Annex B

(informative)

Serial Bus cable test procedures

B.1 Scope

This annex describes a set of test procedures that attempts to characterize completely the electrical performance of the Serial Bus cable assembly. The tests are intended to provide results of maximum relevance to the system implementor.

Toward this goal, the procedures presented in this annex provide an “end to end” characterization of the Serial Bus cable and connector system. This includes the cable itself, two cable assembled plugs, two PCB assembled sockets, and a length of controlled impedance PCB traces relevant for practical applications. While the device under test is only the cable assembly itself, the sockets and the PCB traces are included in the test fixtures. The limit specifications and the test procedures described in this annex apply to complete cable assemblies of any length.

The measuring equipment listed in the following text or shown in the figures is shown for completeness and to guarantee maximum repeatability of measurements. Equipment of equal capabilities may be used, although the procedures described in this annex may have to be modified accordingly.

B.2 Test fixture

The test procedures described utilize 2 different test fixtures with each providing the transition between a Serial Bus board-mounted socket (which can receive the cable assembly under test) and ~~six~~ 50 ¾ SMA connectors (which can be connected to standard 50 ¾ coaxial test equipment).

The first fixture described in Figure B-1 does not isolate the socket shield from the fixture ground plane and provides an SMA connector to interface the Serial Bus socket pin (VG) to test equipment. A total of six SMA connectors can port all socket pins to the test equipment.

Figure B-1 — Cable test fixture schematic

The second fixture described in Figure B-2 does isolate the socket shield from the fixture ground plane and provides a controlled RC shunt between the socket shield and the fixture ground plane. The equivalent RC circuit values were chosen in accordance with those recommended in Figure 3-30 of IEEE standard 1394-95.

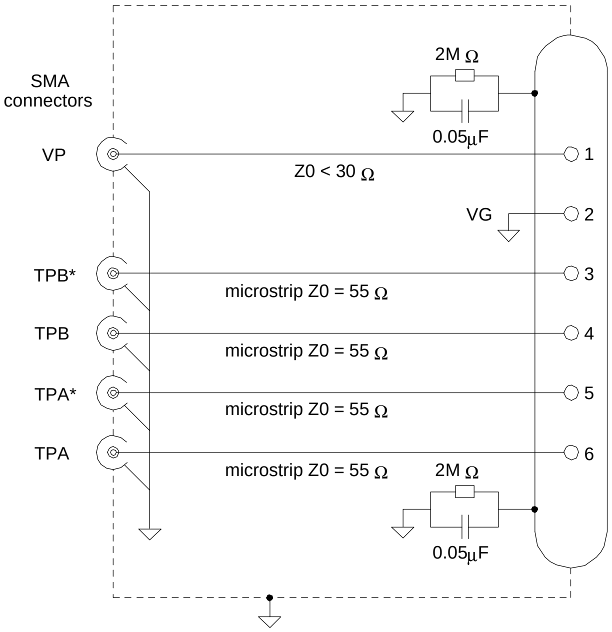

Figure B-2 — Alternate differential cable test fixture schematic

~~The electrical diagram of such a test fixture is shown in figure B-1. The~~ Both fixtures shall be constructed using a multilayer board enclosed in a metal case. For the cable test fixture described in Figure B-1, the case is electrically connected to the shield of the Serial Bus socket and to the shield of the six SMA connectors. For the alternate differential cable test fixture described in Figure B-2, the case and the five SMA connector shields are isolated from direct contact to the shield of the Serial Bus socket but interface through a distributed RC shunt.

In both cases the Serial Bus socket shall be surface mounted to the board. The four signal pins of the socket (TPA, TPA*, TPB, and TPB*) are connected to the four SMA connectors using microstrip lines with a characteristic impedance of 55¾ ± 3 ¾. The length of the connections shall be less than 50 mm. The length mismatch between any two of the four connections shall be less than 2 mm. It is important to minimize crosstalk within the fixture by using the ground plane to isolate the connections corresponding to different signal pairs.

For the cable test fixture described in figure B-1, the two power pins on the Serial Bus socket (VP and VG) are connected to the two SMA connectors using traces with a characteristic impedance of less than 30 ¾. These traces shall be designed such as to minimize their dc resistance. The uniformity of their characteristic impedance is of a lesser significance so via holes can be used along the connection traces.

For the alternate differential cable test fixture described in Figure B-2, only one power pin on the Serial Bus socket (VP) is connected to an SMA connector using a trace with a characteristic impedence of less than 30¾. Otherwise power pin trace considerations remain the same as those in the other cable test fixture.

The alternate differential cable test fixture is optimized for non-power pair crosstalk measurements and true differential impedance measurements as designated.

