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IPC-TM-650
TEST METHODS MANUAL

Number	
2.5.18	
Subject	
Characteristic Impedance Flat Cables (Unbalanced)	
Date	Revision
7/84	**B**
Originating Task Group	

1 Scope This method describes the test procedures required to measure the characteristic impedance of flat cables.

To keep this test method as simple and straightforward as possible, balanced and differential signal lines are not addressed. Also, the effect of flat cable against a ground plane is not shown, because of the difficulty in determining what a lab standard ground plane should be.

1.2 General Characteristic impedance (Z_o) for high frequency pulses is defined electrically as the square root of the inductance divided by the capacitance (C). In equation form:

$$Z_0 = \sqrt{\frac{L}{C}}$$

Accuracy and consistency of impedance is required to match the characteristics of the other electronic circuit components. Variations and mismatches in impedance create undesirable pulse reflections and pulse distortions. These reflections and distortions increase attenuation and crosstalk. The characteristic impedance of flat cables is primarily dependent upon the dielectric properties of the insulation and the cable geometry. It is directly proportional to conductor spacing and is inversely proportional to conductor size and the effective dielectric constant of the insulation. Therefore, consistency of impedance is achieved by maintaining uniformity of the insulation dielectric constant and by maintaining accurate control over conductor dimensions and spacing of adjacent conductors.

Characteristic impedance (Z_o) is usually measured by time domain reflectometry (TDR).

Measurement of Z_o with a TDR consists of sending a pulse down a length of cable and then comparing the reflection obtained to that obtained from a laboratory standard of known impedance. Z_o of a cable is fully defined when three values have been measured:

1. The average Z_o for all signal lines in a length of cable when the cable is suspended in air.
2. The maximum change in impedance (or reflection coefficient) at any point on any signal line of the cable when the cable is suspended in air.
3. The maximum change in impedance when the cable is clamped against a ground plane.

Measurement of the preceding values is performed by use of the setup illustrated in Figure 1. The laboratory standard is connected to the TDR generator output, and the cable with unknown Z_o is connected to the end of the laboratory standard. When a single-ended (unbalanced) cable is to be tested, connection to the laboratory standard consists of (1) the cable signal conductor to the laboratory-standard signal conductor, and (2) the ground conductors associated with the cable signal conductor to the laboratory standard ground. The far end of the cable may be left unterminated, or it may be terminated with a precision resistor to verify the laboratory standard. Balanced cable (which carries simultaneous positive and negative pulses) cannot be directly tested for impedance in this manner; however, a close approximation can be achieved by selecting an axis of symmetry between two signal conductors and then testing only one signal conductor and its associated ground conductor.

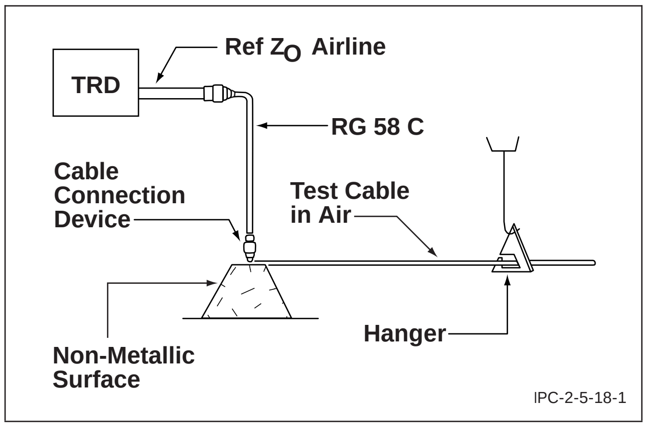

Figure 1 TDR Test Set-up for Measuring Characteristic Impedance

The typical oscilloscope trace obtained when testing a cable is illustrated in Figure 2.

3 Test Specimen

3.1 One pre-production or production sample 0.9 m to 3 m long. The number of test samples should be determined by the manufacturer and/or user.

