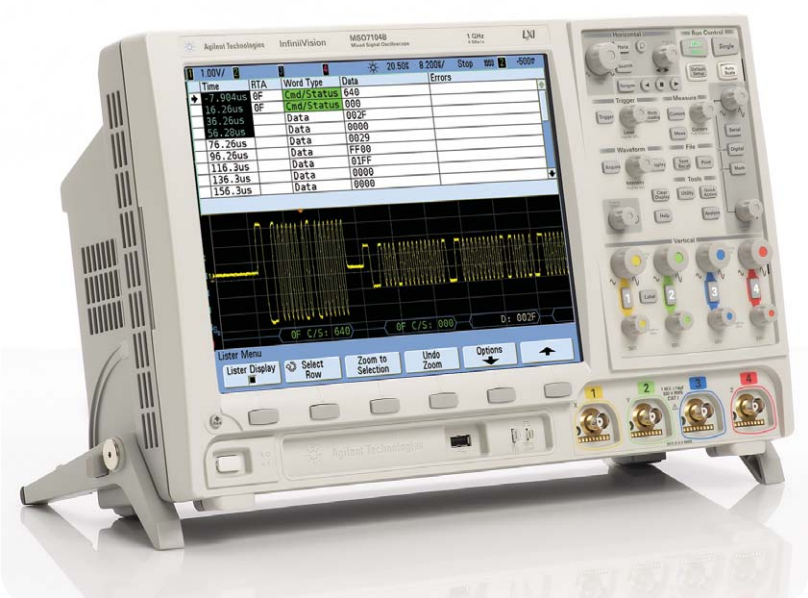
Debug the physical layer characteristics of your MIL-STD 1553 bus faster

Introduction

The differential 1-Mbs MIL-STD 1553 serial bus is widely used today in a broad range of aerospace/defense systems including aircraft avionics equipment, space-based systems, as well as many ground-based military vehicles.

Up until now, capturing and measuring the electrical characteristics of MIL-STD 1553 signals has been a difficult and tedious process using a conventional analog or digital oscilloscope. Setting up the scope to trigger and synchronize on specific transmitted words often required an external synchronization signal or guessing at a specific trigger hold-off setting. And then to determine the contents of a captured and displayed communication packet/word required a commonly used visual "bit-counting" technique, which is slow and prone to errors. But those days are over.

Agilent Technologies InfiniiVision Series oscilloscopes now offers integrated MIL-STD 1553 serial bus triggering, hardware-based decoding, and eye-diagram mask testing to help you debug and characterize the electrical/physical layer of MIL-STD 1553 serial buses.



Features

- Hardware-based decoding of Command/Status and Data Words helps find errors quicker.
- Trigger on specific Command/Status Words, Data Words, and error conditions.
- Perform hardware-based pass/fail MIL-STD 1553 mask testing to test the analog quality of your network.
- Capture more consecutive decoded 1553 Words using Segmented Memory acquisition
- Automatically perform parametric measurements with statistics to compare against published MIL-STD 1553 electrical specifications.
- Make physical layer measurements in the field with the only oscilloscope for MIL-STD 1553 applications with optional battery operation.

Agilent Technologies

Time-correlate MIL-STD 1553 protocol decoding with physical layer waveforms

With Option 553 on your Agilent InfiniiVision series oscilloscope (or N5469A for after-purchase upgrades), you can now view MIL-STD 1553 protocol decoded communication time-correlated with your physical layer signals. And with Agilent's unique hardware-based protocol decoding, which provides the fastest decode update rates in the oscilloscope industry, the scope can capture and decode up to 100,000 waveforms per second. Not only does fast waveform and decode update rates enhance usability of the scope, but most importantly it improves the scopes probability of capturing random and infrequent communication errors.

Figure 1 shows an example of the scope capturing and displaying MIL-STD 1553 communication between a Bus Controller (BC) and a Remote Terminal (RT). The decode trace at the bottom of the display, which is time-correlated with the captured waveform just above it (yellow trace), shows the decoded Command Word followed by the Status Word response color-coded in green. Following the Status Word we see the beginning of a stream of Data Words transmitted by the RT. The upper half of the scope's display shows the scope's protocol "lister" display. This display shows the "big picture" of MIL-STD 1553 protocol communication that occurs both before and after the trigger event. And with Agilent's new 7000B series scopes, you can also easily Search & Navigate within the lister display to find particular events of interest with direct time-correlation to the waveform display.