Two test fixtures of the designated type are used for every cable assembly test, and their electrical performance becomes an integral part of the test results. The effect of the test fixtures upon the test results is not calibrated out during the test setup calibration. Thus, the test fixtures should be maintained in conditions representative for reasonable practical system usage. The socket shall be replaced at least every 1000 connections.

The graphic symbol ~~schematic diagram~~ of the test fixture used in all the following test configuration diagrams which are not specially designated for the alternate differential cable test fixture is shown in figure B-3.

Figure B-3 — Test fixture graphic symbol

The graphic symbol of the alternate differential cable test fixture used in specially designated test configuration diagrams is shown in Figure B-4.

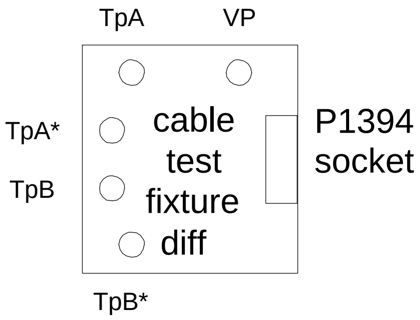

Figure B-4 — Alternate differential cable test fixture graphic symbol

The construction of both ~~the~~ test fixtures raises the issue of impedance matching between a pair of single-ended 50 ¾ coaxial connectors and the differential mode 110 ¾ Serial Bus signal lines. The connection traces for the signal lines located inside the test fixture are single-ended 55 ¾ matched electrical length; thus, it can be assumed that there is a reasonable differential mode matching between them and the Serial Bus socket and cable assembly. The impedance matching problem is therefore shifted to the level of the SMA connectors, where matching circuits can be added.

In order to improve accuracy, some of the tests use a minimum loss-resistive matching pad. The schematic diagram of such a pad is shown in figure B-5.

Figure B-5 — 100 ¾ to 110 ¾ matching pad

The test configurations contain also precision 20 dB attenuators, which are used to isolate the test equipment from the cable/connector mismatch. Due to the relative low level of mismatch and the isolation of the attenuator, the matching pads may be omitted at the expense of a slight increase in the frequency domain ripple. This effect can be removed by the data filtering algorithms provided by the suggested test equipment.

The impedance matching pads, if utilized, are always included in the test calibration setup to eliminate their effect upon the final test result.

B.3 Signal pairs characteristic impedance

Although a complete cable assembly including both cable and connector parts is specified, the impedance evaluations focus on either cable or connector parts as a result of time of flight into the cable. The differential mode characteristic impedance for the cable section shall be measured in the time domain using a single-ended time domain reflectometer (TDR) with an edge rate of less than 0.2 ns. The differential mode impedance value is calculated from the single-ended measurements described in the following subclauses. The result of each single-ended measurement is calculated as the average of the impedance measured at two points along the cable. These points are selected at 1 ns and at 2.5 ns along the cable from the plug closest to the launching connector. It should be noted that, because the TDR displays the round-trip propagation delay, the measurements shall be made at 2 ns and 5 ns from the plug closest to the launching connector as measured by the TDR instrument. This test shall be repeated for both signal pairs.

The differential mode discrete impedance, through the connector section, shall be measured in the time domain using a differential time domain reflectometer with an equivalent edge rate of 0.5ns.

A TDR will typically establish an equivalent edge rate by establishing a filter algorithm within its data processing software. This allows for a wide range of equivalent risetimes to be evaluated. A representative TDR of this type is the Tektronix 11801 B configured with TDR sampling heads. The differential mode impedance value is displayed directly once the 0.5ns filter algorithm is selected.

True differential mode impedance will be evaluated at three discrete points beyond the plane of signal insertion into the Serial Bus socket. Those points are selected at 50ps, 100ps and 150ps into the connector. Again, since the TDR displays the round-trip propagation delay, the measurements shall be made at 100ps, 200ps and 300ps beyond the plane of signal insertion.

Each of the three connector section impedance values shall be evaluated individually against the range of differential impedance allowed over the defined 100ps exception window (50ps to 150ps). This shall be repeated for both signal pairs.

B.3.1 Signal pairs impedance setup calibration—short and load

This calibration should be performed as shown in figure B-6 when using the calibration algorithms built into the single-ended TDR equipment suggested (HP 54120B and HP 54121A or equivalent). This calibration need not be performed when using the true differential TDR equipment suggested (Tektronix 11801B).

Figure B-6 — Signal pairs impedance setup calibration

B.3.2 Signal pairs impedance test procedure (cable section)

Using the test configuration described in figure B-7 and the connection matrix shown in table B-1 ~~table B-3~~, the various characteristic impedances of the signal wires shall be measured in two points and the results averaged.

