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EIA STANDARD

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Crosstalk Ratio Test Procedure for Electrical Connectors, Sockets, Cable Assemblies or Interconnect Systems

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ELECTRONIC INDUSTRIES ALLIANCE

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(From Standards Proposal No. 3404, formulated under the cognizance of the CE-2.0 National Connector Standards Committee.)

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TEST PROCEDURE No. 90

CROSSTALK RATIO TEST PROCEDURE FOR ELECTRICAL CONNECTORS, SOCKETS, CABLE ASSEMBLIES OR INTERCONNECT SYSTEMS

(From EIA Standards Proposal No. 3404, formulated under the cognizance EIA CE-2.0 Committee on National Connector Standards)

1 Introduction

1.1 Scope

This procedure applies to interconnect assemblies, such as electrical connectors, sockets and cable assemblies.

1.2 Object

This standard describes test methods for measuring the magnitude of the electromagnetic coupling between driven and quiet lines of an interconnect assembly. Both time domain (method A) and frequency domain methods (method B), single-ended and differential transmission, and insertion and reference fixture techniques are described.

1.3 Definitions

1.3.1 Drive signal

For the time domain method, the drive signal is a step waveform. For the frequency domain method, the drive signal is sinusoidal.

1.3.2 Crosstalk ratio

The ratio of the signal coupled (induced) into the quiet signal conductor or conductor pair to the magnitude of the signal in the driven conductor or conductor pair. Both signals shall have the same units of either voltage or current, and the ratio may be expressed as percent or dB.

1.3.3 Near end crosstalk ratio (NEXT)

The crosstalk ratio calculated on the quiet line at or in proximity to the sending (signal source) end of the driven line. This is the ratio of the near end quiet line signal amplitude to the near end driven line signal amplitude.

1.3.4 Far end crosstalk ratio (FEXT)

The crosstalk ratio calculated on the quiet line at or in proximity to the receiving (destination) end of the driven line. This is the ratio of the far end quiet line signal amplitude to the near end driven line signal amplitude.

1.3.5 Measurement system rise time

Rise time measured with fixture in place, without the specimen, and with filtering (or normalization). Rise time is typically measured from 10% to 90% levels.

1.3.6 Specimen environment impedance

The impedance presented to the specimen signal conductors by the fixture. This impedance is a result of transmission lines, termination resistors, attached receivers or signal sources, and fixture parasitics.

1.3.7 Step amplitude

The voltage difference between the 0% and 100% levels, ignoring overshoot and undershoot, as indicated in figure 1.

1.3.8 Isolation standard

A reference fixture without a test specimen and with identical crosstalk characteristics as the test fixture. This fixture may or may not be part of the test board.

1.3.9 Termination (electronics usage)

An impedance connected to the end of a transmission line, typically to minimize reflected energy on the line.

2 Test resources

2.1 Equipment

2.1.1 Method A, time domain

2.1.1.1 A step generator is used on the driven line and an oscilloscope monitors the quiet line. In a differential application both shall be able to process differential signals. Typically, this means complementary outputs with provision for amplitude and skew adjustment, and dual inputs with a display of the difference and sum. Filtering or normalization shall be available for varying the rise time. A time domain reflectometer (TDR) is usually used.

NOTE — The test professional should be aware of limitations of any math operation(s) performed by an instrument, (e.g. normalization or software filtering).

2.1.1.2 Probes

Probes, when used, shall have suitable rise time performance and circuit loading characteristics (e.g. resistance and capacitance).

2.1.2 Method B, frequency domain

A network analyzer is preferred. When greater dynamic range is desired, a signal generator and spectrum analyzer may alternatively be used. An 8 port network analyzer or baluns may be used for differential measurements.

2.2 Fixture

Unless otherwise specified in the referencing document the specimen environment impedance shall match the impedance of the test equipment. Typically this will be 50 ohms for single-ended measurements and 100 ohms for differential.

2.2.1 Specimen conductor assignments

For each measurement, the driven and quiet lines shall be fixtured as indicated in the referencing document. Adjacent signal lines to these should likewise be terminated if possible (electrically long adjacent signal lines may resonate adding error to the results). Unless otherwise specified a 1:1 signal to ground ratio (one differential pair to one ground if differential measurements are performed) shall be used with each end having all grounds commoned, for an example, see figure A.4. The fixture should be designed with equal delays for all lines.