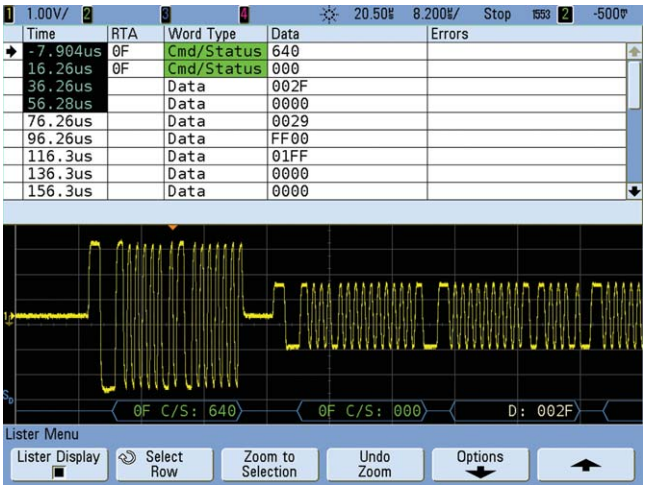
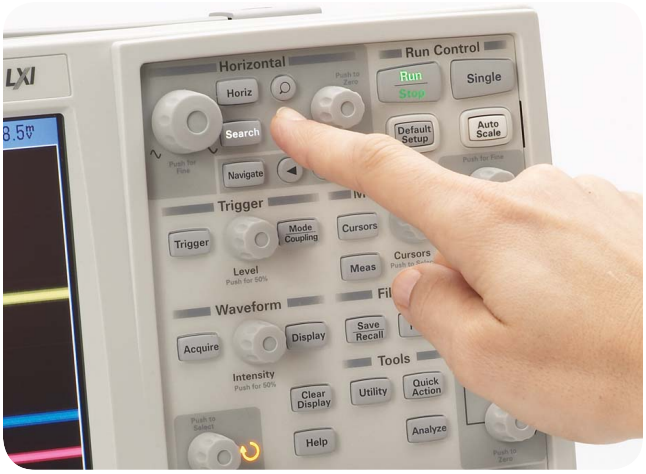


Figure 1: Time-correlated display of the MIL-STD 1553 physical layer signal with protocol decoding.



Flexible MIL-STD 1553 Triggering

With Option 553 on your Agilent InfiniiVision series oscilloscopes, you now have a wide range of triggering possibilities to help you zero-in on specific MIL-STD 1553 communication transactions as shown in Figure 2. The following triggering conditions are supported:

- Data Word Start
- Data Word Stop
- Command/Status Word Start
- Command/Status Word Stop
- Remote Terminal Address
- Remote Terminal Address + 11 Bits
- Parity Error
- Sync Error
- Manchester Error

To uniquely trigger on specific Command or Status Words, the "Remote Terminal Address + 11 Bits" triggering mode can be used. The "11 Bits" refers to bit times 9 through 19, which are the 11 bits that follow the 5 bit remote terminal address (RTA) field. For example, triggering on a specific Command Word can usually be accomplished by specifying the RTA in hex format, and then the transmit/receive bit plus the 5 bit sub-address in binary format.

Figure 3 shows an example of triggering on a Command Word with an RTA of 15dec ($0F_{HEX}$), transmit/receive bit set high, and with a sub-address equal to 17dec (0F + 1 10001 XXXXX). With this combination of "RTA + 11 Bit" triggering, the scope triggers on the desired Command Word that is requesting data from a specific remote terminal. In this case, we can see that a Status Word from a remote terminal (RT) follows this particular Command Word as expected.

