

Connectors for electronic equipment — Tests and measurements —

Part 25-7: Test 25g — Impedance, reflection coefficient and voltage standing wave ratio (VSWR)

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National foreword

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**Connectors for electronic equipment –
Tests and measurements
Part 25-7: Test 25g –
Impedance, reflection coefficient
and voltage standing wave ratio (VSWR)
(IEC 60512-25-7:2004)**

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et rapport d'ondes stationnaires
en tension (VSWR)
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European Committee for Electrotechnical Standardization
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Foreword

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The text of the International Standard IEC 60512-25-7:2004 approved by CENELEC as a European Standard without any modification.

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CONNECTORS FOR ELECTRONIC EQUIPMENT – TESTS AND MEASUREMENTS –

Part 25-7: Test 25g – Impedance, reflection coefficient, and voltage standing wave ratio (VSWR)

1 Scope and object

This part of IEC 60512 applies to interconnect assemblies, such as electrical connectors and cable assemblies, within the scope of IEC technical committee 48.

This standard describes test methods to measure impedance, reflection coefficient, 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 a 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 set up and perform the requested measurements.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1

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

2.2

specimen environment impedance

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

2.3

reflection coefficient

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

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

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.

2.4 impedance

total opposition that a circuit offers to the flow of alternating 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:

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

2.5 voltage standing wave ratio VSWR

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:

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

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

2.6 scattering parameter (s -parameter)

s_{11}
reflection coefficient at the input port of the device under test, defined as the ratio of the reflected voltage to the incident voltage

2.7 termination (electronics usage)

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

2.8 step amplitude

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

3 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 bandwidth = (0,35/rise time) should not be used without further computations and understanding.

3.1 Equipment

3.1.1 Time domain

3.1.1.1 A Time Domain Reflectometer (TDR) is preferred as the measurement accuracy is improved with the use of a step function, 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 mathematical operation performed by an instrument (for example, FFT).

3.1.1.2 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 mathematical operation performed by an instrument or software; for example, normalization or filtering.

3.1.1.3 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.

3.1.2 Frequency domain

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

NOTE 1 The test professional should be aware of the frequency limitations of the fixture.

NOTE 2 The test professional should be aware of any limitations of any mathematical functions performed (for example, normalization, inverse FFT, or software filtering.)

3.1.2.2 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.

3.2 Fixture

The fixture(s) shall allow for enough measurements throughout the specimen so 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 intended use of the product dictates the most meaningful way to fixture it.

3.2.1 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 Ω for single-ended measurements and 100 Ω for differential measurements.

3.2.2 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).

3.2.3 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.

3.2.3.1 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 end points at the same location as the DUT (device under test) starting point and end point. This is because the reference trace(s) length shall be the same as the pc board traces.

3.2.3.2 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 should incorporate features appropriate to that (these) calibration method(s).

3.2.4 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 Ω). 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.

3.2.5 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 Ω). 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.

4 Test specimen

4.1 Description

For this test procedure, the test specimen shall be as follows.

4.1.1 Separable connectors

A mated connector pair.

4.1.2 Cable assembly

Assembled connectors and cables, and mating connectors.

5 Test procedure

5.1 Time domain

5.1.1 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 3.2.3.1 for more detailed information).

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

5.1.3 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 ps	Measurement system rise time ps
100 – 500	100
>500 – 1 000	500
> 1 000	1 000

5.1.4 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 definition in Clause 2 for conversion equations.

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

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

5.1.7 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.

5.1.8 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 definition in Clause 2 for conversion equations. Refer to Figure A.2 for an example of a TDR plot, and Annex D for examples of interpreting TDR impedance graphs.

5.1.8.1 Single-ended measurement

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

5.1.8.2 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.

5.1.9 When required, vary the measurement system rise time and repeat 5.1.2 through 5.1.8. 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 (for example, normalization or software filtering).

5.1.10 If requested, repeat 5.1.5 through 5.1.9 for multiple lines throughout the specimen.

5.2 Frequency domain

5.2.1 General

5.2.1.1 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 3.2.3.2 for more detailed information).

NOTE The test professional is reminded that the calibration should be performed in the mode to be used for the measurements, for example, s_{11} .

5.2.1.2 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 is not capable of displaying the requested parameter directly, see the applicable definition in Clause 2 for conversion equations.

5.2.2 Specimen measurement – Direct method

5.2.2.1 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.

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

5.2.2.3 Measure and record the requested parameter values over the specified test frequency range or discrete frequencies. If the equipment is not capable of displaying the requested parameter directly, see the applicable definition in Clause 2 for conversion equations.

5.2.2.4 If requested, repeat 5.2.2.1 through 5.2.2.3 on multiple lines throughout the specimen.

5.2.2.5 When additional measurements with different test frequencies or ranges are required, perform the calibration step defined in 5.2.1.1, then repeat 5.2.2.1 through 5.2.2.4 as necessary.

5.2.3 Specimen measurement – Open/short method

5.2.3.1 Connect the analyzer line(s) to the driven line(s) of the fixture with the specimen installed.

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