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Test Plan/Procedure for
AS5643/1 S400 Copper Media Interface
Characteristics Over Extended Distances

RATIONALE

The purpose of this document is to establish test plans/procedures for the SAE AS5643/1 Slash Sheet.

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1. SCOPE

This document establishes test plans/procedures for the AS5643/1 Slash Sheet. The AS5643/1 Slash Sheet establishes guidelines for the use of IEEE-1394b as a data bus network in military and aerospace vehicles. It encompasses the data bus cable and its interface electronics for a system utilizing S400 over copper medium over extended lengths.

1.1 Purpose

The purpose of this document is to establish test plans/procedures for the AS5643/1 Slash Sheet.

This document is controlled and maintained by the SAE with technical support from subsystem vendors.

1.2 Application

The information herein may be used to assist the test of the subsystems that interface via the vehicle's network.

1.3 Interpretation

The following interpretations shall be placed upon these words, unless stated otherwise, where they are used in this document.

May An allowed action

Shall A mandatory requirement

Should A recommended action

Will A declaration of intent

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

MIL-STD-461E Department of Defense Interface Standard, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

MIL-HDBK-454A Department of Defense Handbook, General Guidelines for Airborne Electronic Equipment

MIL-HDBK-5400 Military Handbook, Electronic Equipment, Airborne, General Guidelines

2.1.2 IEEE Publications

Available from IEEE, 445 Hoes Lane, Piscataway, NJ 08854-1331, Tel: 732-981-0060, www.ieee.org.

IEEE Std 1394-1995 IEEE Standard for a High Performance Serial Bus

IEEE Std 1394a-2000 IEEE Standard for a High Performance Serial Bus, Amendment 1

IEEE Std 1394b-2002 IEEE Standard for a High Performance Serial Bus, High Speed Supplement

2.2 Acronyms and Definitions

BER Bit Error Rate

C Celsius

dB Decibels

DC Direct Current

ft Feet

GHz Gigahertz

Link The point-to-point connection between two ports

LRU Line-Replaceable Unit

mA Milliamps

MBd Megabaud

Mbits Megabits

Mb/s Megabits Per Second

MHz Megahertz

ms Milliseconds

mV Millivolts

N/A Not Applicable

pF Picofarad

PHY 1394 Physical Interface Device

ppm Parts Per Million

ps Picoseconds

UI Unit Interval, duration of one bit cell

UUT Unit Under Test

V Volts

VRMS Volts Root Mean Square

Ω Ohms

3. IEEE-1394B REQUIREMENTS, S400 COPPER MEDIA

The requirements are based on the IEEE Standard for a High Performance Serial Bus (IEEE-1394-1995), Amendment One (IEEE-1394a-2000), and High-Speed Supplement (IEEE-1394b-2002). This section delineates the options selected and interprets any ambiguities.

3.1 Cable

3.1.1 Cable Requirements

3.1.1.1 Test Requirements

- Verify that the cable is of quad construction and contains two differential pair transmission lines (positioned on orthogonal axes) with nominal differential impedance of 110 Ω.

- Verify that the insulated wires for the two differential pairs in the cable are color-coded as follows: pair 1 consists of one Blue wire and one Orange wire (Blue x Orange), and pair 2 consists of one Red wire and one Green wire (Red x Green). For the Blue x Orange pair, the blue wire connects to the positive signal and the orange wire connects to the negative of a given port; for the Red x Green pair, the Red wire connects to the positive signal and the green wire connects to the negative of a given port.

- When connecting between two 1394b nodes, verify that one connects from the transmit (TX) of one port to the receive (RX) of the other. (For example, for the Blue x Orange pair, the Blue wire connects to TX+ and the Orange wire connects to TX- on one end of the cable, and the Blue wire connects to RX+ and the Orange wire connects to RX- on the other end of the cable.)

- Cable temperature will affect the values of the tests below; perform tests at 200 °C or your application's maximum expected temperature.

- Verify that the cable meets all of the cable requirements identified in Table 1, as per the test procedures described in sections 3.1.1.2.1 through 3.1.1.2.6.