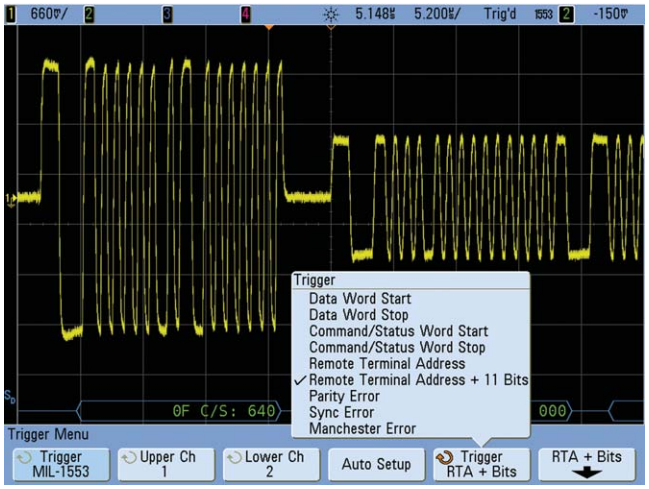


Figure 2. Trigger on specific MIL-STD 1553 communication words and errors.

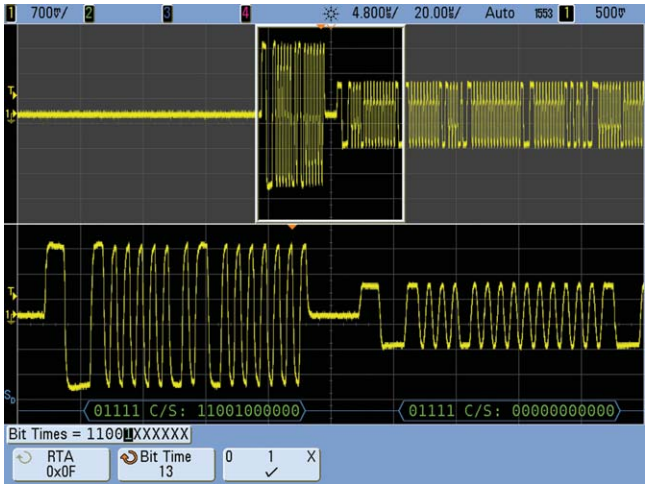


Figure 3. Triggering on a Command Word with a transmit data instruction.

Flexible MIL-STD 1553 Triggering (continued)

Figure 4 shows a similar triggering example. But this time the transmit/receive bit (bit time 9) has been set to "0" (0 10001 XXXXX). Now we can see that after a "receive" instruction is sent, a Data Word sent by the Bus Controller (BC) follows the Command Word as expected.

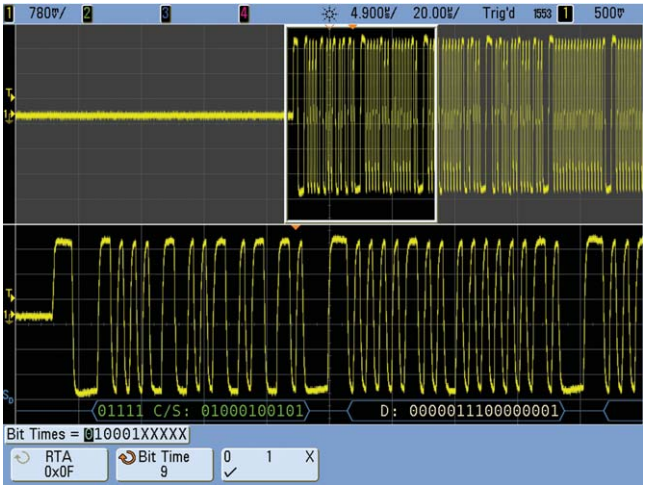


Figure 4. Triggering on a Command Word with a receive data instruction.

In addition to triggering on specific Command and Status Words, Agilent InfiniiVision series scopes can trigger on error conditions including sync errors, Manchester encoding errors, and parity errors. Figure 5 shows an example of the scope setup to trigger on a Manchester encoding error. Using this trigger condition to catch errors, we can see that a Status Word that should be responding to a Command Word (RTA: 0F) sent by the BC has been severely corrupted.

