ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

2215 Sanders Road
Northbrook, IL 60062-6135

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_0) 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_0) is usually measured by time domain reflectometry (TDR).

Measurement of Z_0 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_0 of a cable is fully defined when three values have been measured:

1. The average Z_0 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_0 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.

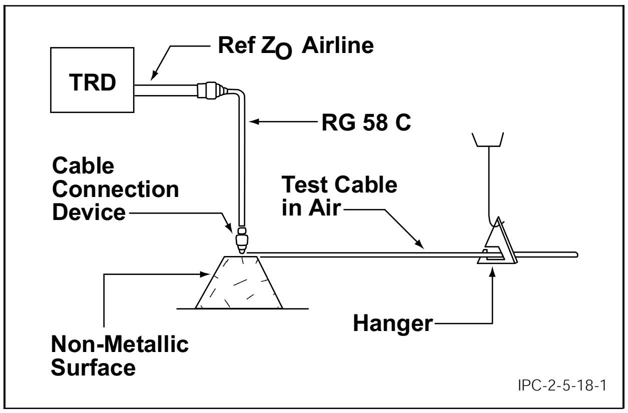

Figure 1 TDR Test Set-up for Measuring Characteristic Impedance

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

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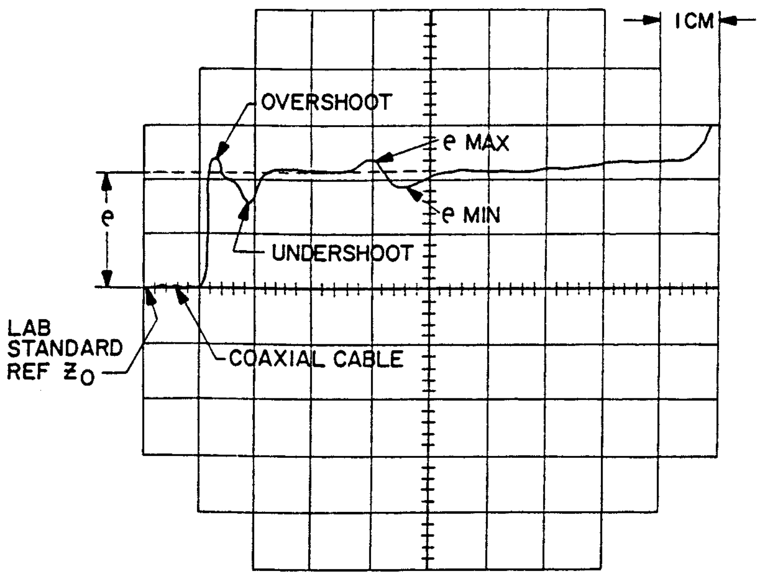

Figure 2 TDR Trace for a Typical Cable

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_0 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_0 = 50Ω.