TABLE 1 - CABLE REQUIREMENTS

Dielectric Withstanding Voltage Conductor/Conductor (Maximum)	1500 VRMS
Dielectric Withstanding Voltage Conductor/Shield (Maximum)	1000 VRMS
Capacitance (Typical) Between Pairs, Ground Floating	12 pF/ft
Differential Impedance @ (100 to 500 MHz)	110 Ω ± 6 Ω
Temperature Range	-55 to +200 °C
Insertion Loss at 250 MHz (Maximum, With Active Transformer)	6.0 dB
Insertion Loss at 250 MHz (Maximum, With Passive Transformer)	2.0 dB
Time Delay Skew (Maximum) Within Pairs	200 ps

3.1.1.2 Test Procedures for Cable Requirements

3.1.1.2.1 Dielectric Withstanding Voltage

a. Equipment: High Pot Tester (1500 VRMS voltage source minimum, 6 mA current detection minimum) (Biddle Instruments Model # 230425 is one example).

b. Setup: One end of the cable shall be prepared according to Figure 1. Expose 1/4 in of bare conductor on each of the 4 lines. This end will be connected to the High Pot Tester. The opposite end of the cable shall be prepared such as to ensure that no two conductors are in contact and that no conductors are in contact with the shield.

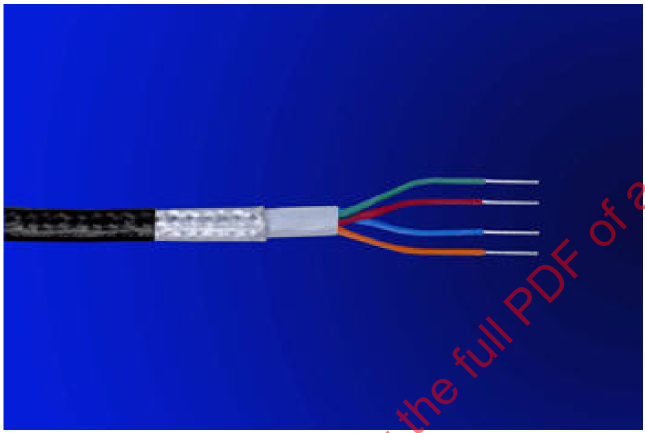


FIGURE 1 - CABLE PREPARATION FOR TESTS

c. Procedure: Conductor/conductor withstand voltage shall be tested by applying a 1500 VRMS test voltage between the following combinations of conductors:

Blue - Red
Blue - Orange
Blue - Green
Red - Orange
Red - Green
Orange - Green

d. Failure Criteria: A failure condition is defined by either an immediate short circuit or a leakage current in excess of 6.0 mA. It is suggested that 100% of the cable be tested for conductor/conductor withstand voltage

3.1.1.2.2 Dielectric Withstanding Voltage Conductor/Shield

a. Equipment: High Pot Tester Tester (1000 VRMS voltage source minimum, 6 mA current detection minimum) (Biddle Instruments Model # 230425 is one example).

b. Preparation: One end of the cable shall be prepared according to Figure 1. Expose 1/4 in of bare conductor on each of the 4 lines. This end will be connected to the High Pot Tester. The opposite end of the cable shall be prepared such as to ensure that no two conductors are in contact and that no conductors are in contact with the shield.

c. Procedure: Conductor/shield withstand voltage shall be tested by applying a 1000 VRMS test voltage between the following shield to conductor combinations:

Blue - Shield
Orange - Shield
Red - Shield
Green - Shield

A failure condition is defined by either an immediate short circuit or a leakage current in excess of 6.0 mA. It is suggested that 100% of the cable be tested for conductor/shield withstand voltage.

3.1.1.2.3 Capacitance Between Pairs

a. Equipment: LCR Meter capable of capacitance measurements at 1 kHz (Agilent Model 6263B is one example).

b. Preparation: One end of the cable under test shall be prepared according to Figure 1. Expose 1/4 in of bare conductor on each of the 4 lines. This end will be connected to the LCR meter. The opposite end of the cable shall be prepared such as to ensure that no two conductors are in contact and that no conductors are in contact with the shield. The length of the test sample shall be a minimum of 10 ft.

c. Procedure: Connect the following differential pairs to the LCR meter:

Blue - Orange
Red - Green

Measure the capacitance of the test sample at the 1 kHz setting. Divide this capacitance by the cable length in feet to produce a value of capacitance per foot. Each of the two differential pairs in the Quad construction (Blue/Orange and Red/Green) must be measured separately.

A failure condition is defined by a capacitance measurement greater than 13.2 pF/ft (12 pF/ft +10% = 13.2 pF/ft).