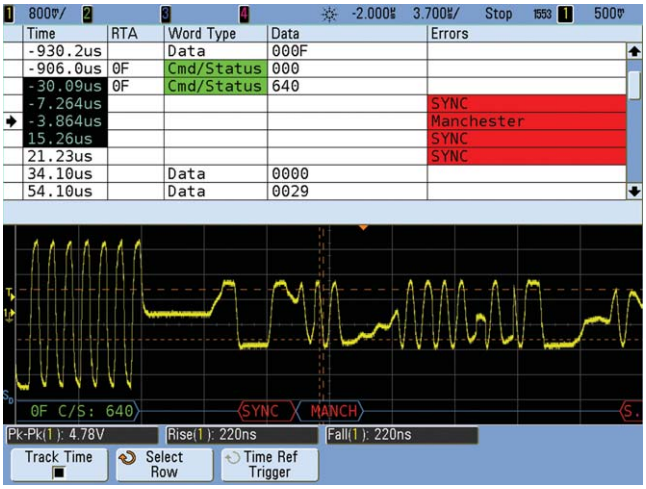


Figure 5. MIL-STD 1553 error triggering helps to uncover signal integrity problems.

MIL-STD 1553 Eye-diagram Mask Testing

With the addition of Agilent's mask testing option (Option LMT) to your InfiniiVision series oscilloscope, you can also perform automatic pass/fail eye-diagram mask tests on your MIL-STD 1553 serial bus. Eye-diagram testing is used in a broad range of today's serial bus applications. An eye-diagram is basically an overlay of digitized bits that shows when bits are valid. This provides a composite picture of the quality of a system's physical layer characteristics, which includes amplitude variations due to transmission line affects, reflections, system noise, over-shoot, ringing, signal edge placement shift, and jitter.

Figure 6 shows a MIL-STD 1553 eye-diagram mask test at the input of a remote terminal (RT). The scope repetitively captures and overlays all 17 Manchester-encoded bits of every Data Word received at the input test points of a specific remote terminal. Notice that some of the lower amplitude signals received at the input of this remote terminal are failing the mask test. This is indicated by the waveform areas highlighted in red that cross through the pass/fail mask.

Although mask limit standards/specifications have not yet been established for MIL-STD 1553 differential signals, Agilent has created diamond-shaped polygon mask limits based on the existing zero-crossing-distortion input specification of +/- 150 ns and the minimum voltage swing input specification of 860 mV p-p for transformer-coupled systems or 1.2 V p-p for direct-coupled systems.

Since the MIL-STD 1553 serial bus is based on Manchester bi-phase encoded data transmission, there are actually two "eyes" and two separate masks for each bit as shown in Figure 6. With this type of data encoding, signal edge transitions should occur near the mid point of each bit field for bit times 4 through 20. We should never see a signal remain high or remain low extending across this pair of half-bit masks. Since the 3-bit synchronization bit field does not adhere to Manchester encoding, these particular bits of each word are not tested.

In addition to performing system eye-diagram mask testing on every received Data Word, Agilent provides a variety of MIL-STD 1553 mask files for testing specific Command or Status Word transmissions received at different input test points in your system. Figure 7 shows an example of testing Command Words transmitted from a Bus Controller and received by a Remote Terminal with RTA equal to $0F_{HEX}$. The following mask files can be downloaded from Agilent's website at no charge

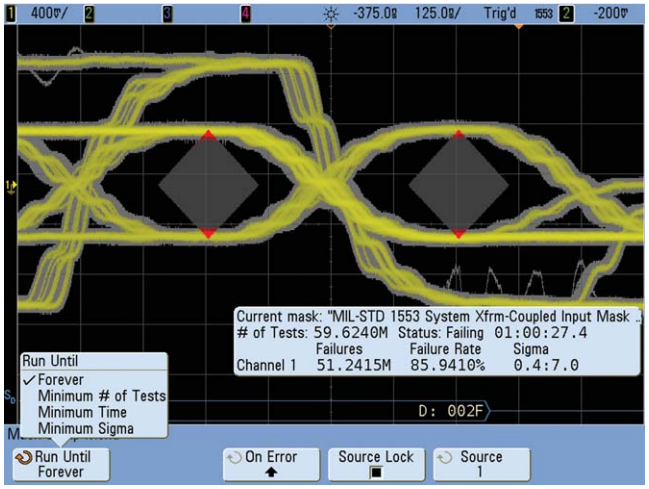


Figure 6. A system eye-diagram mask test on a transmission coupled system at the input of a remote terminal.