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

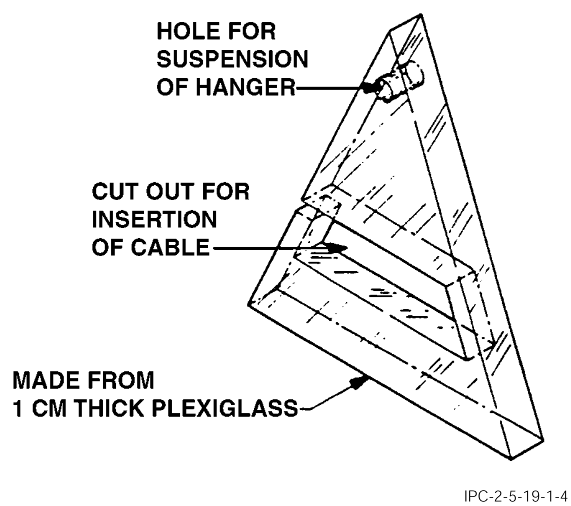

Figure 3 Sample Cable Hanger

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

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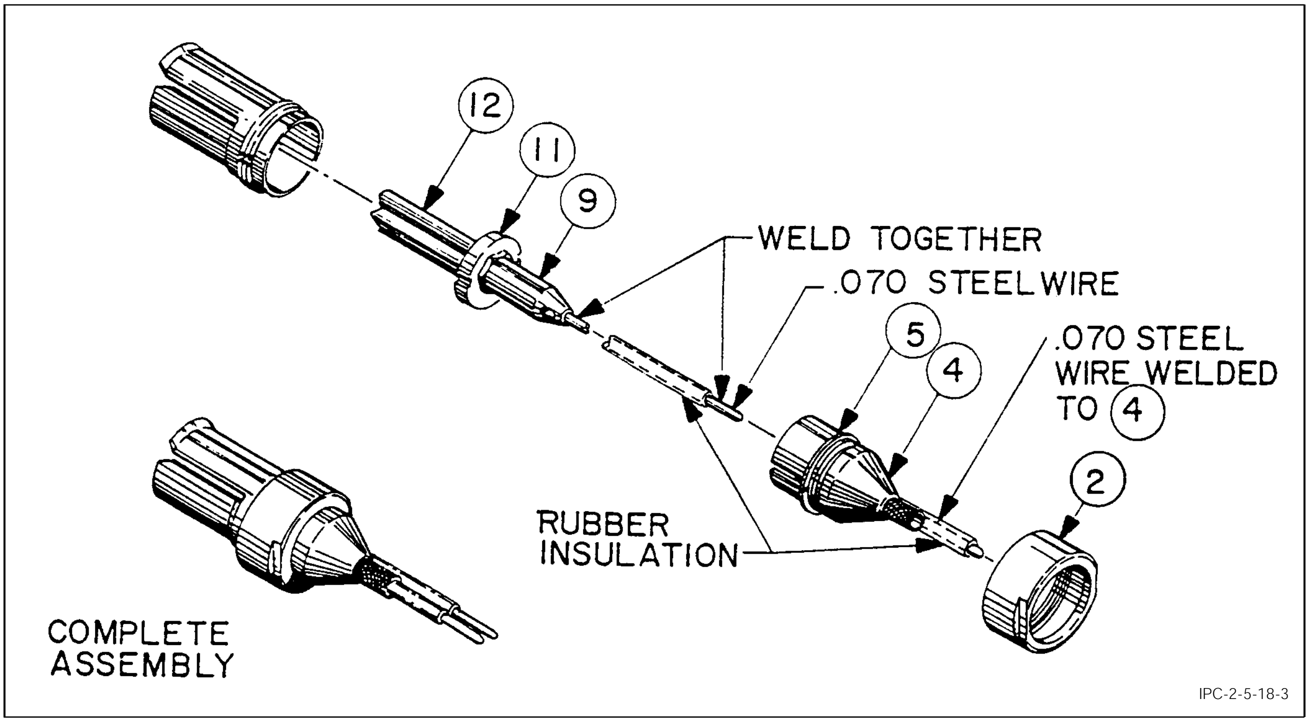

Figure 4 Cable Connection Device. Refer circled items to parts list. Made from General Radio Co. Type 874-C62A.

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.

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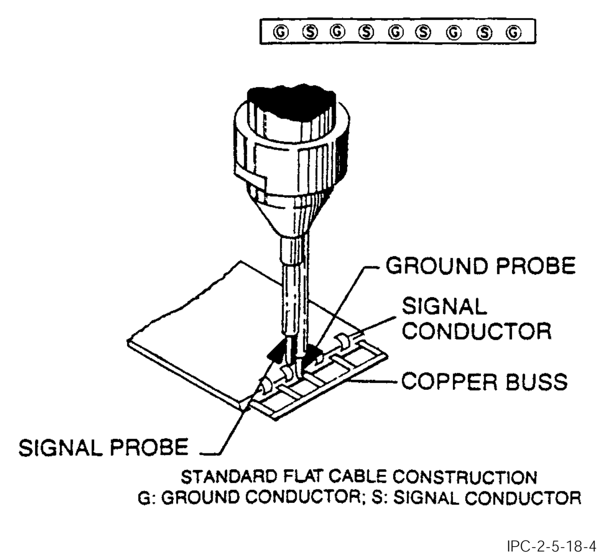

Figure 5 Connection of Impedance Probe to Sample under Test

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_0 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_0 cable may be positioned after the RG58C cable and before the cable connection device. Therefore, the reference Z_0 is adjacent to the test cable on the TDR trace.