NOTE — When the drive signal is differential and not balanced, the common mode energy shall be terminated.

2.2.2 Termination

The far end of the driven lines and both ends of the quiet line shall be terminated in the specimen environment impedance specified using one of the methods in figures A.2 and A.3. Matching networks may be used if the specimen environment impedance does not match that of the test equipment. Care should be taken to minimize the reactances of the resistive terminations over the range of test frequencies.

NOTE — The fixture geometry and materials may impact the measurements due to the fixture parasitics. Usually the product's intended use dictates the most meaningful way to fixture it.

2.2.3 Crosstalk

It may be difficult to separate fixture crosstalk from that of the specimen. The referencing document should specify the fixture so that its crosstalk contribution is minimized.

NOTE 1— Since the test board footprint or cable assembly termination technique can significantly impact the crosstalk it is recommended that an isolation standard (for measuring fixture crosstalk) be included in the fixture.

2.2.4 Insertion technique fixture

The fixture shall be designed to allow measurement of crosstalk with and without the specimen, see figure A.1. If baluns are used for a balanced measurement, or minimum loss pads used for impedance matching; see figures A2 and A.3, these are included in the fixture.

2.2.5 Reference fixture technique

In this technique a separate fixture that combines both near end and far end is used for the fixture crosstalk measurement. This fixture shall be a duplicate of the specimen fixture, only without the specimen. Traces, if used, shall include fixture connectors, vias, bends and corners. If baluns are used for a balanced measurement, or minimum loss pads used for impedance matching; see figures A.2 and A.3, these are included in the fixture.

3 Test specimen

3.1 Description

For this test procedure the test specimen shall have more than one signal line and shall be one of the following:

3.1.1 Separable connectors

A mated connector pair.

3.1.2 Cable assembly

Assembled connectors and cables, and mating connectors.

3.1.3 Sockets

A socket and test device or a socket and pluggable header adapter.

4 Test procedure

The far end of the driven lines and both ends of the quiet line(s) shall be terminated in the specimen environment impedance specified using one of the methods in figures A.2 and A.3.

4.1 Method A, time domain

4.1.1 General

4.1.1.1 Place the specimen a minimum of 5 cm from any objects that would affect measured results.

4.1.1.2 Reference measurement and fixture crosstalk

4.1.1.2.1 Measure and record the measurement system rise time from 10% to 90% levels, unless otherwise specified in the referencing document.

4.1.1.2.2 Fixture crosstalk contributes to the specimen crosstalk. The fixture includes minimum loss pads, if used. If the referencing document precisely describes the fixture so that its crosstalk contribution is known, then the fixture crosstalk measurement is optional. These results are a magnitude versus time plot. Measure the measurement system rise time, drive amplitude and fixture crosstalk with one of the following techniques.

4.1.2 Insertion technique

4.1.2.1 Assemble the fixture so that the near end is connected to the far end without the specimen in between, and connect the oscilloscope and pulse generator to the appropriate locations of the driven line fixture. For multiple simultaneously driven lines, match amplitudes and minimize the skew between lines, and if balanced, minimize skew within the pair. Measure and report the skew values.

4.1.2.2 If the number of lines to be driven simultaneously exceeds the equipment capability or channel skew elimination is a concern, the lines may be driven one at a time and the crosstalk calculated by superposition.

4.1.2.3 Measure the step rise time and amplitude of the drive signal transmitted through the fixture alone. (If requested this can be done using the fixture with specimen.) Adjust the filtering (or normalization) so the measured rise time matches the value requested, or a value from table 1.

4.1.2.4 Connect the oscilloscope to the quiet line location as specified in the referencing document. Measure the fixture crosstalk amplitude with the specimen removed. Calculate the fixture crosstalk ratio by dividing the fixture crosstalk amplitude by the step amplitude and express as a percent. Unless otherwise specified record the peak values and the sign.

