



ASSOCIATION CONNECTING
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IPC-TM-650 TEST METHODS MANUAL

1 Scope This procedure outlines a test method to determine the permittivity (dielectric constant or E') and loss tangent (dissipation factor or $\tan\delta$) of printed wiring materials at various frequencies (from 1 MHz to 1.5 GHz) using a single test fixture for the measurement.

The permittivity and loss tangent are measured using a narrow sweep of frequency around the target or desired frequency. The test method is built around the capability of currently available materials analyzers, which use a capacitance method to determine permittivity.

This test method is not intended for low loss materials, such materials may be tested at fixed frequencies using other IPC test methods.

2 Applicable Documents

HP 4291A-5 Product Note "Dielectric Constant Evaluation of Rough Surface Materials," which describes how to make accurate measurements using the HP 4291A and HP 16453A.

HP Application Note 380-1 "Dielectric Constant Measurements of Solid Materials," which contains a technical background, suitable for this subject.

3 Test Specimen

3.1 Each specimen shall be 50 mm x 50 mm by the thickness of the substrate material. Within the limits of the test fixture, the thicker the sample the less error in the measurements. Multilayer samples can be used to increase the thickness of the sample, but these cannot be simple stacked layers; they must be physically bonded with no air gaps between the layers. A target thickness would be 1.0 mm, but both thinner and thicker samples will work.

3.2 Three specimens are required for this test.

3.3 All materials are affected by moisture, including all reinforced laminates and most films. Therefore, all samples shall be conditioned at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and $50\% \text{ RH} \pm 5\% \text{ RH}$ for a minimum of 24 hours prior to testing. However, if a sample has recently been etched or exposed to excessive moisture, it should be dried in an air-circulating oven for two hours at $105^{\circ}\text{C} +5^{\circ}\text{C}$, -2°C prior to testing and conditioned at room temperature as mentioned above.

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3.4 Sample Surface Preparation

3.4.1 It is preferred that the sample be patterned with a conductive material in the shape and size of the test electrode. This conductive material is preferably 100 angstroms of vapor deposited copper. Other metals may be used. In all cases, the conductor on the sample must make good electrical contact with the fixture electrode. Such a conductive pattern eliminates air gaps and other potential sample mounting errors.

3.4.2 Bare dielectric materials may be tested with this test method. The fixture electrodes must be applied with some level of force to ensure a gap-free contact area. Determining the correct force setting may require some trial and error testing for each type of sample (see 6.4).

4 Equipment/Apparatus

4.1 The Hewlett-Packard Impedance Material Analyzer, model 4291A, or equivalent is recommended.

4.2 Hewlett-Packard model number 16453A test fixture, or equivalent

4.3 An appropriate calibration-verification kit and a fixture-correction kit as recommended in the instrument's manual (i.e., HP4291A Calibration kit). Such a kit usually includes the following devices:

- OPEN and SHORT for fixture correction
- 50 Ohms impedance
- Dielectric (PTFE) of known characteristic for the purpose of the calibration verification

4.4 Micrometer, capable of 0.001 mm resolution

4.5 Circulating oven capable of $105^{\circ}\text{C} +5^{\circ}\text{C}$, -2°C

5 Procedure

5.1 Calibrate the instrument using the calibration kit according to the recommendations of the instrument manufacturer.

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Full document details: IPC TM-650 2.5.5.9 1998

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Calibrations only last 24 hours, so calibration shall be performed within 24 hours of the measurement. See 6.1 for more calibration notes.

5.2 Set up the unit to sweep the target frequency $\pm 0.5\%$ of the target.

5.3 Measure the sample thickness with the micrometer and insert into the test fixture. The sample must make good contact with the fixture electrodes (see 6.1 concerning the proper force to be applied). The sample must not touch the back wall of the fixture. The sample electrode placement and thickness measurement shall be obtained from the same area of the sample.

5.4 Run the test and record the average permittivity and loss over the narrow frequency range sweep. The scanned data may also be saved on disk. See 6.2 for comments on expected behavior for permittivity as a function of frequency.

5.5 Repeat 5.1 through 5.4 for all desired frequencies.

5.6 Report the average permittivity and loss at the frequencies requested.

6 Notes

6.1 Correct calibration and operation of the test equipment is required to obtain accurate measurement of permittivity and loss. Proper sample preparation is also very important for obtaining useful data from this test. Calibrate the materials analyzer in accordance with manufacturer's instructions. An automatic program has been developed for the HP 4291A, which will ease calibration and setup (see 6.6).

6.2 The permittivity should decrease slightly with increasing frequency. If it increases greatly or decreases more than 0.2 units from approximately 20 MHz to 1.2 GHz, reposition (reset) the sample in the fixture and measure again (check for debris between the electrodes; blow out with air).

6.3 Testing at temperatures and humidities other than room temperature may be performed with this instrument, as a specialized fixture can be placed in a temperature chamber. A temperature chamber must be used when testing with this fixture under conditions where condensation might contaminate the electrodes, as such contamination gives spurious results.

6.4 The pressure of the test fixture on the specimen affects the measured permittivity and loss values, in particular for un-metallized test specimens. Too light of pressure reduces the area of electrode/sample contact, thus leaving air gaps, which result in erroneous measurements. If the pressure is too high, the sample can be reduced in thickness and the measured values would be incorrect because the thickness is unknown. Making measurements while adjusting the force should lead the operator to a force setting where the measured value is independent of the force applied.

6.5 The HP 4291 Materials Analyzer and related fixtures and calibration kits are available from Hewlett Packard, (800) 452-4844.

6.6 Reference Program for Automatic Calibration and Operation This automatic calibration and operation program was developed for the HP 4291A and is published in this method as a reference. Although the program listed in this section has been tested and used, it is given here for "reference only."

6.6.1 Procedure Using Automatic Program Turn on the analyzer with the program/calibration disk in the drive and follow the user friendly calibration instructions, which appear on the monitor. The calibration on the HP4291 lasts about 24 hours; after that, it begins to drift and provides slightly higher values as a function of time. The calibration procedure in 6.6.1.1 through 6.6.1.10 should therefore be performed, at a minimum, on a daily basis. During the calibration procedure, the line traces on the monitor should be observed during each step. Noisy or erratic traces are an indication of external interference. If noise is observed, the calibration procedure should be aborted and rerun. Clean the electrode on the test head, standards, and fixture connections and electrodes on a regular (weekly) basis. Blow dry.

6.6.1.1 Allow at least 30 minutes for the unit to warm up and stabilize.

6.6.1.2 As the unit is a frequency sweeping unit, enter the start and stop frequency (in megahertz) of the test (single frequency tests use close start/stop frequencies, which should be $\pm 0.5\%$ of the target frequency).

6.6.1.3 Place the OS (open) calibration standard on the test head as prompted on the unit's monitor and press Return on the unit's keyboard or "x1" on the unit.