Figure B-7 — Signal pairs impedance measurement configuration

Table B-1 — Connection matrix for signal pairs impedance tests

Measured value	Fixture 1						Fixture 2					
	VP	**TPA**	**TPA***	**TPB**	**TPB***	**VG**	**VP**	**TPA**	**TPA***	**TPB**	**TPB***	**VG**
Single-ended TPA (Z_{TPA1})	0 ¾	TDR	0 ¾	50 ¾	50 ¾	0 ¾	0 ¾	50 ¾	50 ¾	×	0 ¾	0 ¾
Single-ended TPA (Z_{TPA2})	0 ¾	0 ¾	TDR	50 ¾	50 ¾	0 ¾	0 ¾	50 ¾	50 ¾	0 ¾	×	0 ¾
Single-ended TPB (Z_{TPB1})	0 ¾	50 ¾	50 ¾	TDR	0 ¾	0 ¾	0 ¾	×	0 ¾	50 ¾	50 ¾	0 ¾

Table B-1 — Connection matrix for signal pairs impedance tests

Measured value	Fixture 1						Fixture 2					
	VP	**TPA**	**TPA***	**TPB**	**TPB***	**VG**	**VP**	**TPA**	**TPA***	**TPB**	**TPB***	**VG**
Single-ended TPB (Z_{TPB2})	0 ¾	50 ¾	50 ¾	0 ¾	TDR	0 ¾	0 ¾	0 ¾	×	50 ¾	50 ¾	0 ¾
Common-mode TPA (Z_{TPA3})	0 ¾	TDR	TDR	50 ¾	50 ¾	0 ¾	0 ¾	50 ¾	50 ¾	×	×	0 ¾
Common-mode TPB (Z_{TPB3})	0 ¾	50 ¾	50 ¾	TDR	TDR	0 ¾	0 ¾	×	×	50 ¾	50 ¾	0 ¾

$Z_{TPn}(2)$ is measured along the cable 2 ns from the plug connected to test fixture 1.

$Z_{TPn}(5)$ is measured along the cable 5 ns from the plug connected to test fixture 1.

Z_{TPn} is calculated as

$$Z_{TPn} = (Z_{TPn}(2) + Z_{TPn}(5)) / 2 \qquad \text{(K1)}$$

“TP*n*” is TPA1, TPA2, TPA3, TPB1, TPB2, or TPB3.

The differential mode characteristic impedance of signal twisted pair TPA is calculated as

$$Z_{TPA} = 4 \cdot Z_{TPA3} \cdot (Z_{TPA1} + Z_{TPA2}) / (8 \cdot Z_{TPA3} - Z_{TPA1} - Z_{TPA2}) \qquad \text{(K2)}$$

The differential mode characteristic impedance of signal twisted pair TPB is calculated as

$$Z_{TPB} = 4 \cdot Z_{TPB3} \cdot (Z_{TPB1} + Z_{TPB2}) / (8 \cdot Z_{TPB3} - Z_{TPB1} - Z_{TPB2}) \qquad \text{(K3)}$$

The common mode characteristic impedance of signal twisted pair TPA is calculated as

$$Z_{TPACM} = Z_{TPA3} \qquad \text{(K4)}$$

The common mode characteristic impedance of signal twisted pair TPB is calculated as

$$Z_{TPBCM} = Z_{TPB3}) \qquad \text{(K5)}$$

B.3.3 Signal pairs impedance test procedure (connector section)

Using the test configuration described in figure B-8 and the connection matrix shown in table B-2, the discrete differential impedances of the signal wires through the connector section shall be measureed at three points and compared to the allowed limits through the exception window.