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TEST METHODS MANUAL

Number	
2.5.19	
Subject	
Propagation Delay of Flat Cables Using Time Domain Reflectometer	
Date	Revision
7/84	A
Originating Task Group	

1 Scope This method describes the test procedures required to measure propagation delay in flat cables. Propagation delay is defined as the time required for a pulse to traverse a unit length of cable. Excessive propagation delay will result in the malfunction of critical circuits due to the late arrival of pulses. Propagation delay is directly proportional to the effective dielectric constant of the insulation.

2 Applicable Documents None

3 Test Specimen

3.1 One pre-production or production sample 1 m to 3 m long. The number of test samples should be determined by the manufacturer and/or user.

4 Apparatus

4.1 In this test, propagation delay is measured using time domain reflectometry (TDR). Commercial TDRs are readily available and consist of a pulse generator and sampling oscilloscopes. The TDR to be used should be a Hewlett-Packard 1415A, Hewlett-Packard 1815A, Tektronix 1 S2 or equal.

4.2 Two standard cable connection devices to terminate each end of the test cable, which should match Figure 1. It is made from a General Radio cable connector type 874-C62A.

4.3 A 509 load, type GR874 or equivalent, to terminate the output of the TDR

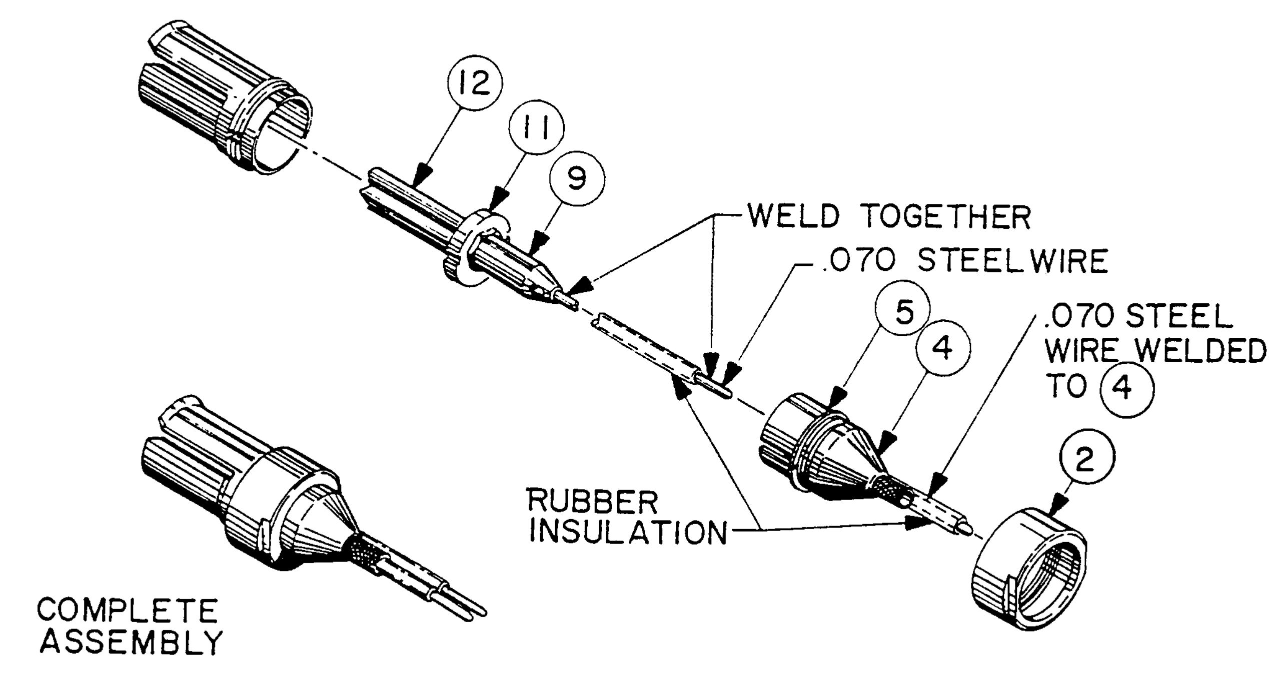

Figure 1 Cable Connection Device

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4.4 Fixture of plexiglass or other nonmetallic material. Cable hangers to suspend the cable in air (see Figure 2)