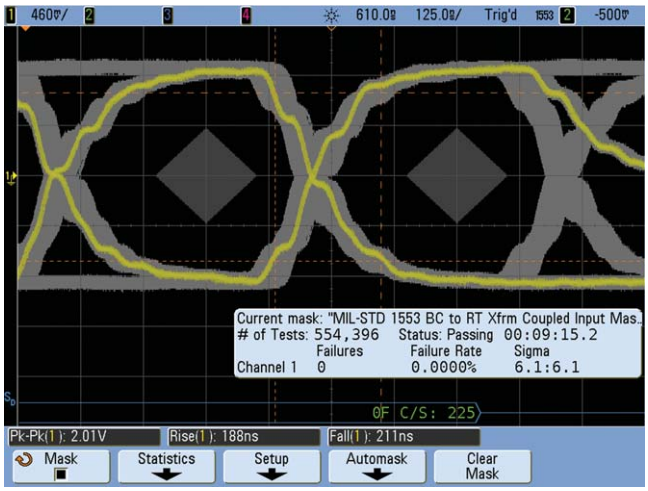


Figure 7. BC to RT 0FHEX transformer-coupled input mask test.

- System xfmr-coupled Input.msk
- System direct-coupled Input.msk
- BC to RT xfmr-coupled Input.msk
- BC to RT direct-coupled Input.msk
- RT to BC xfmr-coupled Input.msk
- RT to BC direct-coupled Input.msk
- RT to RT xfmr-coupled Input.msk
- RT to RT direct-coupled Input.msk

MIL-STD 1553 Eye-diagram Mask Testing (continued)

Agilent's InfiniiVision series oscilloscope mask testing is the only hardware-based mask testing in the oscilloscope industry. This produces the industry's fastest mask testing with test rates up to 100,000 waveforms tested per second. With test rates this fast the scope can quickly uncover very infrequent anomalies and provide detailed pass/fail statistics, including a Sigma quality report. In addition, you have the ability to customize your testing based on a variety of test criteria including:

- Test continuously
- Test until 1st error detected
- Test until a user-specified number of tests has been satisfied
- Test until a user-specified test time has been satisfied
- Test until a user-specified potential Sigma quality has been satisfied

Figure 8 shows an example of a "Stop-on-error" mask test while testing Command and Status Words with an RTA of $0F_{HEX}$. The first mask violation occurred after testing over 1,300 bits. In this example we can see what appears to be a Manchester encoding error.

After acquisitions have been stopped due to this mask violation, we can then re-scale the timebase to effectively "unfold" the eye in order to observe each bit of the last captured Status Word that produced the mask violation as shown in Figure 9. We can now see that it appears that all signal transitions during this word were shifted. Not only did the scope catch this timing error using mask testing, but it also detected and decoded the Manchester encoding error.

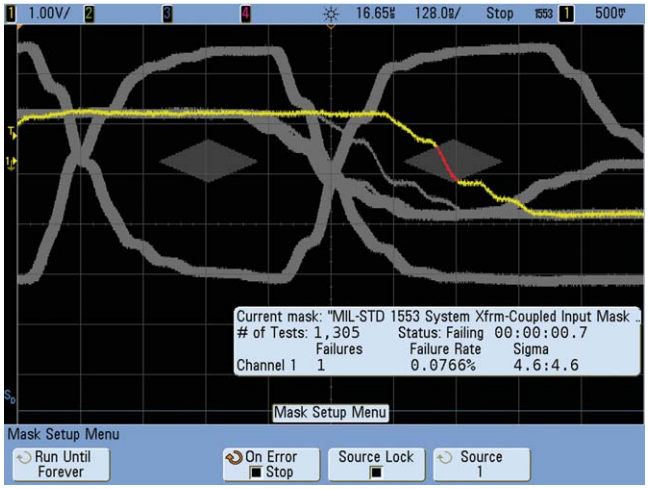


Figure 8: A "stop-on-error" mask test uncovers a bit shift error.