3.1.1.2.4 Differential Impedance

a. Equipment: Digital Sampling Oscilloscope with Differential Time Domain Reflectometry (TDR) capable Sampling Module (minimum 5 GHz bandwidth) (Tektronix TDS 8000 with 80E04 Sampling Module is one example).

b. Preparation: One end of the cable under test shall be prepared according to Figure 1. Expose 1/4 in of bare conductor on each of the 4 lines. This end will be connected to the sampling module. The opposite end of the cable shall be prepared such as to ensure that no two conductors are in contact and that no conductors are in contact with the shield. The length of the test sample shall be a minimum of 10 ft.

c. Procedure: Connect the following differential pairs to the Sampling module:

Blue - Orange - Shield
Red - Green - Shield

NOTE: Most equipment manufacturers use SMA connections to the sampling modules. Connecting the differential pairs of the Quad cable construction can be accomplished in many ways. The termination effects can significantly alter the impedance measurements. It is strongly recommended to make the impedance measurement at a point at least 2 in past the termination point. The measurement region should only include the first 4 to 5 ns of cable to minimize effects of A/C resistance of the conductors. However, the entire length of cable under test should be analyzed for anomalous impedance spikes of ±6 Ω.

With the Sampling Module in the differential TDR mode, measure the reflection coefficient (rho) of the cable under test from a 100 Ohm reference standard. Most equipment manufacturers have automated the Impedance measurements on the equipment to read in Ohms. Each of the two differential pairs in the Quad construction (Blue/Orange and Red/Green) must be measured separately. See Figure 2 for example measurement.

A failure condition is defined by an impedance measurement outside of the 110 Ω ± 6 Ω acceptance range.

FIGURE 2 - EXAMPLE DIFFERENTIAL IMPEDANCE MEASUREMENT

3.1.1.2.5 Insertion Loss

a. Equipment: Network Analyzer with Differential Baluns (capable of 250 MHz) (Agilent Model # 8753E with MaCom H-9 baluns is one example).

NOTE: Agilent also sells 4 port Network Analyzers with differential mode capabilities.

b. Preparation: Both ends of the cable under test shall be prepared according to Figure 1. Expose 1/4 in of bare conductor on each of the 4 lines. For the length of the test sample see Table 2. The Insertion Loss measurement is a through measurement; therefore each end of the cable under test will be attached to the test equipment.

NOTE: Bulk testing the cable in this manner validates the assumptions used in the cable selection guide.

TABLE 2 - LENGTH OF TEST SAMPLE

AWG	Cable Test Length (feet)
22	73
24	59
26	47
28	38
30	30

c. Procedure: Calibrate the Network Analyzer over a frequency range inclusive of 250 MHz.

Connect the following differential pairs to the Network Analyzer:

Blue - Orange - Shield
Red - Green - Shield

Once the cable under test is attached to the Network Analyzer, measure the Insertion Loss in dB at 250 MHz. Each of the two differential pairs in the Quad construction (Blue/Orange and Red/Green) must be measured separately.

For systems using active transformers a measurement >6.0 dB per cable test length at 250 MHz is considered a failure condition.

For systems using passive transformers a measurement >2.0 dB per cable test length at 250 MHz is considered a failure condition.

3.1.1.2.6 Time Delay Skew

This test is used to determine the variance in the electrical length between two conductors in the same pair. A Time Domain Reflectometer is used to generate two fast rise time differential pulses simultaneously on both conductors of a pair. At the opposite end of the cable, the voltage zero crossings of each conductor will be viewed; the difference in time between these crossings is the Time Delay Skew.

a. Equipment: Digital Sampling Oscilloscope with two Differential Time Domain Reflectometry (TDR) capable Sampling Modules (minimum 5 GHz bandwidth) (Tektronix TDS 8000 with 80E04 Sampling Module is one example).

b. Preparation: Both ends of the cable under test shall be prepared according to Figure 1. Expose 1/4 in of bare conductor on each of the 4 lines. For the length of the test sample see Table 2. The Time Delay Skew measurement is a through measurement; therefore each end of the cable under test will be attached to the test equipment.

NOTE: Bulk testing the cable in this manner validates the assumptions used in the cable selection guide.

c. Procedure: Connect one end of the differential pair of the Quad cable construction to one of the Sampling Modules in Differential TDR mode and the other end of the differential pair in the Quad cable construction to the second Sampling module in sampling mode. Activating the Sampling module in sampling mode, find the point in time where the differential signals are switching. At the switching point, measure the time between the negative going and positive going signals at the 0 level. This value is the Time delay skew. See Figure 3 for an example.

The following differential pairs must be measured separately.

Blue - Orange - Shield
Red - Green - Shield

A failure condition is defined by a time delay skew value greater than 200 ps per the cable test length.