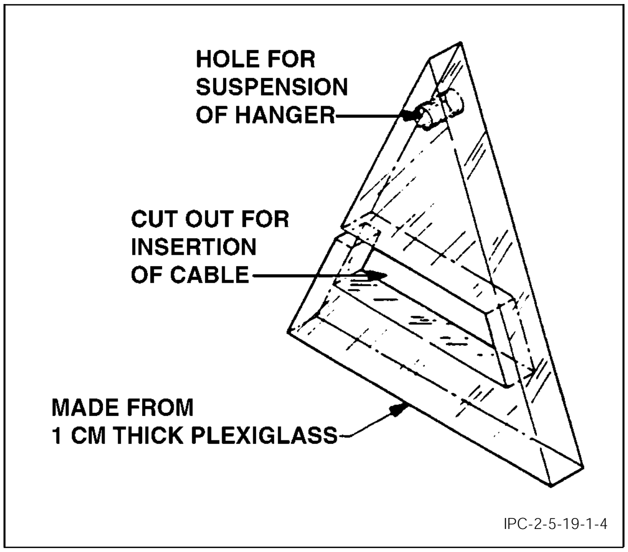

Figure 2 Sample Hanging Device

5 Procedure

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

5.2 Prepare the test specimen by stripping approximately 13 mm of insulation from both ends of the cable. Separate the ground and signal conductors and solder a copper buss across the grounds of each end (see Figure 3). Solder a standard cable connection device to each end of the cable (see Figure 4).

5.3 Adjust the TDR settings as follows: Vertical-0.2 p/cm; Distanceltime-20 ns/cm; Magnifier-10X. (For equipment other than Hewlett-Packard, use settings as close as possible to these.)

5.4 Terminate TDR output using the 509 load.

5.5 Adjust the magnitude delay dial so the 50Ω termination is visible and positioned to the left on the screen. Adjust the vertical position so the pulse trace leading edge crosses the horizontal graticule center line at 10% of pulse height (see Figure 5). Mark the position of the leading edge of the pulse on the horizontal graticule (mentally or by camera). If a camera is used, don't advance the film; a second exposure will be made in 5.8.

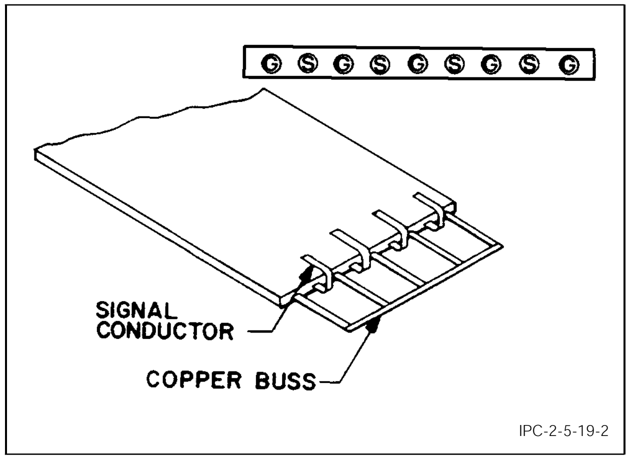

Figure 3 Cable Preparation

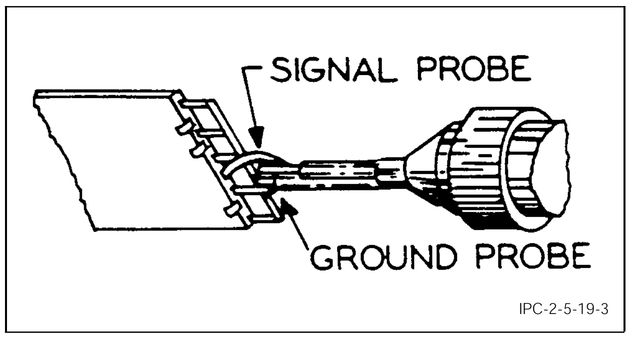

Figure 4 Cable Connection

5.6 Remove the U section of coaxial GR connectors connecting the step out and signal in. Position each L connector (made from the U connector) in the ''STEP OUT'' and ''SIGNAL IN'' connectors.