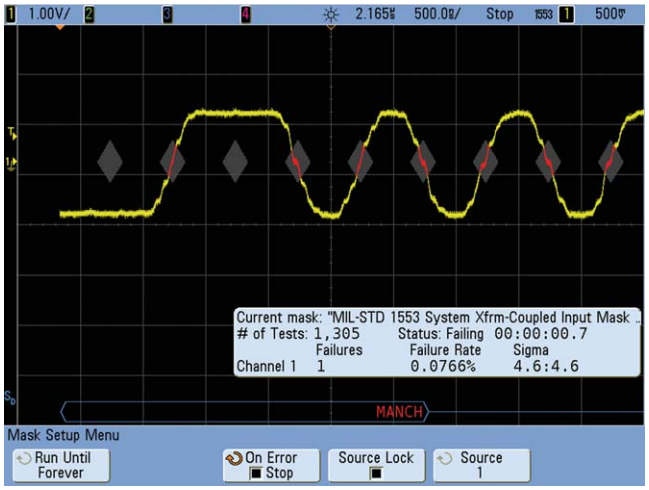


Figure 9. "Unfolding" the eye reveals that all bits within this Status Word have bit transition shifts that produces a Manchester encoding error.

Segmented Memory acquisition captures and stores more MIL-STD 1553 words

The Segmented Memory acquisition option (Option SGM) for Agilent's InfiniiVision Series oscilloscopes can optimize your scope's acquisition memory, allowing you to capture more MIL-STD 1553 Command, Status, and Data Words while using less memory. Segmented memory acquisition optimizes the number of MIL-STD 1553 words that can be captured consecutively by selectively ignoring (not digitizing) unimportant idle time between words. And with a minimum 250 picoseconds time-tagging resolution, you will know the precise time between each captured word.

Figure 10 shows a MIL-STD 1553 measurement with the scope set up to trigger on Status Words with an RTA of $0F_{HEX}$. Using this trigger condition with the segmented memory acquisition mode turned on, the scope easily captures 2000 consecutive occurrences of this word for a total acquisition time of 2 seconds. After acquiring the 2000 Status Words, we can then scroll through all words individually to look for any anomalies or errors.

Agilent's InfiniiVision Series oscilloscopes are the only scopes on the market today that capture, store, and decode MIL-STD 1553 communication traffic using Segmented Memory acquisition.