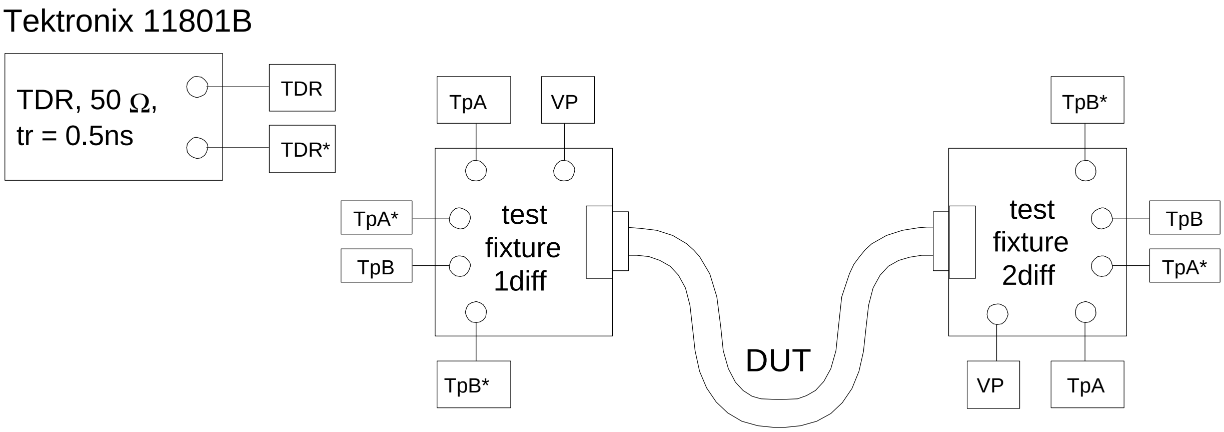

Figure B-8 — Signal pairs impedance measurement configuration (connector section)

Table B-2 — Connection matrix for signal pairs impedance tests (connector section)

Measured value	Fixture 1 diff					Fixture 2 diff				
	TPA	TPA*	TPB	TPB*	VP	TPA	TPA*	TPB	TPB*	VP
Differential Mode TPA ($ZTPA_{conn}$)	TDR	TDR*	50 ¾	50 ¾	0 ¾	50 ¾	50 ¾	50 ¾	50 ¾	0 ¾
Differential Mode TPB ($ZTPB_{conn}$)	50 ¾	50 ¾	TDR	TDR*	0 ¾	50 ¾	50 ¾	50 ¾	50 ¾	0 ¾

The true differential mode discrete impedance of connector signal pair TPA_{conn} is displayed as $ZTPA_{conn.}$ The true differential mode discrete impedance of connector signal pair TPB_{conn} is displayed directly as $ZTPB_{conn}$.

B.3.4 Signal pairs impedance limits (cable section)

The test limits are

ZTPA = 110 ¾ ± 6 ¾
ZTPB = 110 ¾ ± 6 ¾
ZTPA1 = ZTPA2 ± 4%
ZTPB1 = ZTPB2 ± 4%
ZTPACM = 33 ¾ ± 4 ¾
ZTPBCM = 33 ¾ ± 4 ¾

B.3.5 Signal pairs impedance limits (connector section)

The test limits, for the 100ps exception window are

$ZTPA_{conn}$ = 110 ¾ ± 25 ¾
$ZTPB_{conn}$ = 110 ¾ ± 25 ¾

B.4 Signal pairs attenuation

The differential mode attenuation of the signal pairs shall be measured in the frequency domain using a network analyzer in the frequency range of 1 MHz to 500 MHz.

The three frequency points (100 MHz, 200 MHz, and 400 MHz) at which the cable is measured are only coincidentally the same approximate numbers at the three bit rates. These numbers were chosen because

a) In fact, only one point is adequate in characterizing the cable. For reasonable accuracy, this test frequency point should be higher than the maximum fundamental frequency component that will be transmitted through the cable which in this case is about 200 MHz for an S400 (393.216 Mbit/s) transmission. For relatively simple and repeatable cable measurements, this test frequency should not be too high. 400 MHz was selected because it is about double the maximum frequency and the multiplication factor becomes $\sqrt{2}$. A higher number will make the measurements more difficult (many RF test fixtures have a 500 MHz maximum frequency limit), while a lower number will make computations more difficult (for example, if 300 MHz is chosen, calculations will need to be made using $\sqrt{1.5}$).

b) The selection of the attenuation value at 400 MHz is such that the proposed cable construction will be adequate at 4.5 m under worst-case circumstances.

c) The additional two data points (at 100 MHz and 200 MHz) are just a means of assistance. If pure skin effect cable attenuation is assumed, the attenuation numbers would be higher at 200 MHz (4.1 dB) and 100 MHz (2.9 dB), which will make the transceiver design harder. In reality, the cable attenuation is specified for the *cable assembly*. It contains not only the attenuation of the cable itself (the skin effect) but also the attenuation of the connectors, the effect of the wire termination, etc. These numbers change faster than the square root of frequency, and this is the reason the attenuation values are more optimistic at 100 MHz and 200 MHz.

In order to perform this measurement using a single-ended test instrument, a differential excitation is generated using a 180° splitter. The output is reconverted to single ended using a 180° combiner. It is very important for the accuracy of this measurement to maintain identical electrical length for the two branches of the differential signal path (in figure B-9 the electrical length of the segments a, b, c, d, and e shall match the electrical length of the corresponding segments a', b', c', d', and e'; in figure B-10 the electrical length of the segments a, b, d, e, f, and g shall match the electrical length of the corresponding segments a', b', d', e', f', and g').