5.7 Connect the test specimen, one end to the ''Step Out'' and the other end to ''Signal In'' (see Figure 6).

5.8 The trace on the TDR screen will have moved to the right from its original position in 5.5. Mark the position of the leading edge of the pulse on the horizontal graticule (again at 10% of pulse height). At this time, a second exposure on the same film used in 5.5 can be made. This will result in both traces on one film. The distance between this mark and the mark in 5.5 is the measured propagation delay (TD). Multiply the measured T_D by 20 (distance/time set at 20 ns/cm), then

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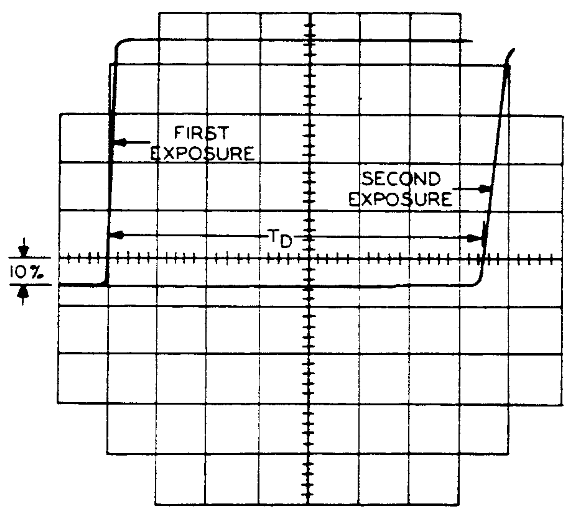

Figure 5 Dual Exposure Picture TDR Trace

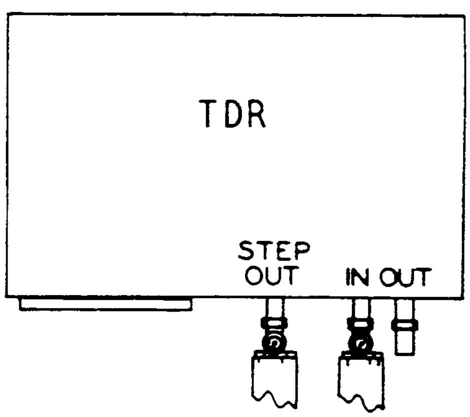

Figure 6 Test Cable Hookup

divide the result by 10 (distance/time magnifier set at 10) to get the total T_D of the test specimen. Subtract 0.20 ns x 2 = 0.40 ns delay caused by the connection device used at each end of the test cable and divide this result by the exact length of the test specimen to get the propagation delay in ns/0.3 m.

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TEST METHODS MANUAL

Number	
2.5.19.1	
Subject	
Propagation Delay of Flat Cables Using Dual Trace Oscilloscope	
Date	Revision
7/84	**A**
Originating Task Group	

1 Scope This test method describes the test procedures required to measure propagation delay in flat cables. This test method is an alternative to IPC-TM-650, Method 2.5.19. Propagation delay is defined as the time required for a pulse to traverse a unit length of cable. Excessive propagation delay will result in the malfunction of critical circuits due to the late arrival of pulses. Propagation delay is directly proportional to the effective dielectric constant of the insulation.

2 Applicable Documents

IPC-TM-650 Test Methods Manual

2.5.19 Propagation Delay of Flat Cables Using Time Domain Reflectometer (TDR)

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

4.1 Oscilloscope: Tektronix 7623 with a 7B53A dual time base, or equivalent.The oscilloscope is dual time based, triggered by the pulse generator, and capable of accuracy to 5 ns/div.

4.2 Pulse generator: Tektronix PG501, Hewlett-Packard 8013B, or equivalent. The pulse characteristics from the pulse generator should be determined by the manufacturer and/or user.