4.1.3 Reference fixture technique

4.1.3.1 Connect the oscilloscope and pulse generator to the appropriate locations of the driven line. For balanced measurements, make positive and negative steps equal in amplitude and remove skew at the signal source, (this assumes that the fixture has been designed with equal delays between all lines). For multiple simultaneously driven lines, match amplitudes and remove skew.

4.1.3.2 If the number of lines to be driven simultaneously exceeds the equipment capability or channel skew elimination is a concern, the lines may be driven one at a time and the crosstalk calculated by superposition.

4.1.3.3 Measure the step rise time and amplitude of the drive signal transmitted through the reference fixture. (If requested for FEXT do this using the fixture with specimen). Adjust the filtering (or normalization) so the measured rise time matches the value requested, or a value from table 1.

Table 1 - Recommended measurement system rise time (including fixture and filtering)

Expected application signal rise time, picoseconds	Measurement system rise time, picoseconds
100 – 500	100
>500 - 1,000	500
> 1,000	1000

4.1.3.4 Connect the oscilloscope to the quiet line location of the reference fixture specified in the referencing document. Measure the amplitude of the quiet line signal at its maximum excursion. Subtract from this value the amplitude of the quiet line signal prior to the time of the edge of the driven line signal to obtain the quiet line crosstalk value (maintaining the sign). Calculate the fixture crosstalk ratio by dividing the quiet line crosstalk value by the step amplitude and express as a percent.

4.1.4 Specimen crosstalk measurement

4.1.4.1 Add specimen to fixture.

4.1.4.2 Connect the oscilloscope to the quiet line and the step generator to the driven line at the locations requested. For balanced measurements, make positive and negative steps equal in amplitude and remove skew at the signal source, (this assumes that the fixture has been designed with equal delays between all lines). For multiple simultaneously driven lines, match amplitudes and remove skew.

4.1.4.3 If the number of lines to be driven simultaneously exceeds the equipment capability or channel skew elimination is a concern, the lines may be driven one at a time and the crosstalk calculated by superposition.

4.1.4.4 Measure the amplitude of the quiet line signal at its maximum excursion. Subtract from this value the amplitude of the quiet line signal prior to the time of the edge of the driven line signal to obtain the quiet line crosstalk value (maintaining the sign). Calculate the specimen-with-fixture crosstalk ratio by dividing the specimen-with-fixture quiet line crosstalk value by the step amplitude and express as a percent.

> NOTE — Care shall be taken in interpreting the results when the fixture crosstalk approaches the same magnitude as the specimen-with-fixture crosstalk. It is not valid to subtract fixture crosstalk from this measurement.

4.2 Method B, frequency domain

4.2.1 General

4.2.1.1 Place the specimen a minimum of 5 cm from any objects that would affect measured results.

4.2.1.2 Calibration (reference measurement) and measurement of fixture crosstalk.

If baluns are used for a balanced measurement, or minimum loss pads used for impedance matching; see figures A.2 and A.3, these are included in the term "fixture". If the referencing document specifies the fixture so that its crosstalk contribution is known, then the fixture crosstalk measurement is optional.

4.2.1.3 Unless otherwise specified all measurement results shall contain a minimum of 200 frequency points. Generate a magnitude versus frequency plot; 10 dB per division vertical scale and log frequency sweep are recommended. When applicable, single frequency results shall be tabulated, as specified in the referencing document.

4.2.2 Insertion technique

4.2.2.1 Network analyzer

4.2.2.1.1 Assemble the fixture so that the near end is connected to the far end without the specimen in between. Connect the network analyzer ports to the appropriate locations of the fixture. Perform a "through" calibration. If the requesting document specifies the measurement be referenced to the output of the driven line rather than the input, perform this calibration with the specimen in the fixture.

4.2.2.1.2 Measure S_{21} in dB without the specimen, which is the fixture crosstalk ratio.

4.2.2.2 Spectrum analyzer

4.2.2.2.1 Driven line power

Assemble the fixture with the near end connected to the far end without the specimen in between. Connect the signal generator and spectrum analyzer to the appropriate locations of the driven line fixture. Measure and record the driven line signal power in dBm. When requested, this signal may be measured at the far end of the specimen by including the specimen in this measurement.