This test shall be repeated for both signal pairs. Because of the cross-connection of the two signal pairs at the two plugs, a simple way of accomplishing this goal is to maintain the test setup and to reverse the two ends of the cable. In order to represent this procedure, one plug of the assembly under test is arbitrarily labeled as “A” while the other plug is labeled as “B” in the following diagrams.

The test consists of four distinct steps to be performed in the order described in the following subclauses.

B.4.1 Signal pairs attenuation setup calibration

The “through” calibration shall be performed as shown in figure B-9. The electrical characteristics of the two interconnects (labeled c and c') between the two match pads are essential for the accuracy of this calibration. Their length shall be kept to a minimum, and the difference between their length shall be less than 1 mm. Practically, they can be implemented using two identical SMA female-to-female adaptors.

Figure B-9 — Signal pairs attenuation and velocity setup calibration

The network analyzer shall use the following setup:

Format	Log Mag
Sweep	Log Freq
Averaging	16
Power	6 dBm
Start	1 MHz
Stop	500 MHz
Measure	A/B
Display	Data
Move data into memory	

B.4.2 ATPA

The signal pair A attenuation variation with frequency shall be tested as shown in figure B-10. Three data points shall be measured as follows: ATPA(100) is measured at 100 MHz, ATPA(200) is measured at 200 MHz, and ATPA(400) is measured at 400 MHz.

Figure B-10 — Signal pair attenuation and velocity measurement

B.4.3 ATPB

The signal pair B attenuation variation with frequency shall be tested as shown in figure B-10 using the reversed cable position (“TPB tests”). Three data points shall be measured as follows: ATPB(100) is measured at 100 MHz, ATPB(200) is measured at 200 MHz, and ATPB(400) is measured at 400 MHz.

B.4.4 Signal pairs attenuation limits

The absolute maximum attenuation limit for the two signal twisted pairs is verified by the following relations:

ATPA(100) ð 2.3 dB
ATPA(200) ð 3.2 dB
ATPA(400) ð 5.8 dB
ATPB(100) ð 2.3 dB
ATPB(200) ð 3.2 dB
ATPB(400) ð 5.8 dB

B.5 Signal pairs velocity of propagation

The differential mode velocity of propagation of the signal pairs shall be measured in the frequency domain using a vector network analyzer in the frequency range of 1 MHz to 500 MHz. The calibration and measurement setup is identical to that used for signal pairs attenuation, with exception of the network analyzer setup.

The result of this test is directly dependent upon the length of the cable assembly under test. This length in meters is represented by “L” in the following test descriptions.

This test shall be repeated for both signal pairs. Because of the cross-connection of the two signal pairs at the two plugs, a simple way of accomplishing this goal is to maintain the test setup and to reverse the two ends of the cable. In order to represent this procedure, one plug of the assembly under test is arbitrarily labeled as “A” while the other plug is labeled as “B” in the following diagrams.

The test consists of four distinct steps to be performed in the order described in the following subclauses.

B.5.1 Signal pairs velocity of propagation setup calibration

The “through” calibration shall be performed as shown in figure B-9. The electrical characteristics of the two interconnects (labeled c and c') between the two match pads are essential for the accuracy of this calibration. Their length shall be kept to a minimum, and the difference between their electrical length shall be less than 1 mm. The DUT interconnect segments labeled f, f', g, and g' in figures B-9 and B-10 are included in the calibration interconnects c and c'. Practically, they can be implemented using identical SMA adaptors.

The network analyzer shall use the following setup (items different from the attenuation test are shown in bold type):

Format	**Delay**
Sweep	Log Freq
Averaging	**32**
Smoothing aperture	5%
Power	6 dBm
Start	1 MHz
Stop	500 MHz
Measure	A/B
Display	Data
Move data into memory	

B.5.2 VTPA

The signal pair A velocity of propagation variation with frequency shall be tested as shown in figure B-10. Three data points shall be measured as follows: VTPA(50) is measured at 50 MHz, VTPA(100) is measured at 100 MHz, and VTPA(200) is measured at 200 MHz.

The average velocity of propagation for the signal pair A is calculated as

$$\mathrm{VTPA} = (\mathrm{VTPA}(50) + \mathrm{VTPA}(100) + \mathrm{VTPA}(200)) / (3 \cdot \mathrm{L}) \tag{K6}$$

B.5.3 VTPB

The signal pair B velocity of propagation variation with frequency shall be tested as shown in figure B-10 using the reversed cable position (“TPB tests”). Three data points shall be measured as follows: ATPB(50) is measured at 50 MHz, ATPB(100) is measured at 100 MHz, and ATPB(200) is measured at 200 MHz.