4.3 Oscilloscope test probes, preferably high speed, with matched propagation delay

4.4 Cable holder: Fixture of plexiglass or other nonmetallic material

4.5 Cable hangers to suspend the cable in air (see Figure 1)

4.6 A termination resistor equal to the characteristic impedance of the test specimen is required to terminate the output end of the cable. When oscilloscope probes are attached to the cable, the termination resistance (RT) has to be calculated:

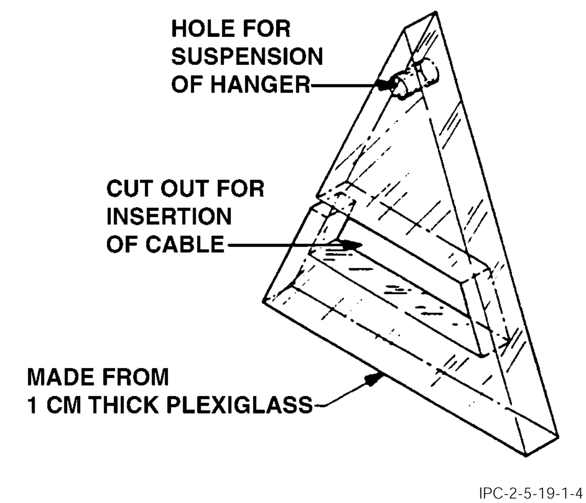

Figure 1 Sample Cable Hanger

$$R_T = \frac{R_{PROBE} + Z_{oCABLE}}{R_{PROBE} - Z_{oCABLE}}$$

4.7 An input resistor is required in series between the pulse generator and the test specimen (only) when the characteristic impedance of the cable is equal to or less than the output impedance of the pulse generator. In this case:

Input Resistance = $Z_{oGENERATOR} - Z_{oCABLE}$

4.8 Standard cable connection device matching Figure 2. It is made from a General Radio cable connector type 874-C62A (propagation delay 0.2 ns).

4.9 A 50Ω General Radio to BNC female adaptor is required to connect the pulse generator to the test specimen.

5 Procedure

5.1 Allow one hour for the test equipment to warm up. Connect the pulse generator Trig output to the oscilloscope main Trig in. Set the pulse generator output pulse characteristics as specified for the test. Hook up both test probes from each oscilloscope input to the single pulse generator output. Adjust the scope sweep rate to 5 ns/div and view both channels.

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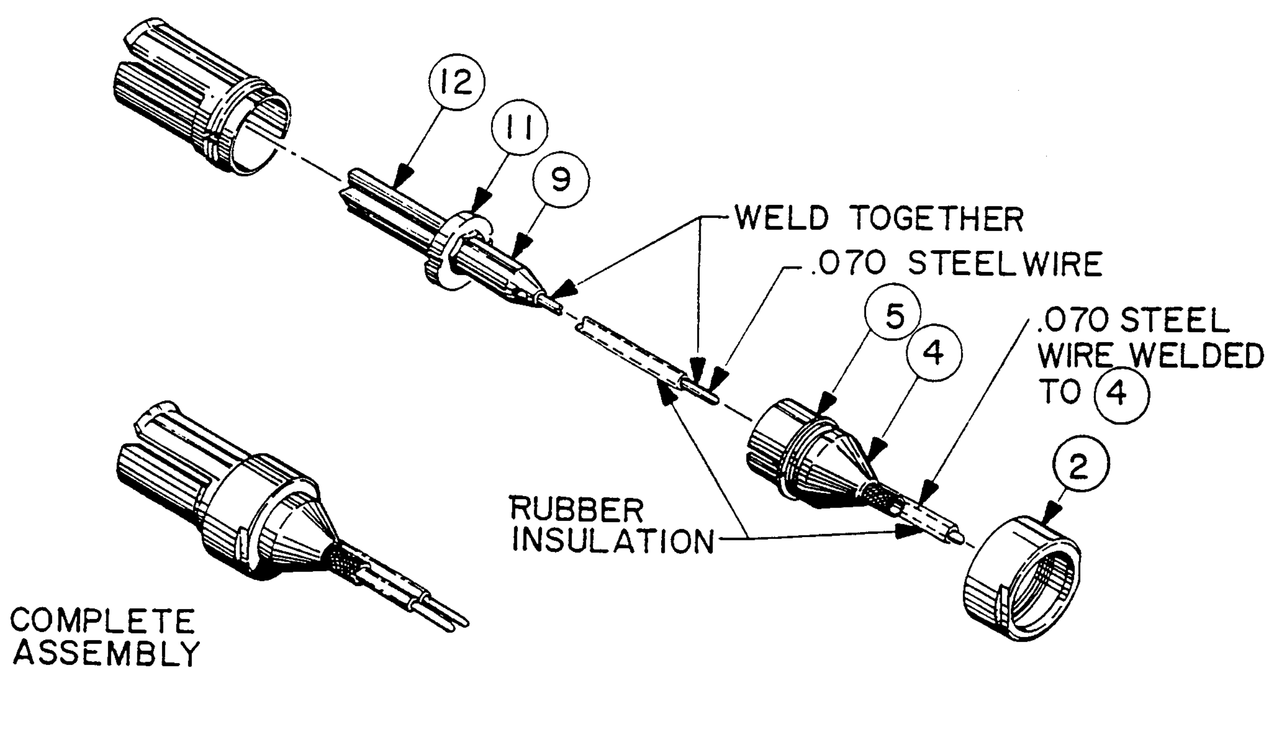

