AN-757 Measuring Ethernet Tap Capacitance

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Measuring Ethernet Tap Capacitance

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Larry Wakeman
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INTRODUCTION

When a node is added to an Ethernet network, its nodal capacitance changes the impedance of the cable at the point of connection to the cable. The impedance change causes a reflection of the Ethernet waveform, which distorts the waveform. The more the capacitance the greater the distortion, and eventually with large enough node capacitances the Ethernet signal could become so distorted that the packet data would become corrupted when decoded by a network node. For this reason the IEEE802.3 standard specifies a maximum value of capacitance that a node may add to the network, as well as a minimum node to node distance spacing. Since the capacitance of a node includes stray inductances, the effective capacitance of a node connection cannot be measured simply by using a capacitance meter. This note presents the method for measuring capacitance of an Ethernet tap for 10BASE5 or a BNC "T" for 10BASE2.

THE STANDARD'S REQUIREMENTS

To properly make the measurement, it is important to understand how the standard specifies the capacitance of a node. To quote the IEEE802.3 standard:

8.3.1.1 Input Impedance: The shunt capacitance presented to the coaxial cable by the MAU circuitry (not including the means of attachment to the coaxial cable) is recommended to be no greater than 2 pF. The resistance to the coaxial cable shall be greater than 100 kΩ.

The total capacitive load due to MAU circuitry and the mechanical connector as specified in 8.5.3.2 shall be no greater than 4 pF.

These conditions shall be met in the power-off and power-on, not transmitting states (over the frequencies BR/2 to BR).

The magnitude of the reflection from a MAU shall not be more than that produced by a 4 pF capacitance when measured by both a 25 ns rise time and 25 ns fall time waveform. This shall be met in both the power-on and power-off, not transmitting states.

To summarize the maximum allowable capacitance specifications for both Thinwire and Thickwire Ethernet the following table is provided.

TABLE I. Maximum Capacitance Allowed in IEEE802.3

Standard	Electrical Circuitry	Mechanical Connector
10BASE5	2 pF	2 pF
10BASE2	4 pF	4 pF

Note: Thickwire or Thick Ethernet refers to 10BASE5 and Thinwire or Thin Ethernet refers to 10BASE2.

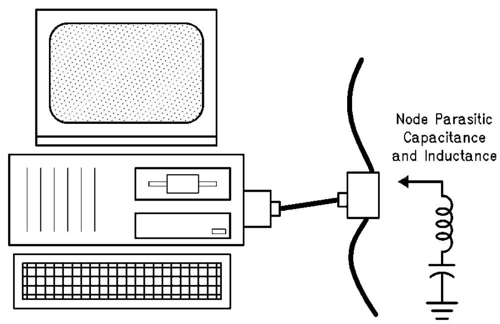

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FIGURE 1. Simple Model of the Parasitics Presented to the Ethernet Cable

THE TEST METHOD

Due to the nature of the capacitance of a DTE (Data Terminal Equipment), rather than perform a simple capacitive measurement using a meter, the capacitance of the network node is more accurately measured by testing it in an environment where the actual signal reflection caused by the capacitance of a node attachment is measured when applying a typical Ethernet signal. The magnitude of the reflection is then correlated to an equivalent capacitance. This is the most appropriate method, since it is the signal degradation due to the capacitive load that is the important consideration in defining the above specifications.

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With the above in mind, the test is performed by first measuring the reflection caused by the attachment of a node. Then the DTE is replaced with a reference variable capacitor, and the capacitor's value is adjusted until the capacitance that causes the same size reflection is determined. The capacitance of the node is therefore the same as the reference capacitance value that causes the same amplitude reflection.

TEST SETUP AND CABLE

An example test configuration which measures the capacitance of the Thickwire Ethernet is shown in *Figure 2.* The waveform applied to the test node is an important consideration in setting up the test, as it will affect the resultant value of capacitance. In particular the rise and fall times must be carefully chosen to reflect the capacitance seen in an Ethernet network, as described in the next section.

The cable lengths and spacing between the scope input and the transceiver's connection are chosen to ensure that the reflection due to the transceiver appears on the flat portion of the test waveform. This allows accurate measurement. The total cable length is equivalent to the full 10BASE5 length of 500m.

An oscilloscope is used to measure the voltage of the reflection. The scope, with a 1 MΩ input impedance, as shown in *Figure 2,* is connected directly to the cable without a probe. This eliminates any errors due to the probe. The distance between transceiver connection point "A" and the scope is set so that the reflections will arrive at the scope right after the signal rise and fall times. Moving point "A" any further makes the reflections smaller in amplitude (cable attenuation) and therefore harder to measure.

On the scope's display measurements are made at the point immediately after the rise time. Reflections are then compared to the ones for known discrete capacitors.

THE TEST WAVEFORM

In normal network operation the signal on the coax cable has rise and fall times of 25 ns ±5 ns (defined by the IEEE802.3 standard). With a purely capacitive load applying signals with faster (or slower) edges cause larger (or smaller) reflections than would be seen on a typical network. If the node were purely capacitive this would not affect the measurement. The larger (or smaller) node reflection for a given parasitic capacitance would track with the reference capacitance's reflection yielding accurate measurements.

However, the node is actually not a pure capacitance, but has some series inductance associated with the network connection as shown in *Figure 1.* The application of signals with faster than 20 ns rise and fall times actually result in an unrealistically low capacitance measurement. This is because the nodes capacitance is buffered by the stray series inductances which reduce the reflection magnitude when compared to the pure capacitance. This correlates to a lower than actual capacitance.