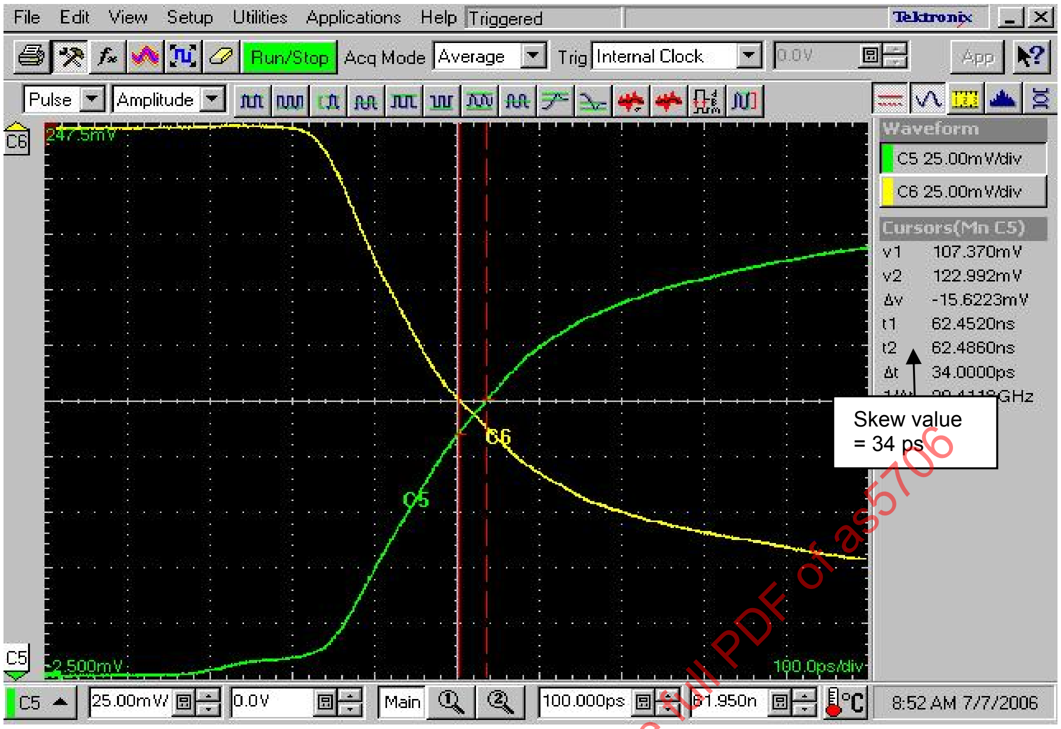


FIGURE 3 - TIME DELAY SKEW EXAMPLE

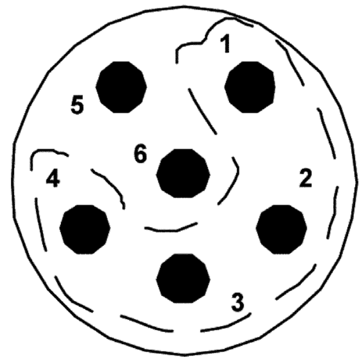
3.1.2 Cable Termination

3.1.2.1 MIL-DTL-38999 Option

- Verify that the connectors use #22D contacts, with pins used at the LRU and #22D contact sockets by the vehicle cabling.
- Verify that all pin locations designated as “not used” remain empty and are not utilized for other non-1394 signals.

3.1.2.1.1 MIL-DTL-38999, Shell Size A

- Verify that for cabling and LRUs utilizing a MIL-DTL-38999 Series 3 connector shell size A (9), insert arrangement 35 is used and is pinned as per Figure 4.

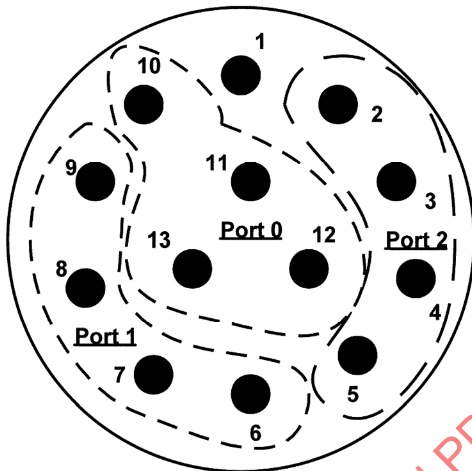


Pin	Signal Name	Description
1	Port 1 - TA	Port 1 Receive +
2	Port 1 - TA*	Port 1 Receive -
3	Port 1 - TB	Port 1 Transmit +
4	Port 1 - TB*	Port 1 Transmit –
5	Not Used	N/A
6	Not Used	N/A

FIGURE 4 - CONNECTOR PIN-OUT, MIL-DTL-38999 SERIES 3 SHELL SIZE A (9)

3.1.2.1.2 MIL-DTL-38999, Shell Size B

- Verify that for cabling and LRUs utilizing a MIL-DTL-38999 Series 3 connector shell size B (11), insert arrangement 35 is used and is pinned as per Figure 5.