Figure 2 Cable Connection Device

There should be no time delay difference between the channels caused by the probes. If there is any delay, it should be noted and added to the final T_D calculation.

5.2 Prepare the test specimen by stripping approximately 13 mm of insulation from each end of the cable. Separate the ground and signal conductors and solder a copper buss across the grounds (see Figure 3). The exact length of the cable should be noted.

5.3 Solder the termination resistor from signal lead to ground buss at the output end of the cable.

5.4 Solder the input resistor in series with the signal lead on the input end of the cable (only if required).

5.5 Solder the standard cable connection device to the test specimen signal-to-signal lead and ground-to-ground buss.

5.6 Connect the pulse generator to the GR to BNC adapter via a short length of coaxial cable. Connect the input end of test specimen to the adapter.

5.7 Connect the oscilloscope input probes to the test specimen, one at the input and the other at the output termination (see Figure 4).

5.8 Set the oscilloscope sweep rate at 5ns/div and view both channels on the CRT. Measure the distance between the leading edge (at 10% pulse height) of each channel using the display graticule as a guide (see Figure 5). Divide the result by the cable length to get propagation delay in ns/0.3 m.

6 Notes

6.1 If using a small sample (0.9 m), the scope should be capable of accuracy to 1 ns/div.

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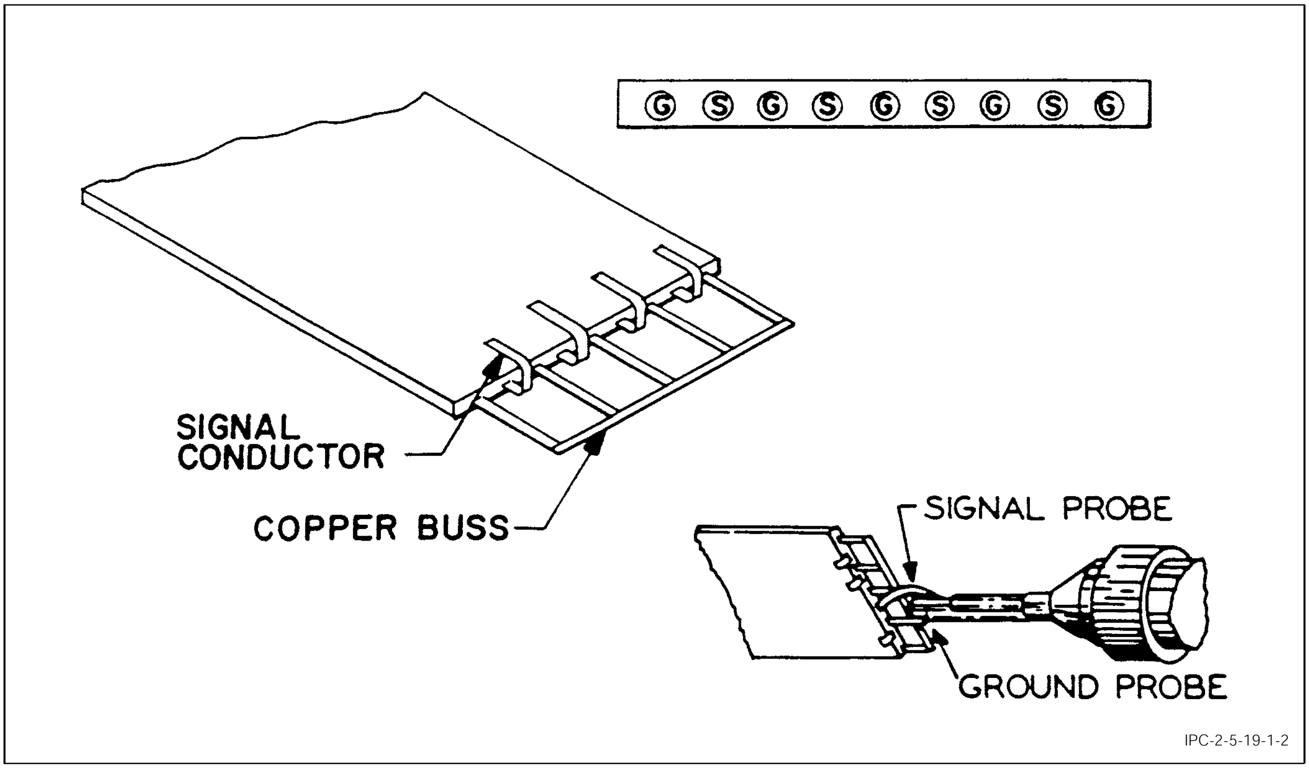

Figure 3 Cable Preparation and Cable Connection

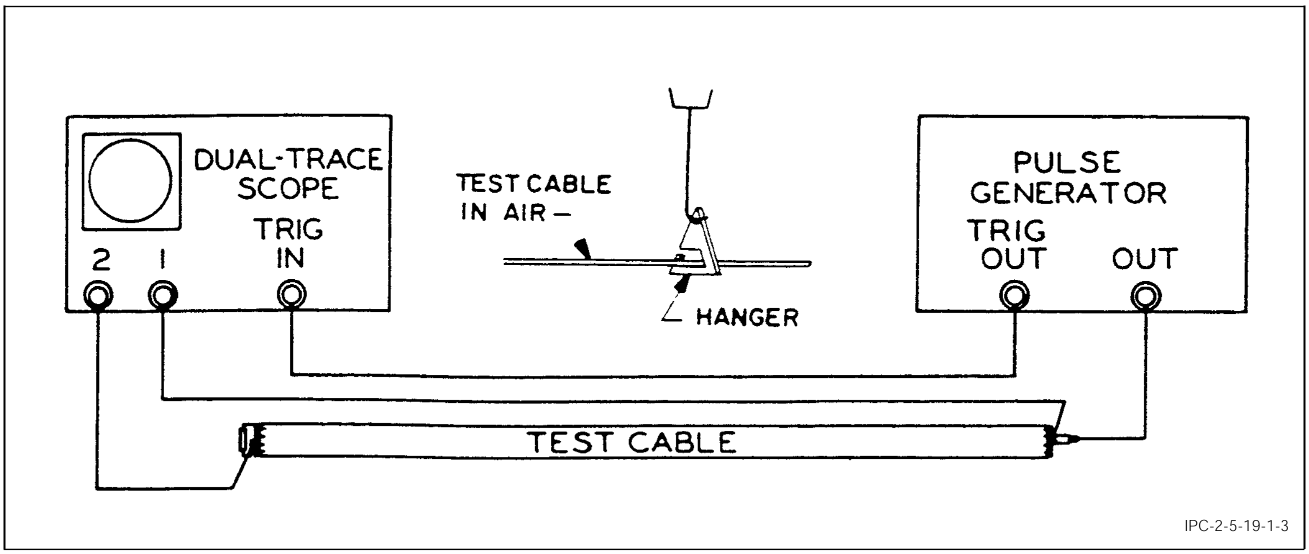

Figure 4 Test Cable Hookup

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