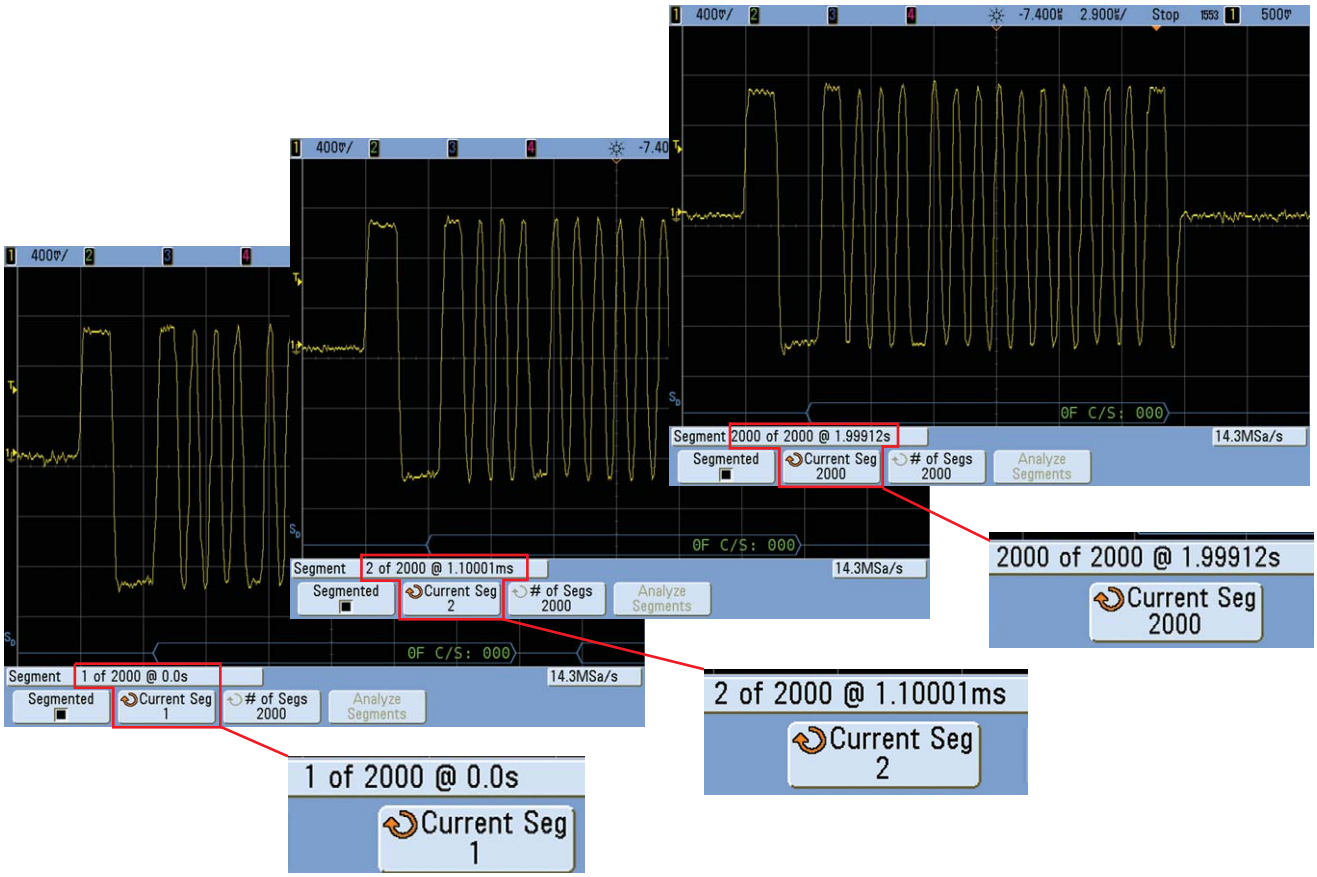


Figure 10. Segmented Memory acquisition captures up to 2000 consecutive 1553 words with precise time-tagging.

Measure the electrical characteristics of MIL-STD 1553 based on published specifications

With the InfiniiVision scope's built-in parametric measurements, it's easy to measure voltage swings and transition times of your signals and then compare them to MIL-STD 1553 input and output electrical specifications. Also included are comprehensive measurement statistics of each selected measurement including min, max, mean, and standard deviation as shown in Figure 11.

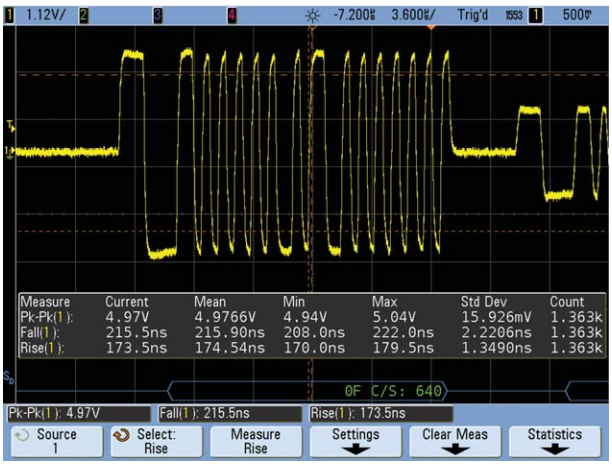


Figure 11. Automatic parametric measurements with statistics makes it easy to test electrical characteristics of MIL-STD 1553 signals against published specifications.

Probe MIL-STD 1553 signals with precision

Signal integrity measurements on differential MIL-STD 1553 signals require precision differential active probing. Agilent offers a wide range of differential active probes for various bandwidth and dynamic range applications. For most MIL-STD 1553 testing, Agilent recommends the N2791A 25-MHz, 8-MΩ differential active probe. This probe can measure signals up to 70 V peak when used in the 10:1 attenuation setting, or up to 700 V peak when used in the 100:1 attenuation setting.

Figure 12. Agilent recommends the N2791A 25-MHz differential active probe for MIL-STD 1553 applications.