The average velocity of propagation for the signal pair B is calculated as

$$\mathrm{VTPB} = (\mathrm{VTPB}(50) + \mathrm{VTPB}(100) + \mathrm{VTPB}(200)) / (3 \cdot \mathrm{L}) \tag{K7}$$

B.5.4 Signal pairs velocity of propagation limits

The absolute minimum velocity of propagation limit for the two signal twisted pairs is verified by the following relations:

VTPA ð 5.05 ns/m
VTPB ð 5.05 ns/m

B.6 Signal pairs relative propagation skew

The difference between the differential mode propagation delay of the two signal twisted pairs shall be measured in the frequency domain using a vector network analyzer in the frequency range of 1 MHz to 500 MHz.

While the signal pairs relative skew can be calculated from the velocity of propagation measurement described in B.5, the very high accuracy required by the intended application of this cable assembly demands a separate, high-resolution test.

In order to perform this measurement using a single-ended test instrument, a differential excitation is generated using a 180° splitter. The output is reconverted to single ended using a 180° combiner. It is very important for the accuracy of this measurement to maintain identical electrical length for the two branches of the differential signal path (in figure B-11, the electrical length of the segments b1, b3, c1, c3, f1, f3, g1, and g3 shall match the electrical length of the corresponding segments b2, b4, c2, c4, f2, f4, g2, and g4; the electrical length of the segments b1, b3, c1, c3, d1, d3, e1, e3, f1, f3, g1, and g3 shall match the electrical length of the corresponding segments b2, b4, c2, c4, d2, d4, e2, e4, f2, f4, g2, and g4).

The test consists of three distinct steps to be performed in the order described in the following subclauses.

B.6.1 Signal pairs skew setup calibration

The “through” calibration shall be performed as shown in figure B-11. The electrical characteristics of the four calibration interconnects (labeled i1, i2, i3, and i4) between the match pads are essential for the accuracy of this procedure. Their length shall be kept to a minimum, and the difference between their electrical length shall be less than 1 mm. The DUT interconnect segments labeled d1, d2, d3, d4, e1, e2, e3, and e4 in figure B-12 are included in the calibration interconnects i1, i2, i3, and i4. Practically, they can be implemented using identical SMA adaptors.

Figure B-11 — Skew setup calibration

The skew is measured by comparing the signal propagation delay on the two twisted pairs. The calibration process attempts to remove the difference in electrical length between the two measurement paths. A close matching of these two paths by construction will help the setup accuracy. Accordingly, in figure B-11 the electrical length of the connection segments marked a1, b1, b2, c1, c2, f1, f2, g1, g2, and h1 shall match the electrical length of the corresponding segments a2, b3, b4, c3, c4, f3, f4, g3, g4, and h2. Similarly, in figure B-12 the electrical length of the connection segments marked a1, b1, b2, c1, c2, d1, d2, e1, e2, f1, f2, g1, g2, and h1 shall match the electrical length of the corresponding segments a2, b3, b4, c3, c4, d3, d4, e3, e4, f3, f4, g3, g4, and h2.

The network analyzer shall use the following setup:

Format	Delay
Sweep	Log Freq
Averaging	32
Smoothing aperture	10%
Power	6 dBm
Start	1 MHz
Stop	500 MHz
Measure	A/B
Display	Data/Memory

B.6.2 Signal pairs skew test procedure

The signal pairs relative propagation skew shall be tested as shown in figure B-12. Three data points shall be measured as follows: S(50) is measured at 50 MHz, S(100) is measured at 100 MHz, and S(200) is measured at 200 MHz.

Figure B-12 — Skew measurement

The average value for the signal pairs relative propagation skew is calculated as

$$S = (S(50) + S(100) + S(200)) / 3 \tag{K8}$$

B.6.3 Signal pairs skew limits

The absolute maximum relative propagation skew of the two signal pairs is verified by the following relation:

S ð 400 ps

B.7 Power pair characteristic impedance

The differential mode characteristic impedance shall be measured in the time domain using a single-ended TDR with an edge rate of less than 0.1 ns. The differential mode impedance value is calculated from the three single-ended measurements described in the following subclauses. The result of each single-ended measurement is calculated as the average of the impedance measured at two points along the cable. These points are selected at 1 ns and at 2.5 ns along the cable from the plug closest to the launching connector. It should be noted that, because the TDR displays the round-trip propagation delay, the measurements shall be made at 2 ns and 5 ns from the plug closest to the launching connector as measured by the TDR instrument.

This test procedure uses the same test setup described in B.3 (cable section), only with a different connection matrix.