On the other hand applying very slow rise and fall times (slower than 30 ns) result in the measurement of a larger capacitance than actual. This is because the series inductance effects are less than would be seen with a nominal waveform.

Since it is desirable to measure the capacitance in such a way as to correlate to the effective capacitance seen when IEEE802.3 signaling is used, the best compromise choice is to select a 25 ns rise and fall times for this test. (This is the reason for this choice in the actual standard.)

Again, the reason behind this decision is that although the ≥ 30 ns edges indicate larger capacitances a signal with 25 ns edge produces results that more correctly represent the actual effect of the attached node's capacitance.

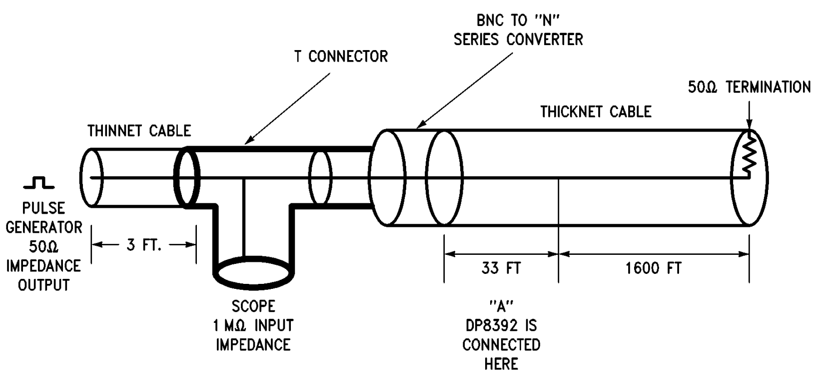

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FIGURE 2. Test Setup

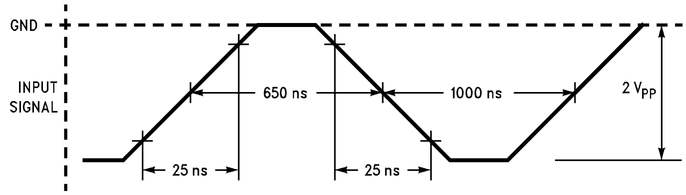
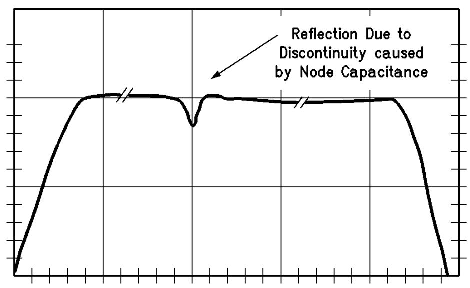


FIGURE 3. Input Test Waveform

As shown in *Figure 3,* a low frequency trapezoidal signal is used. This will keep the reflections from each edge of the signal well away from the next edge enabling easier measurement. The 2 V_{PP} test input signal is the typical voltage swing on the coax cable in normal operation. In the case of a discrete capacitor the voltage level of the signal may not be important. However, due to the non-linearity of the node and DP8392 capacitance a typical voltage signal should be used following the same rational as was used for the signal rise and fall times.



Note: This figure is conceptual. It does not show the waveform details.

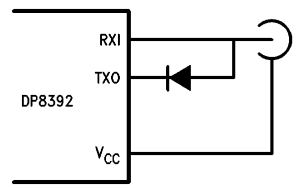
FIGURE 4. Example of Reflection

TEST RESULTS

A special jig was built to connect the ICs to point ''A'' in *Figure 2.* This greatly improves measurement repeatability. Data repeatability of 0.01 pF is achieved.

Typical data for RXI and TXO capacitances are 1.0 pF and 2.0 pF respectively. Total node capacitance can be reduced to around 1.6 pF with the addition of a small capacitance diode in series with the TXO output, as shown in *Figure 5.* For Ethernet applications two diodes in series can be used instead.

Thinwire



Thickwire

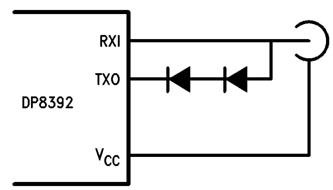


FIGURE 5. DP8392 Connection Diagram

INACCURACIES OF THE CAPACITANCE METER

As stated, in a real network, it is not the node capacitance that creates a problem, but too large a reflection caused by this capacitance. This reflection distorts the cable signal. Therefore the best method of test is to measure the reflection under true network waveforms. By the same analogy capacitance meters which have a test signal frequency that does not correspond to 25 ns rise and fall time do not reveal a true measurement of capacitance, and so capacitive measurements done only with a capacitance meter are usually (almost always) inaccurate to the true effective capacitance as seen by the network cable.

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2900 Semiconductor Drive
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Santa Clara, CA 95052-8090
Tel: 1(800) 272-9959
TWX: (910) 339-9240

National Semiconductor GmbH
Livry-Gargan-Str. 10
D-82256 Fürstenfeldbruck
Germany
Tel: (81-41) 35-0
Telex: 527649
Fax: (81-41) 35-1

National Semiconductor Japan Ltd.
Sumitomo Chemical Engineering Center
Bldg. 7F
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Chiba-City,
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Tel: (043) 299-2300
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13th Floor, Straight Block,
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Tel: (852) 2737-1600
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National Semiconductores Do Brazil Ltda.
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120-3A
Sao Paulo-SP
Brazil 05418-000
Tel: (55-11) 212-5066
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Fax: (55-11) 212-1181

National Semiconductor (Australia) Pty, Ltd.
Building 16
Business Park Drive
Monash Business Park
Nottinghill, Melbourne
Victoria 3168 Australia
Tel: (3) 558-9999
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