4 Equipment/Apparatus

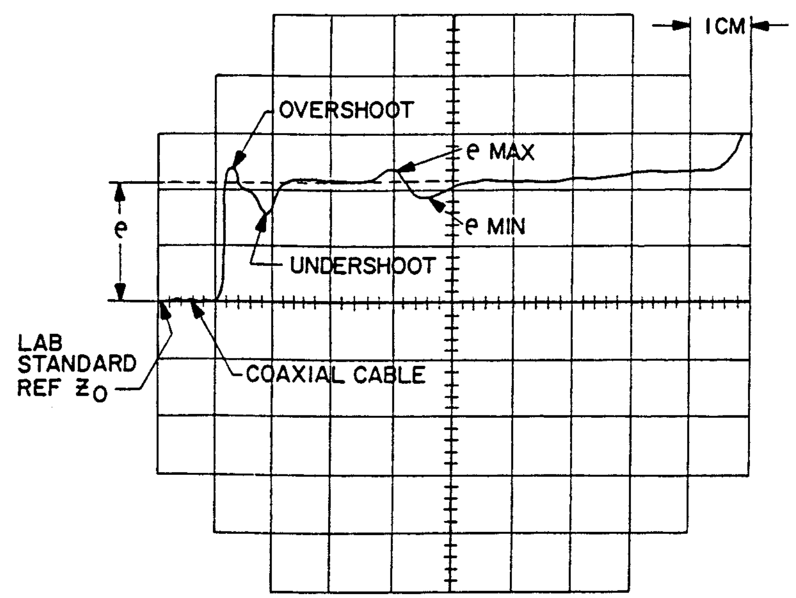

Figure 2 TDR Trace for a Typical Cable

4.1 In this test, characteristic impedance is measured by TDR. Commercial TDRs are readily available and consist of pulse generator and sampling oscilloscopes. Rise times of the pulses are usually less than 250 picoseconds (250 x 10-12 sec.), which gives a resolution sufficient to detect discontinuities smaller than 2.5 cm in length. Since the pulse rise times generally used now in electronic equipment are not this fast, a TDR is adequate for testing. Also required for this test is a lab standard air line to establish a reference impedance (Z_o ref.) and a standard cable connection device at the air line output (see Figure 1).

4.2 A TDR, such as a Hewlett-Packard 1415A, Hewlett-Packard 1815A, Tektronix 1 S2, or equivalent

4.3 The standard air line used should be a General radio 874-L20 (20 cm), 874-L30 (30 cm), or equivalent for Z_o = 50Ω.

4.4 Cable Holders Fixture of plexiglass or other nonmetallic material. Cable hangers to suspend the cable in air. Refer to Figure 3.

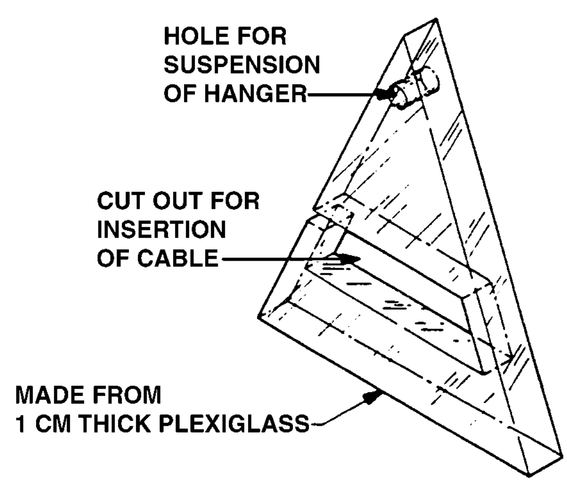

Figure 3 Sample Cable Hanger

4.5 The standard cable connection device used should match Figure 4. It is made from a General radio cable connector type 874-C62A.