4.2.2.2.2 Fixture crosstalk ratio

Without changing any equipment settings, connect the spectrum analyzer to the quiet line location requested in the referencing document. Measure and record the quiet line signal power in dBm Divide these results by the driven line power measurement (subtract dBm) to obtain the fixture crosstalk ratio in dB.

4.2.2.2.3 Specimen plus fixture crosstalk ratio

Insert the specimen and measure the quiet line signal power in dBm. Divide this value by the driven line power measurement (subtract dBm) to obtain the fixture plus specimen crosstalk ratio in dB.

4.2.2.2.4 Specimen crosstalk ratio

Divide the fixture plus specimen crosstalk ratio by the fxture crosstalk ratio (subtract dBm) to obtain the specimen crosstalk ratio in dB. When requested, the reference signal may be measured at the far end of the specimen by including the specimen in this measurement.

4.2.3 Reference fixture technique

Construct a reference fixture that is missing provision for a specimen, but is otherwise identical. This reference fixture combines both the near end and far end. Connect the network analyzer ports, or the signal generator and spectrum analyzer to the appropriate locations of the driven line fixture. Perform a "through" calibration with the network analyzer, or make a reference measurement with the signal generator and spectrum analyzer. (If requested, do this using the fixture with specimen). Connect the receiver port of the network analyzer or the spectrum analyzer to the quiet line location of the reference fixture requested in the referencing document. Measure the fixture crosstalk ratio in dB (network analyzer) or fixture crosstalk in dBm (spectrum analyzer) without the specimen. To get fixture crosstalk ratio with a spectrum analyzer, divide this by the reference measurement.

4.2.4 Specimen crosstalk measurement

4.2.4.1 Add specimen to fixture.

4.2.4.2 Connect the signal source to the driven line and the receiver port of the network analyzer or the spectrum analyzer to the quiet line locations requested.

4.2.4.3 Record the crosstalk in dB. This will be the crosstalk ratio with a network analyzer. When using a spectrum analyzer, divide the specimen measurement by the reference measurement, see 4.2.1.2. The resulting crosstalk ratio is a magnitude versus frequency plot. Record single frequency results, if requested.

4.2.4.4 Compare this measurement to the fixture crosstalk measured in 4.2.2 or 4.2.3. For all frequencies, measured crosstalk shall be 20 dB greater than the fixture crosstalk. Data not meeting this requirement shall be labeled appropriately.

NOTE — Care shall be taken in interpreting the results when fixture electrical length is greater than 1/8 wavelength at the highest test frequency, unless special precautions are taken to ensure good impedance matching throughout the measurement path. This can be confirmed by sweeping across a wide frequency range and observing if there are nulls due to moding, fixture or balun resonances, etc.

5 Details to be specified

The following details shall be specified in the referencing document:

5.1 All tests

5.1.1 Specimen signal and ground assignments for each measurement. At a minimum, the driven conductors, quiet conductor(s), and associated (adjacent) grounds of all these, shall be identified. If different crosstalk ratio results can be expected due to different rows or parts of a repeating pattern, measure each.

5.1.1.1 Unless otherwise specified for single-ended measurements a 1:1 signal to ground ratio shall be used and the crosstalk shall be measured on the closest (adjacent) or the most closely coupled quiet lines to the driven line.

5.1.1.2 Unless otherwise specified for differential measurements one signal pair to one ground ratio shall be used and the crosstalk shall be measured on the closest (adjacent) or the most closely coupled quiet lines to the driven line.

5.1.2 Type of measurement, single-ended or differential

5.1.3 Specimen environment impedance

5.1.4 Points at which the crosstalk shall be measured on the quiet conductor

5.1.5 The point where drive is to be applied on the driven line

5.1.6 Whether the reference measurement is taken with or without the specimen

5.1.7 Maximum skew allowed between driven lines, and if differential, maximum skew allowed within a pair

5.1.8 It is preferred that the referencing document precisely specify the fixture so that its crosstalk contribution is fixed and termination impedances are precisely specified; see 2.2.2. If this is not done fixture crosstalk shall be measured; see 4.1.1.2 and 4.2.1.2.