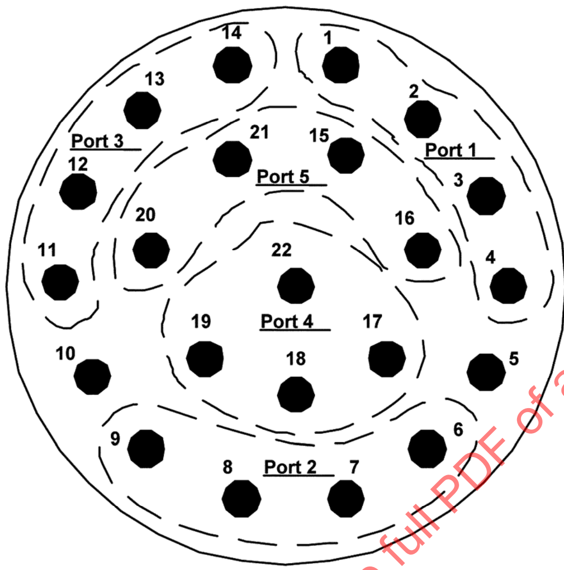
Pin	Signal Name	Description
1	Not Used	N/A
2	Port 2 -	Port 2 Receive +
3	Port 2 -	Port 2 Receive -
4	Port 2 -	Port 2 Transmit +
5	Port 2 -	Port 2 Transmit -
6	Port 1 -	Port 1 Receive +
7	Port 1 -	Port 1 Receive -
8	Port 1 -	Port 1 Transmit +
9	Port 1 -	Port 1 Transmit -
10	Port 0 -	Port 0 Receive +
11	Port 0 -	Port 0 Receive -
12	Port 0 -	Port 0 Transmit +
13	Port 0 -	Port 0 Transmit -

FIGURE 5 - CONNECTOR PIN-OUT, MIL-DTL-38999 SERIES 3 SHELL SIZE B (11)

- Verify that the cabling internal to the LRU is electrically connected to all three 1394b ports of a node.

3.1.2.1.3 MIL-DTL-38999, Shell Size C

- Verify that for cabling and LRUs utilizing a MIL-DTL-38999 Series 3 connector shell size C (13), insert arrangement 35 is used and is pinned as per Figure 6.



Pin	Signal Name	Description
1	Port 1 - TA	Port 1 Receive +
2	Port 1 - TA*	Port 1 Receive -
3	Port 1 - TB	Port 1 Transmit +
4	Port 1 - TB*	Port 1 Transmit -
6	Port 2 - TA	Port 2 Receive +
7	Port 2 - TA*	Port 2 Receive -
8	Port 2 - TB	Port 2 Transmit +
9	Port 2 - TB*	Port 2 Transmit -
11	Port 3 - TA	Port 3 Receive +
12	Port 3 - TA*	Port 3 Receive -
13	Port 3 - TB	Port 3 Transmit +
14	Port 3 - TB*	Port 3 Transmit -
17	Port 4 - TA	Port 4 Receive +
18	Port 4 - TA*	Port 4 Receive -
19	Port 4 - TB	Port 4 Transmit +
22	Port 4 - TB*	Port 4 Transmit -
16	Port 5 - TA	Port 5 Receive +
15	Port 5 - TA*	Port 5 Receive -
21	Port 5 - TB	Port 5 Transmit +
20	Port 5 - TB*	Port 5 Transmit -
5,10	Not Used	N/A

FIGURE 6 - CONNECTOR PIN-OUT, MIL-DTL-38999 SERIES 3 SHELL SIZE C (13)

3.1.2.2 Quadrax MIL-DTL-38999 and ARINC 600 High Density Options

AS5643/1 provides examples of ARINC 600 and MIL-DTL-38999 style connector inserts that have size #8 contacts and support the use of Quadrax inserts.

3.1.2.2.1 Quadrax Pin Definitions

- Verify that for cabling and LRUs utilizing a Quadrax connector, each port is pinned as per Table 3.