Make MIL-STD 1553 measurements in the field under battery operation

Agilent 6000 Series oscilloscopes provide an optional internal rechargeable lithium ion battery that will enable 2+ hours without line power. Option BAT on 6000 Series scopes was specifically designed for applications where line power is not available and for when a handheld scopemeter lacks the needed measurement capability for MIL-STD 1553 applications. The Agilent 6000 Series oscilloscopes offer the only high-performance scope (up to 1 GHz bandwidth) with battery option on the market.

Figure 13. Agilent's 6000 Series oscilloscopes are available with a battery option for remote/field testing of MIL-STD 1553 applications.

Operating Characteristics and Ordering Information

Characteristics

Option 553 or N5469A	
MIL-Std 1553 Input Source	**Analog channels 1 & 2 or 3 & 4 (using a differential active probe)**
Triggering	• Data Word Start • Data Word Stop • Command/Status Word Start • Command/Status Word Stop • Remote Terminal Address (hex) • Remote Terminal Address (hex) + 11 Bits (hex or Binary) • Parity Error • Sync Error • Manchester Error
Color-coded, hardware-accelerated decode	• Base: HEX or Binary • Command or Status Word (“C/S” in green) • Remote Terminal Address (hex or binary digits in green) • 11 Bits following RTA (hex or binary digits in green) • Data Word (“D” in white) • Data Word Bits (hex or binary digits in white) • Parity Error (entire decoded word in red) • Synchronization Error (“Sync” in red) • Manchester Error (“Manch“ in red)

Ordering Information

The MIL-STD 1553 trigger and decode option is compatible with all 4-channel and 4+16 channel Agilent InfiniiVision Series oscilloscopes (5000, 6000, and 7000 series scopes). This option is available as a factory-installed option if ordered as Option-553 along with a specific oscilloscope model. Existing InfiniiVision Series oscilloscope owners can upgrade their scopes with this option if ordered as the N5469A.

Option number – factory installed	Model number – user installed	Description
553	N5469A	MIL-STD 1553 triggering and decode (4 and 4+16 channel models only)
LMT	N5455A	Mask test option
SGM	N5454A	Segmented Memory acquisition option
	N2791A	25-MHz differential active probe

Note that additional options and accessories are available for Agilent InfiniiVision Series oscilloscopes. Refer to the appropriate 5000, 6000, or 7000 Series data sheet for ordering information about these additional options and accessories, as well as ordering information for specific oscilloscope models.

Related Agilent literature

Publication title	Publication type	Publication number
Agilent Oscilloscope Probes and Accessories	Selection guide	5989-6172EN
Evaluating Oscilloscope Segmented Memory for Serial Bus Applications	Application note	5990-5817EN
Evaluating Oscilloscopes for best Waveform Update Rates	Application note	5989-7885EN
Evaluating Oscilloscopes to Debug Mixed-Signal Designs	Application note	5989-5733EB
Evaluating Oscilloscopes Sample Rates vs. Sampling Fidelity	Application note	5989-5732EN
Evaluating Oscilloscopes Vertical Noise Characteristics	Application note	5989-3020EN
Evaluating Oscilloscope Bandwidths for your Applications	Application note	5989-3702EN

7000 series

12.1″ display – nearly 40% larger than the nearest competitor

DSO and MSO models from 100 MHz to 1 GHz for analog, digital or serial measurements

8 Mpts memory standard

6000L Series

1U-high, 19″ wide package saves valuable rack space

Optimized for automated and manufacturing test

LXI class C compliant for efficient, cost-effective creation and reconfiguration of test systems

DSO models from 100 MHz to 1 GHz are upgradeable to MSO models at any time

6000 Series

DSO and MSO models from 100 MHz to 1 GHz for analog, digital, or serial measurements

Compact form factor with GPIB

Battery option

8 Mpts memory standard

5000 Series

DSO models from 100 MHz to 500 MHz for analog and/or serial measurements

Compact form factor with GPIB

8 Mpts memory standard

Agilent Electronic Measurement Group
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ISO 9001:2008
Quality Management System

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Product specifications and descriptions in this document subject to change without notice.

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