5.2 Time domain only

5.2.1 Measurement system rise time and reference points, if other than from 10% to 90%. The drive signal shall be defined, including the minimum (0%) and maximum (100%) voltage levels, risetime(s), and duty cycle.

5.2.2 Waveform plots, if desired

5.2.3 Peak-to-peak values, if desired

5.3 Frequency domain only

5.3.1 Frequency span

5.3.2 Plot magnitude format, if not dB and log frequency

5.3.3 Equipment preference, if any

5.3.4 Results at a single frequency, if any. When only these results are desired instead of plots, it shall be requested.

6 Test documentation

Documentation shall contain the details specified in clause 5, with any exceptions, and the following:

6.1 Title of test

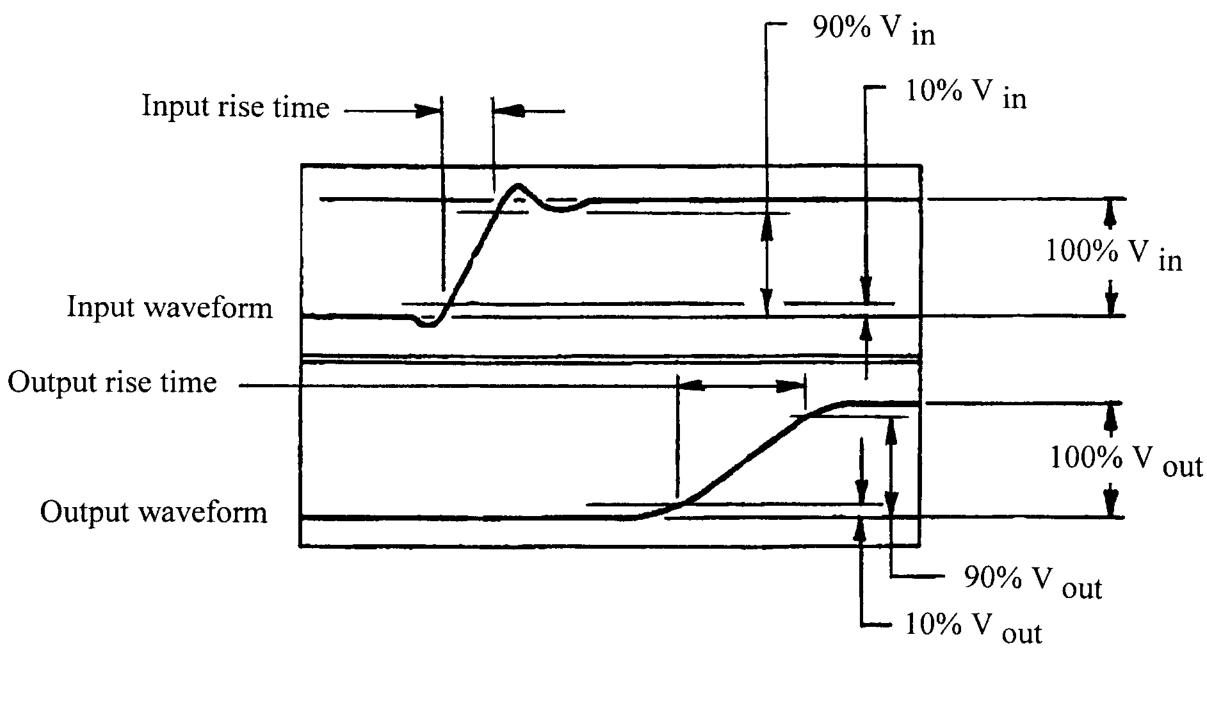
6.2 Calculated crosstalk ratio (zero to peak) values including sign, either positive or negative (time domain), or plots (frequency domain).

6.3 Fixture crosstalk ratio peak values, either positive or negative (time domain), or plots (frequency domain)

6.4 All details relating to data interpretation when specimen or specimen environment impedance is not matched to the measurement system characteristic impedance

6.5 Test equipment used, and date of last and next calibration

6.6 Name of operator and date of test



NOTE — Ignore overshoot and undershoot when calculating 0% and 100% levels.

