



ANSI/EIA-364-108A-2019
Approved: August 22, 2019

EIA-364-108A

EIA STANDARD

TP-108A

**Impedance, Reflection Coefficient,
Return Loss, and VSWR Measured
in the Time and Frequency Domain
Test Procedure for Electrical
Connectors, Cable Assemblies or
Interconnection Systems**

EIA-364-108A

(Revision of EIA-364-108)

August 2019



Electronic Components Industry Association

NOTICE

EIA Engineering Standards and Publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. Existence of such Standards and Publications shall not in any respect preclude any member or nonmember of ECIA from manufacturing or selling products not conforming to such Standards and Publications, nor shall the existence of such Standards and Publications preclude their voluntary use by those other than ECIA members, whether the standard is to be used either domestically or internationally.

NOTE – The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights.

By publication of this standard, no position is taken with respect to the validity of any such claim(s) or of any patent rights in connection therewith. If a patent holder has filed a statement of willingness to grant a license under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license, then details may be obtained from the standards developer.

Neither the standards developer nor ANSI is responsible for identifying patents for which a license may be required by an American National Standard or for conducting inquiries into the legal validity or scope of those patents that are brought to their attention.

Standards and Publications are adopted by ECIA in accordance with the American National Standards Institute (ANSI) patent policy. By such action, ECIA does not assume any liability to any patent owner, nor does it assume any obligation whatever to parties adopting the Standard or Publication.

This EIA Standard is considered to have International Standardization implications, but the International Electrotechnical Commission activity has not progressed to the point where a valid comparison between the EIA Standard and the IEC document can be made.

This Standard does not purport to address all safety problems associated with its use or all applicable regulatory requirements. It is the responsibility of the user of this Standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations before its use.

(From Standards Proposal No. 5434.07, formulated under the cognizance of the EIA CE-2.0 Committee on National Connector and Socket Standards.)

Published by

©Electronic Components Industry Association 2019
EIA Standards & Technology Department
13873 Park Center Road, Suite 315
Herndon, VA 20171

**PLEASE !
DON'T VIOLATE
THE
LAW!**

This document is copyrighted by the ECIA and may not be reproduced without permission.

Organizations may obtain permission to reproduce a limited number of copies through entering into a license agreement. For information, contact:

IHS
15 Inverness Way East
Englewood, CO 80112-5704 or call
USA and Canada (1-877-413-5186), International (303-397-7956)

CONTENTS

Clause	Page
1 Introduction	1
1.1 Scope	1
1.2 Object	1
1.3 Definitions	1
2 Test resources	3
2.1 Equipment	3
2.2 Fixture	4
3 Test specimen	6
3.1 Description	6
4 Test procedure	6
4.1 Time domain	6
4.2 Frequency domain	8
5 Details to be specified	10
6 Test documentation	11
 Table	
1 Additional measurement system rise time (including fixture and filtering)	7
 Figure	
A.1 Example of rise time measurement points	A-1
A.2 Example of TDR output; 2 curves (different rise times) and start and stop specimen points	A-2
A.3 Example of analyzer output, impedance vs. log frequency plot	A-3
C.1 Typical mother board test fixture	C-2
C.2 Typical daughter board test fixture	C-2
C.3 Example of near end reference trace	C-5
D.1 Example of an impedance profile of connector using a measurement system rise time of 35 ps	D-1

CONTENTS (continued)

Clause	Page
D.2 Example of impedance profiles of cable under the rise time of 35 ps and 1 ns	D-2
E.1 Single-ended terminations	E-1
E.2 Differential (balanced) terminations	E-2
G.1 Microstrip (a) and stripline (b) geometries	G-1
G.2 Buried microstrip geometry	G-2
 Annex	
A Measurement system rise time (normative)	A-1
B Determination of the near end and far end of the specimen (informative)	B-1
C Calibration standards and test board reference traces (informative)	C-1
D Interpreting TDR impedance graphs (informative)	D-1
E Terminations - electrical (informative)	E-1
F Practical guidance – variable rise time (informative)	F-1
G Printed circuit board design considerations for electronics measurements (informative)	G-1
H Test signal launch hardware (informative)	H-1