TABLE 3 - QUADRAX CONNECTOR PIN-OUT

Pin (Source)	Signal Name (Source)	Description (Source)	Pin (Destination)	Signal Name (Destination)	Description (Destination)
1	TPA	Receive +	2	TPB	Transmit +
2	TPB	Transmit +	1	TPA	Receive +
3	TPA*	Receive -	4	TPB*	Transmit -
4	TPB*	Transmit -	3	TPA*	Receive -

- Verify that for subsystems that require additional node/ports, a separate Quadrax insert is used for each port.

3.1.3 Cable Interconnects

a. Equipment: Digital Sampling Oscilloscope with two Differential Time Domain Reflectometry (TDR) capable Sampling Modules (minimum 5 GHz bandwidth) (Tektronix TDS 8000 with 80E04 Sampling Module is one example).

The differential-mode discrete impedance of the signal pairs within the mated connector section shall be measured by TDR with the connector-only differential test fixture at an 80 ps rise time. The recommended procedure is described in B.2 of IEEE Standard 1394a-2000 with the following exception in test condition: evaluate differential impedance over a 625 ps exception window with test points at

Connector insertion plane -25 ps
Connector insertion plane (reference point, so offset will be 0 ps)
Connector insertion plane +100 ps Connector insertion plane +300 ps
Connector insertion plane +600 ps

The exception window is extended -25 ps in front of the beginning of a typical mated connector to evaluate settling performance. Also, in making time domain measurements, divide all real time values by two to account for the round trip. Impedance in the exception window shall be within the following limits: 110 +80/-40 Ω (differential).

See Figures 7 and 8 for example measurements.