Figure 1 - Waveform

Annex

A Normative

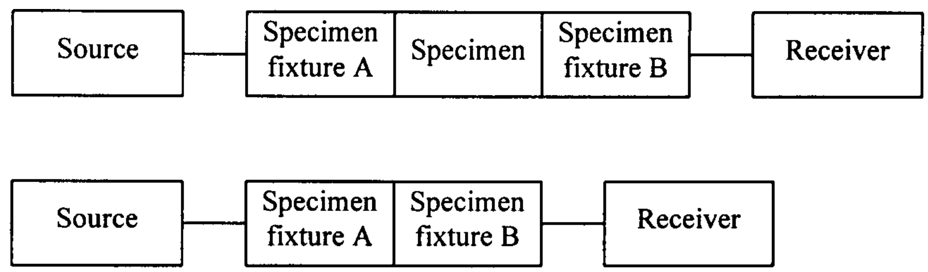


Figure A.1.a - Insertion technique

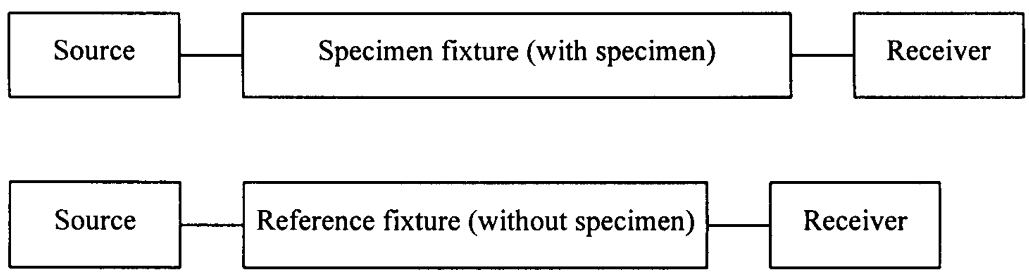
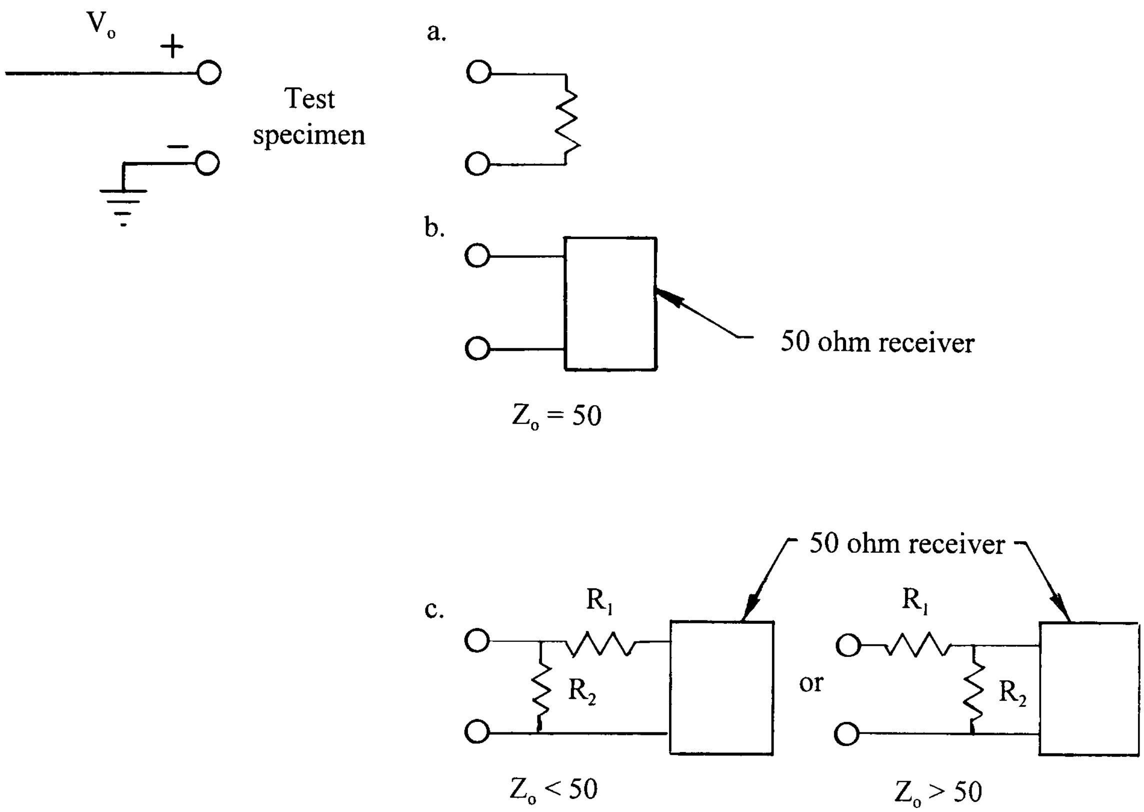