TEST PROCEDURE No. 108A

IMPEDANCE, REFLECTION COEFFICIENT, RETURN LOSS, AND VSWR MEASURED IN THE TIME AND FREQUENCY DOMAIN TEST PROCEDURE FOR ELECTRICAL CONNECTORS, CABLE ASSEMBLIES OR INTERCONNECTION SYSTEMS

(From EIA Standards Proposal No. 5434.07, formulated under the cognizance of the EIA CE-2.0 Committee on National Connector and Socket Standards, and previously published as EIA-364-108.)

1 Introduction

1.1 Scope

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

1.2 Object

This standard describes test methods to measure impedance, reflection coefficient, return loss, and voltage standing wave ratio (VSWR) in the time and frequency domains.

NOTE — These test methods are written for test professionals who are knowledgeable in the electronics field and are trained to use the referenced equipment. Because the measurement values are heavily influenced by the fixturing and equipment this method cannot describe all of the possible combinations. The major equipment manufacturers provide Application Notes for more in-depth technical description of how to optimize the use of their equipment. It is imperative that the referencing document include the necessary description and sketches for the test professional to understand how to setup and perform the requested measurements.

1.3 Definitions

1.3.1 Measurement system rise time

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

1.3.2 Specimen environment impedance

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

1.3.3 Reflection coefficient

The ratio of the reflected to incident voltages at any given point. The reflection coefficient is given by:

$$\text{Gamma } (\Gamma) = \frac{V_{\text{reflected}}}{V_{\text{incident}}} = \frac{Z_L - Z_O}{Z_L + Z_O} = s_{11}$$

where Z_L is the fixture or specimen impedance and Z_O is the specimen environment impedance.

NOTE — In the time domain, the reflection coefficient symbol typically used is rho (ρ), while Gamma (Γ) is used for frequency domain measurements.

1.3.4 Impedance

The total opposition that a circuit offers to the flow of alternating current or any other varying current at a particular frequency. It is a combination of the resistance (R) and reactance (X) measured in ohms (Ω). The equation for impedance as a function of s-parameters is:

$$Z = Z_0 \frac{1 + s_{11}}{1 - s_{11}} = R + jX = Z_0 \left[\frac{(1 + \rho)}{(1 - \rho)} \right]$$

1.3.5 Return loss

The ratio in decibels (dB) of the power incident upon the impedance discontinuity to the power reflected from the discontinuity. The equation for return loss calculated from the reflection coefficient is:

$$\text{Return Loss} = -20 \log_{10} |\Gamma| = -20 \log_{10} |s_{11}|$$

1.3.6 Voltage Standing Wave Ratio (VSWR)

The ratio of the maximum magnitude of the voltage on a line to the minimum magnitude at any given point. VSWR can be expressed by the following equations:

$$\text{VSWR} = \frac{|V_{\text{max}}|}{|V_{\text{min}}|} = \frac{|V_{\text{inc}} + V_{\text{refl}}|}{|V_{\text{inc}} - V_{\text{refl}}|}$$

or

$$\text{VSWR} = \frac{(1 + |\Gamma|)}{(1 - |\Gamma|)}$$

1.3.7 Scattering parameter (s-parameter), s_{11}

The reflection coefficient at the input port of the device under test, defined as the ratio of the reflected voltage to the incident voltage.

1.3.8 Termination (electronics usage)

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

1.3.9 Step amplitude

The voltage difference between the 0% and 100% levels, ignoring overshoot and undershoot.

2 Test resources

Care should be taken when establishing the equivalence between time and frequency domain measurements. The relationship between the two is complex and the application of $\text{bandwidth} = (0.35/\text{rise time})$ should not be used without further computations and understanding.

2.1 Equipment

2.1.1 Time domain

2.1.1.1 A Time Domain Reflectometer (TDR) is preferred, although an oscilloscope and pulse generator may be used. A network analyzer may be used with FFT (Fast Fourier-Transform) software.