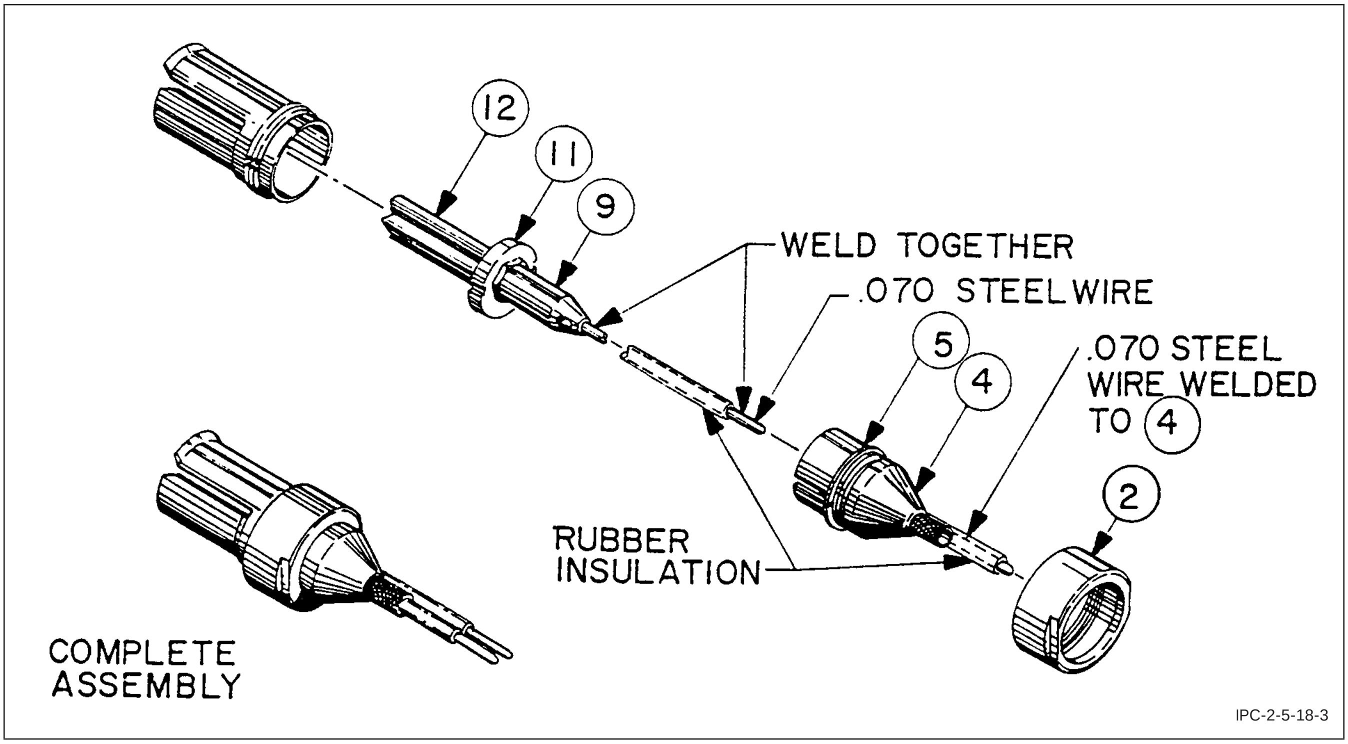

Figure 4 Cable Connection Device. Refer circled items to parts list. Made from General Radio Co. Type 874-C62A.

4.6 Coaxial Cable Impedance: 50 - 2Ω RG-58A, RG-58C, or equivalent; Termination: GR874 connectors, both ends; Length: approximately 61 cm

4.7 Load General Radio type GR874 or equivalent 50Ω load. This is an optional item, which is used to calibrate the TDR.

5 Procedure

5.1 Allow a minimum of one hour for TDR warm-up and calibrate the instrument per manufacturer's instructions.

5.2 Prepare the test specimen by stripping approximately 13 mm of insulation from one end of cable. Separate the ground and signal conductors and solder a copper buss across the grounds (see Figure 5).

5.3 Adjust the TDR settings as follows:

Vertical: 0.1 e/cm
Distance/time: 20 ns/cm.
Magnifier: 50 x (For equipment other than Hewlett-Packard, use settings as close as possible to these.)

Insert the 30 cm air line into the output of the TDR. This will serve as the 50Ω reference. Attach the coaxial cable to the air line and terminate with the impedance probe. Vertically center the 50Ω reference line on the TDR graticule.

5.4 Press the probe against the conductor to be tested insuring the ground of the probe is against the cable ground (see Figure 5) and check the vertical placement of the 50Ω reference; re-center if necessary.

5.5 Adjust the distance/time magnifier to 5 or 10 and rotate the magnifier delay dial until the total length of the cable is visible on the screen. Measure the vertical reflection coefficient (e) in cm as illustrated in Figure 2.

5.7 Calculate the characteristic impedance (Z_0) as follows:

$$Z_0 = 50\left(\frac{1+e}{1-e}\right)(\Omega)$$

Calculate Z_0 of the cable measuring as shown in Figure 2. Calculate Z_0 max., $e = e$ max; Z_0 min., $e = e$ min.

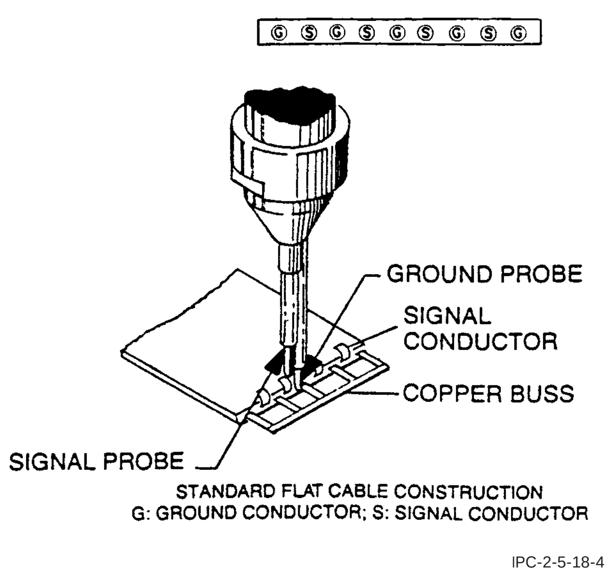

Figure 5 Connection of Impedance Probe to Sample under Test

6 *Notes*

6.1 The TDR employs a pulse rise time less than 250 picoseconds. A pulse of this rise time is extremely rich in harmonics extending well into the GHz region of the frequency spectrum. The impedance probe illustrated in Figure 1 is designed to minimize the effects of impedance mismatch at the connection; therefore, it is suggested that a probe of this type be used for the impedance measurement. The importance of a good connection between the cable under test and the TDR can not be overemphasized.

Cables longer than 3 m in length may be tested, but care must be exercised so as not to confuse the effect of increased wire resistance with an apparent increase in impedance as the magnifier delay dial is rotated to observe the longer cable length (function of attenuation, which includes wire size).

6.2 Under no circumstances should the cable be tested while in a coiled form due to the effect of increased inductance.

6.3 Keep cable a minimum of 15 cm away from any dielectric or ground plane including metal, wood, etc. (except in step 5.5).

6.4 Measurement of Z_o of unknown cable length should be made as close as possible to the cable connection device (after overshoot and undershoot).

6.5 The reference Z_o cable may be positioned after the RG58C cable and before the cable connection device. Therefore, the reference Z_o is adjacent to the test cable on the TDR trace.