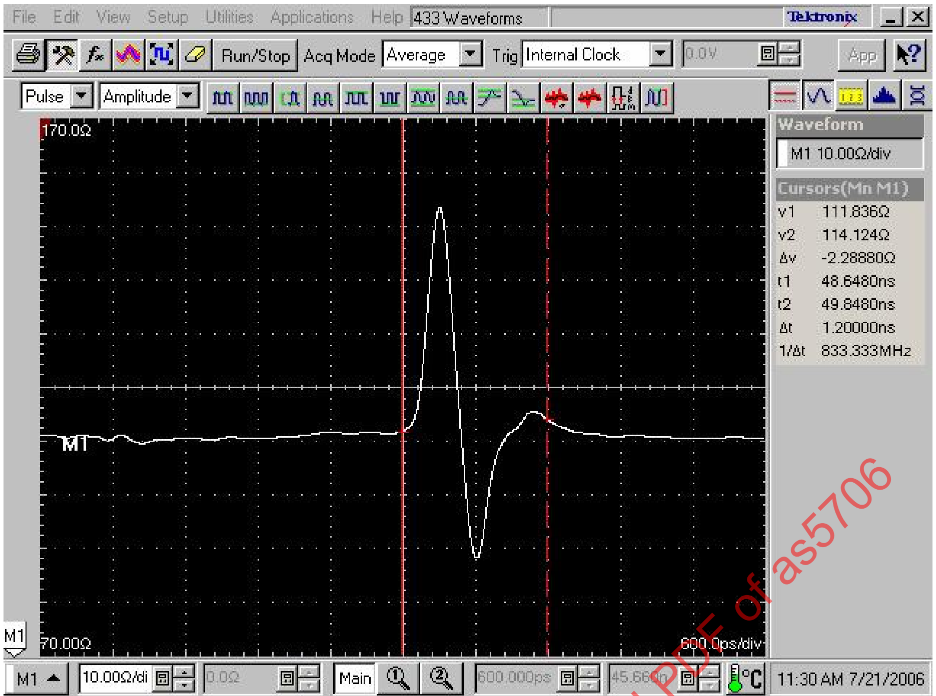


FIGURE 7 - 600 PS EXCEPTION WINDOW EXAMPLE SHOWING 1.2NS/2 = 600 PS WINDOW

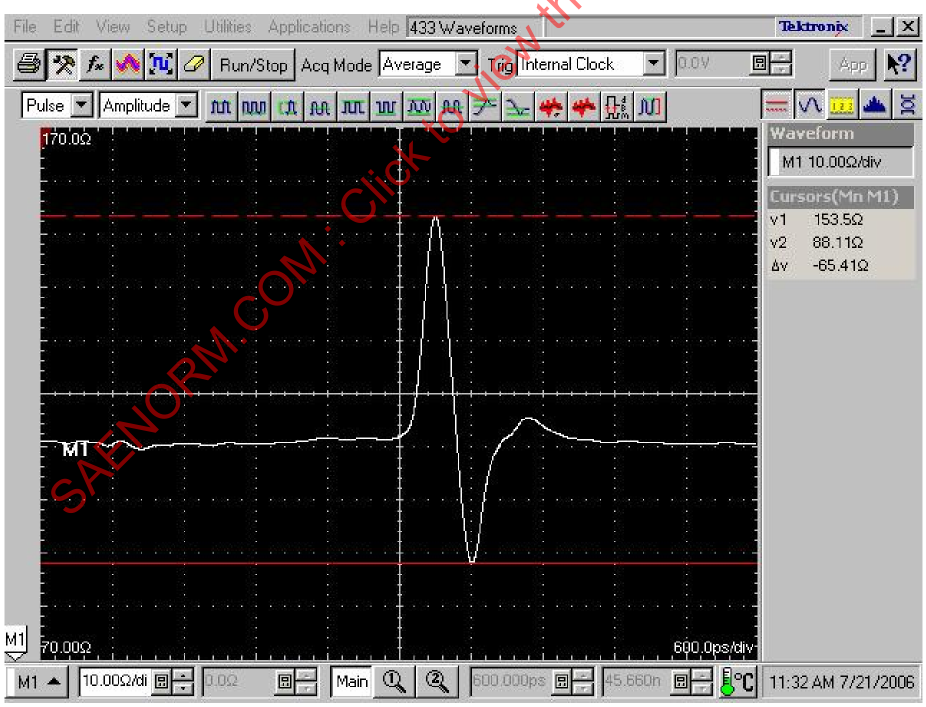


FIGURE 8 - 600 PS EXCEPTION WINDOW EXAMPLE SHOWING 110 +43.5/-21.9 Ω DIFFERENTIAL

3.2 Bus Isolation

- Verify that the shield from all cabling is connected to chassis ground and isolated from signal ground of the LRU circuitry.

3.2.1 Link Termination

- Verify that every link is terminated at both ends with an impedance equal to the selected cable nominal characteristic impedance, as specified in Table 1 ± 2.0%.

3.3 Link Signal Specification

3.3.1 Signal Configuration

Figure 9-2 of IEEE-1394b-2002 identifies link test measurement points; due to the inclusion in this document of transformers and active transmit circuitry, the resulting network block diagram and corresponding link test points are as shown in Figure 9.

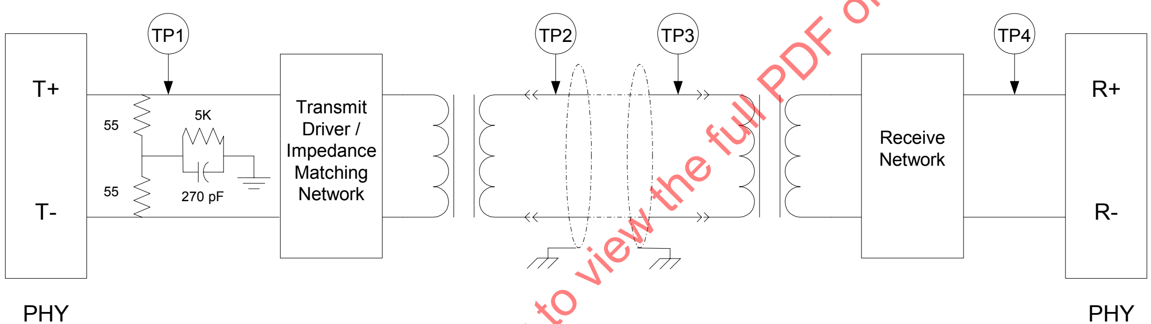


FIGURE 9 - LINK MEASUREMENT POINTS (HALF CONNECTION IS SHOWN)

As with the IEEE-1394b-2002 standard, the interface specifications apply at the points of entry and exit from the equipment (LRU), corresponding to the points TP2 and TP3.

3.3.2 Verified Transmit Parameters

- Verify that all of the transmitter electrical signaling properties identified in Table 4 (TP2) are met, as per the test procedures described in the proceeding sections.