NOTE — The test professional should be aware of limitations of any math operation performed by an instrument (e.g., FFT).

2.1.1.2 Variable rise time

A means should be provided for varying the signal rise time if required. This may be included within the test equipment itself, or possibly through additional filtering or software.

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

2.1.1.3 Differential measurements

The test equipment shall have the capability to perform differential measurements directly, or provisions shall be made to calculate the impedance from multiple single-ended measurements.

2.1.2 Frequency domain

2.1.2.1 A vector network analyzer or impedance analyzer shall be used.

NOTES

- 1 The test professional should be aware of the frequency limitations of the fixture.
- 2 The test professional should be aware of any limitations of any mathematical functions performed (e.g., normalization, inverse FFT, or software filtering.)

2.1.2.2 Differential measurements

For differential measurements, a network analyzer and baluns may be used.

NOTE — The test professional should be aware of the electrical characteristics of the baluns, that become part of the test fixture and can significantly affect the measurement.

2.2 Fixture

The fixture(s) shall allow for enough measurements throughout the specimen such that variations in geometries, materials, transmission paths, etc. may be demonstrated and provide a representative sampling of specimen performance.

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

2.2.1 Specimen environment impedance

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 measurements.

2.2.2 Terminations

When using termination resistors, care should be taken to minimize the parasitic reactances of the terminators over the range of test frequencies; see annex E.

2.2.3 Calibration features

See annex C for calibration and reference traces.

NOTE — The term “calibration” used in this document is not to be confused with the periodic factory equipment calibration. Calibration is used in the sense of characterizing the fixture so that when the “fixture plus specimen” measurement is taken, the characteristics of the specimen alone can be accurately determined.

2.2.3.1 Time domain

The fixture shall include features such that the near and far ends of the specimen may be determined in time; see annex B. The calibration plane should be as close to the specimen as possible. When the fixture includes a pc board with line traces connecting two connectors, it shall have a reference trace(s) that will allow the measurement system rise time to be measured. The reference trace shall have starting points and endpoints at the same location as the DUT starting point and end point. This is because the reference trace(s) length shall be the same as the pc board traces.

2.2.3.2 Frequency domain

It is necessary to include fixture features that will allow for the open, short, and load measurements to be taken. This may be accomplished by one of two methods. Firstly, provide reference traces that include the open, load and short standards. Secondly, provide an interface where these standards can be applied directly to the end of the fixture and immediately before the input plane of the device under test. When using the open/short method, the fixture shall include features such that measurements may be conducted with the far end of the driven line both open-circuited and short-circuited.

NOTE — Other calibration techniques (such as Through-Reflect-Line) may be used. The fixture shall incorporate features appropriate to that calibration method(s).

2.2.4 Single-ended

The fixture shall allow one signal line to be driven at a time. The far end of the driven line shall be terminated in the specimen environment impedance (typically 50 ohms). It is recommended that a length of transmission line be added after the sample that has a propagation delay greater than twice the measurement system rise time. Unless otherwise specified in the referencing document:

- a 1:1 signal to ground ratio shall be used,
- designated ground lines shall be commoned on both the near and far end,
- adjacent signal lines shall be terminated in the specimen environment impedance.

2.2.5 Differential

The fixture shall allow one signal pair to be driven at a time. The driven pair shall be terminated in the specimen environment impedance (typically 100 ohms). It is recommended that a length of transmission line be added after the specimen that has a propagation delay greater than twice the measurement system rise time. Unless otherwise specified in the referencing document:

- a 2:1 signal to ground ratio shall be used (one signal pair for each ground return),
- designated ground lines shall be commoned on both the near and far end,
- adjacent signal lines shall be terminated in the specimen environment impedance.

NOTE — For differential applications in the frequency domain using a 2-port network analyzer, the fixture will include the use of baluns.

3 Test specimen

3.1 Description

For this test procedure the test specimen shall be as follows:

3.1.1 Separable connectors

A mated connector pair.

3.1.2 Cable assembly

Assembled connectors and cables, and mating connectors.