Figure A.1.b - Reference fixture technique

Figure A.1 - Technique diagrams

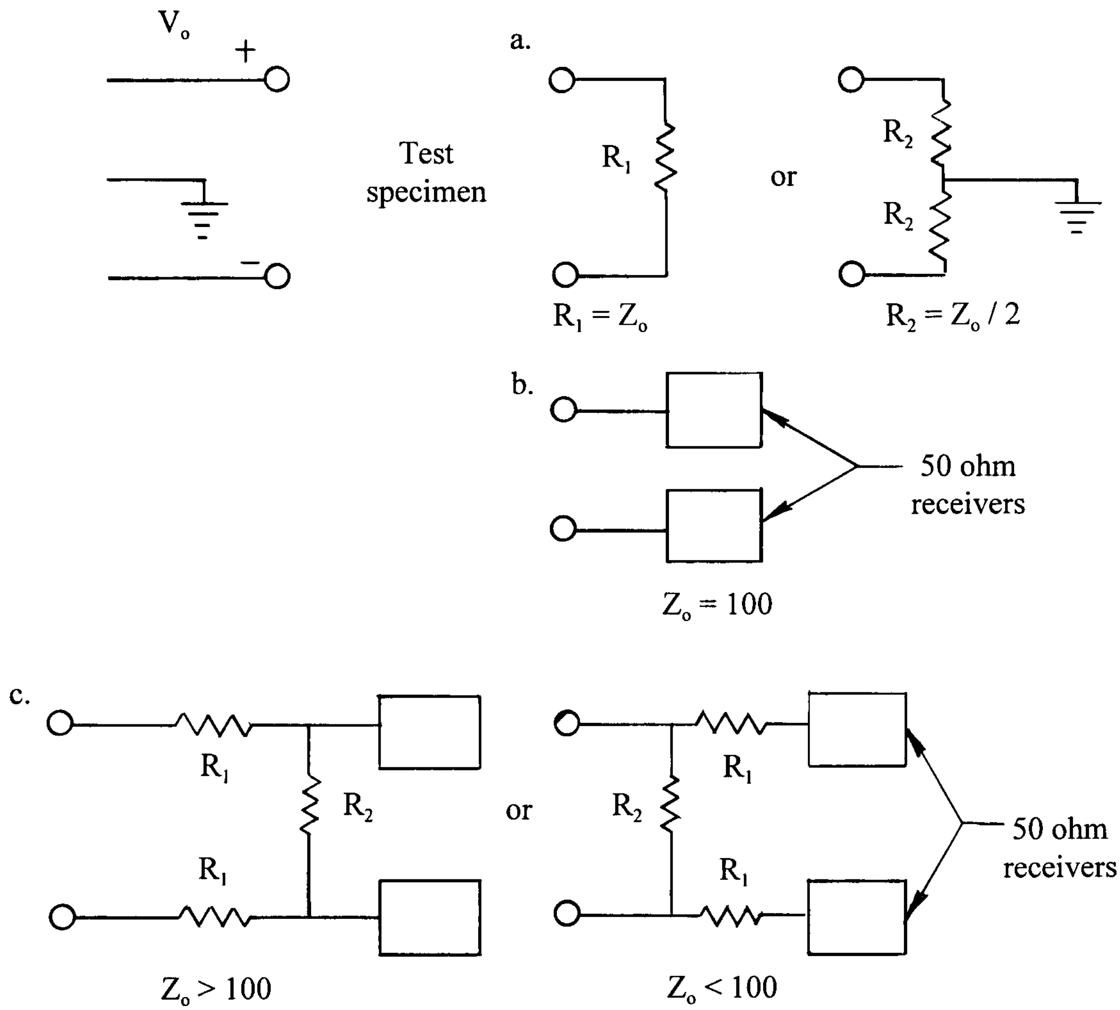


Minimum loss pad equations:

$R_1 = 50 [1 - (Z_o / 50)]^{0.5}$ $R_1 = Z_o [1 - (50 / Z_o)]^{0.5}$

$R2 = Zo / [1 - (Zo / 50)] 0.5$ $R2 = 50 / [1 - (50 / Zo)] 0.5$

Figure A.2 - Single-ended terminations



Minimum loss pad equations:

$R_1 = Z_o\ [\ 1 - (100\ /\ Z_o)\ ]^{0.5}\ /\ 2$ $\quad$ $R_1 = 100\ [\ 1 - (Z_o\ /\ 100)\ ]^{0.5}\ /\ 2$

R2 = 100 / [1 - (100 / Zo)] 0.5 $\quad$ R2 = Zo / [1 - (Zo / 100)] 0.5

Figure A.3 - Differential (balanced) terminations

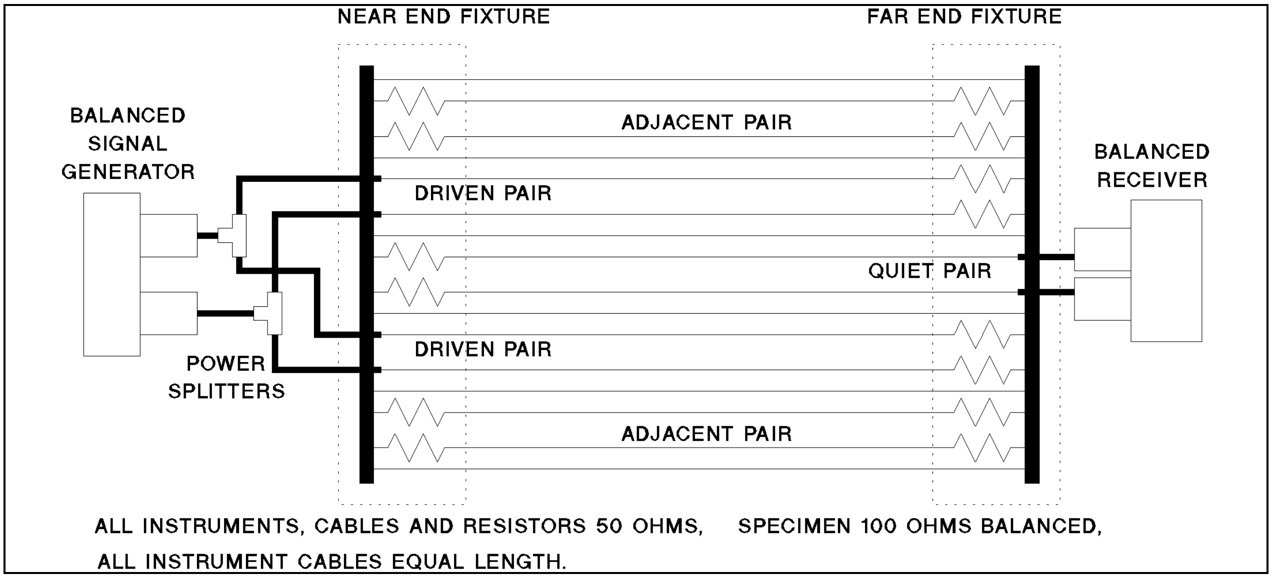


Figure A.4 – Example of far end crosstalk with balanced terminations
[see figure A.3.a (2nd) and figure A.3.b for Z_o = 100]

B Informative

B.1 Practical guidance

Near perfect resistive terminations of the signal lines may not be possible at high frequencies due to parasitic reactances in both signal and ground conductors. These reactances will have an impact on measured results. In this case it is desirable that the test fixture duplicate the exact geometry (parasitics) of the actual application. This may involve the use of transmission lines in addition to the components of figures A.1 and A.2. Most instruments used for these measurements are internally terminated in 50 ohms at both source and detector ports.

EIA Document Improvement Proposal

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