TABLE 4 - LINK SIGNAL TRANSMITTER CHARACTERISTICS (TP2)

Parameter	S400β	Units
Signaling	8B/10B	N/A
Nominal Data Rate	393.22	Mb/s
Nominal Baud Rate	491.52	MBd
Tolerance	±100	ppm
Differential Signal Level, Peak-to-Peak		
Maximum (Using Active Transformer Coupling)	1,800	mV
Typical (Using Active Transformer Coupling)	1,400	mV
Minimum (Using Active Transformer Coupling)	1,100	mV
Maximum (Using Passive Transformer Coupling)	1,271	mV
Typical (Using Passive Transformer Coupling)	794	mV
Minimum (Using Passive Transformer Coupling)	635	mV
Maximum (OFF)	20	mV
Rise and Fall Time (10 to 90%)		
Maximum	800	ps
Minimum	80	ps
Differential Skew, Maximum (Note 1)	50	ps
Common-Mode Output Impedance	<55	Ω
Common Mode Voltage		
Maximum	2.415	V
Typical (Due To Transformer Coupling)	0	V
Jitter	(Note 2)	

NOTE 1: Only applicable for non-transformer implementations.
NOTE 2: Refer to Section 9.7.1 of IEEE-1394b-2002.

3.3.3 Test Equipment

PHY Transmit electrical tests are performed with a digital oscilloscope, a differential probe and an optional test fixture.

The oscilloscope must be capable of sampling at 10x the PHY baud rate. The oscilloscope and probes must pass 5x the UUT baud rate. For example an S400 PHY has a 498 MHz baud rate so the scope must sample at least 5 GHz and the oscilloscope and probes must pass at least 2.5 GHz. Higher sample rates and bandwidths are allowed.

A test fixture to induce the UUT to begin connection training and provide high fidelity test points may be used.

PHY receive electrical tests are performed with a calibrated signal generator combined with bit error rate analysis capability.

Input impedance tests are performed with a TDR system: oscilloscope and TDR module with a minimum 5 GHz bandwidth. A connector assembly (or assemblies) to connect the TDR to the appropriate UUT connector is also required.

3.3.3.1 Sample Stream Capture

The following transmit tests analyze a set of samples captured via digital oscilloscope to evaluate the specified parameters. All of the tests may use one stream dataset for each port.

The sample stream will be at least 3500 UI long for Jitter analysis. The stream should be captured at least 1 ms after connection to allow dissipation of DC effects present before and during connection.

The samples should be taken from test points very near (<5 mm) end of net termination to minimize signal reflections. The termination should be as close as practical to the connector of the UUT (<200 mm) to minimize reflections and cable loading. To achieve the most representative stream, the transmit pair of the UUT should not be connected to another PHY. This may be accomplished via test fixture.

The oscilloscope will be set to sample at least 10x the signal baud rate. For example, an S400 498 baud signal will be sampled at 5 GHz minimum. Higher sample rates are encouraged.

3.3.3.2 Bit Error Rate Analysis

Several of the following receive tests rely on bit error rate analysis of the unit under test while connected to a test generator providing worst case signals. These tests may be run simultaneously with several worst case parameters applied to the same signal. If a test fails, further analysis may be necessary to determine which receive parameter is out of specification.

Bit error rate goals and statistical confidence levels may be set by project requirements. The standard BER goal for 1394b is $1x10^{-12}$. Table 5 provides testing time estimates for BER goals and confidence when no errors are detected using a tester generating and verifying 400 Mbits per second.

TABLE 5 - BER TEST DURATION

BER Goal / Confidence	Bits Required (0 errors detected)	Time Required per port @ 400 Mb/s
$1x10^{-11}$ @ 99%	$5.41x10^{11}$	22.5 minutes
$1x10^{-11}$ @ 99.9%	$9.54x10^{11}$	40 minutes
$1x10^{-12}$ @ 99%	$5.41x10^{12}$	3.75 hours
$1x10^{-12}$ @ 99.9%	$9.54x10^{12}$	6.63 hours

3.3.4 Transmit Test Procedures

All transmit tests are repeated for each port of the unit under test.

3.3.4.1 Signaling

Not applicable (inherent within IEEE-1394b-2002 PHY).

3.3.4.2 Data Rate

Not applicable (proportional function of Baud Rate).

3.3.4.3 Baud Rate

The baud rate is calculated from all the edge times in the 3500 UI differential sample stream.

First a calibrated zero value is set by capturing a sample with both leads of the differential probe connected to ground. If calibration is not performed for a given run, the previous calibration result is used. If calibration has not been performed for any run, 0 V is used. Edge times in the sample stream are calculated by interpolating the two samples on either side of the calibrated zero level for each zero crossing.

The UI period is calculated by fitting a least sum of squares line to all the calculated edges and their corresponding UI number. The slope of that line is the UI period. The inverse of the calculated UI period yields the baud rate.