B.7.1 Power pair impedance setup calibration—short and load

This calibration should be performed as shown in figure B-6 using the calibration algorithms built into the TDR equipment suggested in B.3.1.

B.7.2 Power pair impedance test procedure

Using the test configuration described in figure B-7 and the connection matrix shown in table B-3, the various characteristic impedances of the power pair shall be measured in two points and the results averaged.

Table B-3 — Connection matrix for power pair impedance tests

Measured value	Fixture 1						Fixture 2					
	VP	TPA	TPA*	TPB	TPB*	VG	VP	TPA	TPA*	TPB	TPB*	VG
Single-ended VP (Z_{VP})	TDR	50 ¾	50 ¾	50 ¾	50 ¾	0 ¾	×	50 ¾	50 ¾	50 ¾	50 ¾	0 ¾
Single-ended VG (Z_{VG})	0 ¾	50 ¾	50 ¾	50 ¾	50 ¾	TDR	0 ¾	50 ¾	50 ¾	50 ¾	50 ¾	×
Common-mode power pair (Z_{VPG})	TDR	50 ¾	50 ¾	50 ¾	50 ¾	TDR	×	50 ¾	50 ¾	50 ¾	50 ¾	×

$Z_{Vn}(2)$ is measured along the cable at 2 ns from the plug connected to test fixture 1.

$Z_{Vn}(5)$ is measured along the cable at 5 ns from the plug connected to test fixture 1.

Z_{Vn} is calculated as

$$Z_{Vn} = (Z_{Vn}(2) + Z_{Vn}(5)) / 2 \qquad \text{(K9)}$$

“V*n*” is VP, VG, or VPG.

The differential mode characteristic impedance of the power pair is calculated as

$$Z_V = 4 \cdot Z_{VPG} \cdot (Z_{VP} + Z_{VG}) / (8 \cdot Z_{VPG} - Z_{VP} - Z_{VG}) \qquad \text{(K10)}$$

The test limit is

ZTPA ð 65 ¾

B.7.3 Power pair dc resistance

The dc resistance of the power wires is measured with a milliohmmeter capable of “four-wire” resistance measurements.

The accuracy of this measurement depends upon the connection segments labeled “a” and “b” in figure B-13. Their length and their dc resistance shall be kept to a minimum. In a noisy environment, the accuracy of this measurement can be improved by connecting the Guard terminal of the test instrument to the shield of one of the cable test fixtures.

The test consists of four steps to be performed in the order described in the following subclauses.

B.7.4 DC resistance setup calibration

Previous to the start of the measurement, the test instrument shall be warmed up for at least 1 h followed by a resistance auto calibration procedure (ACAL OHM).

The setup calibration resistance (RCAL) shall be measured as shown in figure B-13. It is essential to maintain a very low-resistance contact between the connection segments a and b during this measurement.

Figure B-13 — Power pair dc resistance setup calibration

B.7.5 DC resistance test procedure

Using the test configuration described in figure B-14 and the connection matrix shown in table B-4 ~~table B-3~~, the DC resistance of the power pair shall be measured.

Figure B-14 — Power pair resistance measurement

Table B-4 — Connection matrix for power pair resistance tests

Measured value	**Fixture 1**						**Fixture 2**					
	VP	**TPA**	**TPA***	**TPB**	**TPB***	**VG**	**VP**	**TPA**	**TPA***	**TPB**	**TPB***	**VG**
Power wire resistance (R_{VP})	a	×	×	×	×	×	a	×	×	×	×	×
Ground wire resistance (R_{VG})	×	×	×	×	×	b	×	×	×	×	×	b

B.7.6 DC resistance limits

The test limits are

RPV - RCAL ð 0.333 ¾
RPG - RCAL ð 0.333 ¾

B.8 Crosstalk

The pair-to-pair crosstalk shall be measured in the frequency domain using a network analyzer in the frequency range of 1 MHz to 75 ~~500~~ MHz.

Although the language “pair-to-pair” is used, it should be noted that it refers only to the location of the designated driven line and quiet line. The actual test configuration is single-ended.

B.8.1 Crosstalk setup calibration

The through calibration can be performed as shown in figure B-15. The attenuation introduced by the calibration interconnect that replaces the DUT shall be kept to a minimum. Practically, it can be implemented using an SMA adaptor.

Figure B-15 — Crosstalk setup calibration

The network analyzer shall use the following setup:

Format	Log Mag
Sweep	Log Freq
Averaging	16
Smoothing aperture	10%
Power	25 dBm
Start	1 MHz
Stop	75 ~~500~~ MHz
Measure	A/B
Display	Data
Move data into memory	

B.8.2 Crosstalk test procedure

Using the test configuration described in Figure B-16 and the connection matrix shown in Table B-5, the crosstalk between ~~signal pairs and between~~ a signal pair and the power pair shall be measured.