4 Test procedure

4.1 Time domain

4.1.1 Calibrate the equipment and fixture according to the manufacturer's specified measurement techniques using precision impedance standards and/or cabling. The calibration plane is to be directly at the input interface of the specimen; see 2.2.3.1 for more detailed information.

4.1.2 Connect the TDR signal line(s) to the reference line(s) of the test fixture.

4.1.3 Unless otherwise specified in the referencing document, the signal rise time shall be the fastest signal of which the equipment is capable. If a slower signal rise time is also desired to approximate the application conditions, one of the rise times in table 1 may be used. Measure and record the measurement system rise time from the reference line, as shown in figure A.1.

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

Typical application rise time in which the specimen will be used, picoseconds	Measurement system rise time, picoseconds
100 – 500	100
>500 – 1,000	500
> 1,000	1000

4.1.4 Measure, record, and plot the requested parameters for the test fixture (impedance, reflection coefficient, and/or voltage). If the equipment does not have the capability to display the requested parameter directly see the applicable clause of 1.3 for conversion equations.

4.1.5 Connect the TDR line(s) to the driven line(s) of the fixture with the specimen installed.

4.1.6 Place the specimen a minimum of 5 cm from any objects that may introduce error into the measurement.

4.1.7 Determine the near end and far end of the specimen. Annex B describes a method for determining the near and far end of the specimen.

4.1.8 Display and record the requested electrical parameter on the test equipment. If the equipment does not have the capability to display the requested parameter directly see the applicable clause of 1.3 for conversion equations. Refer to figure A.2 for example of a TDR plot, and annex D for examples of interpreting TDR impedance graphs.

4.1.8.1 Single ended measurement

Set the test equipment to display the driven signal line waveform.

4.1.8.2 Differential measurement

Set the test equipment to display a waveform representing the difference between the two driven signal line waveforms, (typically, “Trace 1 minus Trace 2”).

NOTE — If not available within the TDR equipment, this mathematical function may be accomplished by collecting the raw voltage data with an acquisition system and manipulating the data with appropriate software.

4.1.9 When required, vary the measurement system rise time and repeat 4.1.2 through 4.1.8. Record the measurement system rise times with the corresponding data.

NOTE — When varying measurement system rise times, the test professional should be aware of limitations of any math operation performed by an instrument, (e.g. normalization or software filtering).

4.1.10 If requested, repeat 4.1.5 through 4.1.9 for multiple lines throughout the specimen.

4.2 Frequency domain

4.2.1 General

4.2.1.1 Calibrate the equipment and fixture according to the manufacturer's specifications using precision impedance standards and/or cabling. The calibration plane is to be directly at the input interface of the specimen, see 2.2.3.2 for more detailed information.

NOTE — The test professional is reminded that the calibration shall be performed in the mode to be used for the measurements; e.g., S_{11} .

4.2.1.2 Fixture measurement

Set the analyzer for a single port (or comparable) measurement. Select the display mode for the desired parameter (impedance, reflection coefficient, return loss, VSWR) as specified in the referencing document. If using a network analyzer, measure and record S_{11} . Refer to figure A.3 for an example of a network analyzer plot. It is recommended that the following equipment settings be used:

- cartesian plots with a logarithmic frequency scale and linear Y-axis,
- minimum of 201 measurement points,
- maximum smoothing of 1%.

If the equipment does not have the capability to display the requested parameter directly see the applicable clause of 1.3 for conversion equations.

4.2.2 Specimen measurement - Direct method

4.2.2.1 Connect the analyzer line(s) to the driven line(s) of the fixture with the specimen installed. Terminate the far end of the test specimen in the specimen environment impedance.

4.2.2.2 Place the specimen a minimum of 5 cm from any object that may introduce error into the measurement.

4.2.2.3 Measure and record the requested parameter values over the specified test frequency range or discrete frequencies. If the equipment does not have the capability to display the requested parameter directly, see the applicable clause of 1.3 for conversion equations.

4.2.2.4 If requested, repeat 4.2.2.1 through 4.2.2.3 on multiple lines throughout the specimen.