For the evaluation of crosstalk between signal pairs, substitute the alternate differential test fixture shown in Figure B-4 and repeated in Figure B-17 for test fixtures 1 and 2 shown in Figure B-16.

Table B-5 is divided to include the alternate differential test fixtures for crosstalk test conditions (XAB), (XAB*), (XA*B) and (XA*B*).

Figure B-16 — Crosstalk Measurement

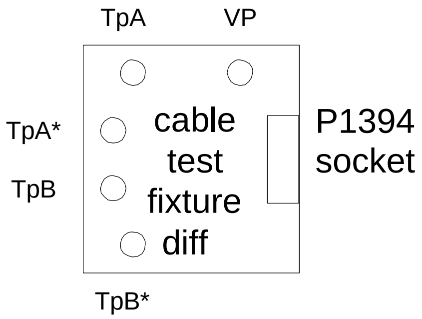

Figure B-17 — Alternate differential test fixtures

Table B-5 — Connection matrix for crosstalk tests

Measured value	**Fixture 1 diff**						**Fixture 2 diff**					
	VP	**TPA**	**TPA***	**TPB**	**TPB***	**VG**	**VP**	**TPA**	**TPA***	**TPB**	**TPB***	**VG**
Crosstalk between TPA and TPB (X_{AB})	0 ¾	Out	50 ¾	50 ¾	50 ¾	╲	0 ¾	In	50 ¾	50 ¾	50 ¾	╲
Crosstalk between TPA and TPB* (X_{AB*})	0 ¾	Out	50 ¾	50 ¾	50 ¾	╲	0 ¾	50 ¾	In	50 ¾	50 ¾	╲
Crosstalk between TPA* and TPB (X_{A*B})	0 ¾	50 ¾	Out	50 ¾	50 ¾	╲	0 ¾	In	50 ¾	50 ¾	50 ¾	╲
Crosstalk between TPA* and TPB* (X_{A*B*})	0 ¾	50 ¾	Out	50 ¾	50 ¾	╲	0 ¾	50 ¾	In	50 ¾	50 ¾	╲
Measured value	**Fixture 1**						**Fixture 2**					
	VP	**TPA**	**TPA***	**TPB**	**TPB***	**VG**	**VP**	**TPA**	**TPA***	**TPB**	**TPB***	**VG**
Crosstalk between VP and TPA (X_{PA})	Out	50 ¾	50 ¾	50 ¾	50 ¾	0 ¾	50 ¾	In	50 ¾	50 ¾	50 ¾	0 ¾
Crosstalk between VP and TPA* (X_{PA*})	Out	50 ¾	50 ¾	50 ¾	50 ¾	0 ¾	50 ¾	50 ¾	In	50 ¾	50 ¾	0 ¾
Crosstalk between VP and TPB (X_{PB})	Out	50 ¾	50 ¾	50 ¾	50 ¾	0 ¾	50 ¾	50 ¾	50 ¾	In	50 ¾	0 ¾
Crosstalk between VP and TPB* (X_{PB*})	Out	50 ¾	50 ¾	50 ¾	50 ¾	0 ¾	50 ¾	50 ¾	50 ¾	50 ¾	In	0 ¾
Crosstalk between VG and TPA (X_{PA})	0 ¾	50 ¾	50 ¾	50 ¾	50 ¾	Out	0 ¾	In	50 ¾	50 ¾	50 ¾	50 ¾
Crosstalk between VG and TPA* (X_{PA*})	0 ¾	50 ¾	50 ¾	50 ¾	50 ¾	Out	0 ¾	50 ¾	In	50 ¾	50 ¾	50 ¾
Crosstalk between VG and TPB (X_{PB})	0 ¾	50 ¾	50 ¾	50 ¾	50 ¾	Out	0 ¾	50 ¾	50 ¾	In	50 ¾	50 ¾
Crosstalk between VG and TPB* (X_{PB*})	0 ¾	50 ¾	50 ¾	50 ¾	50 ¾	Out	0 ¾	50 ¾	50 ¾	50 ¾	In	50 ¾

B.8.3 Crosstalk limits

The test limits are

XAB ð -26 dB
XAB* ð -26 dB

XA*B ð -26 dB
XA*B* ð -26 dB
XPA ð -26 dB
XPA* ð -26 dB
XPB ð -26 dB
XPB* ð -26 dB
XGA ð -26 dB
XGA* ð -26 dB
XGB ð -26 dB
XGB* ð -26 dB