An Overview of the Electrical Validation of 10BASE-T, 100BASE-TX, and 1000BASE-T Devices

Application Note

The number of devices that come with a built-in network interface card has risen steadily and will continue to rise as more and more digital entertainment devices with networking capabilities are designed and sold. Devices with network interface ports now range from personal computers to closed-circuit cameras. This is a far cry from the day when a 10-Mbit/s port could be found only on high-end servers and networking equipment.

The technology used in these ports, commonly known as “LAN” or “NIC” ports, is usually one of the 10BASE-T, 100BASE-TX, and 1000BASE-T standards or a combination of them. These standards transmit 10, 100 or 1000 Mbit/s over UTP cable with an 8-pin RJ-45 connector. In this article, we will take a quick look at the electrical signals used in these technologies and how they can be probed for quick test and validation. This exploration will be useful for engineers involved in the electrical validation of the 10BASE-T, 100BASE-TX, and 1000BASE-T implementations in their devices.

10BASE-T

The long-lived 10BASE-T standard has been around since 1990 and is showing no signs of going away, even though it is considered obsolete by many. It provides 10-Mbit/s data transmission over two pairs of a Category 3 or 5 cable, one pair for transmit and the other for receive. The other two pairs of the cable are unused.

100BASE-TX

100BASE-TX is the most widely used version of 100-Mbit/s Ethernet (also known as fast Ethernet) over UTP cable. It uses the same pairs as 10BASE-T for transmit and receive but requires Category 5 or better cable.

1000BASE-T

1000BASE-T is the most common form of 1000-Mbit/s Ethernet (also known as Gigabit Ethernet) over UTP cable. It uses all four pairs of the UTP cable for both transmit and receive and requires Category 5e or better cable.

Figure 1 and Table 1 below describe the pin assignment of the 8-pin RJ-45 plug as used in a straight-through configuration.

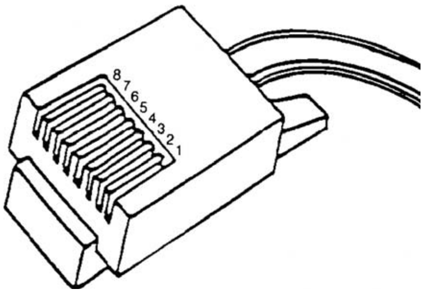

Figure 1. The 8-pin RJ-45 plug, also known as the 8P8C connector.

Pin	10BASE-T / 100BASE-TX	1000BASE-T
1	TD+	BI_DA+
2	TD–	BI_DA–
3	RD+	BI_DB+
4	Unused	BI_DC+
5	Unused	BI_DC–
6	RD–	BI_DB–
7	Unused	BI_DD+
8	Unused	BI_DD–

Table 1. The pin assignment for 10BASE-T, 100BASE-TX, and 1000BASE-T on the 8-pin RJ-45 plug in a straight-through configuration. TD/RD stands for transmit data/receive data. BI_D*x* stands for bi-directional pair *x*.

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Probing and Testing 10BASE-T Signals

10BASE-T transmits a differential signal, and the most straightforward method to probe the signals is with the TD+ and TD– pins connected to a 100 Ω resistive load as shown in Figure 2a. In addition to the 100 Ω resistive load, the standard specifies two additional loads to be used for testing. These two additional loads are illustrated in Figure 3. Apart from the direct connection from the TD circuit to the load, the standard also describes the use of a "twisted-pair model" (also known as TPM in short). The TPM is an equivalent circuit that models the distortion introduced by a simplex link segment, and is made up of 4 segments of RLC circuitry not shown here. Tests for some of the 10BASE-T parameters are done iteratively with and without the TPM and on loads 1 and 2 including the 100 Ω resistive load. This makes for a lot of tests!

Let us take a look at the 10BASE-T waveforms. There are typically four different types of waveforms that need to be used for testing. All the waveforms in this article will be based on the circuit in Figure 2a with a 100 Ω resistive load unless otherwise mentioned.

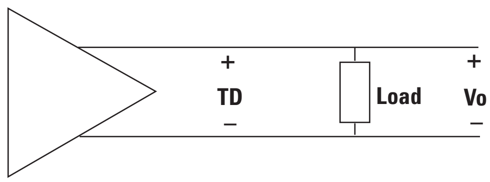

Figure 2a. The 10BASE-T TD circuit directly connected to the load. The output voltage Vo is measured across the load.

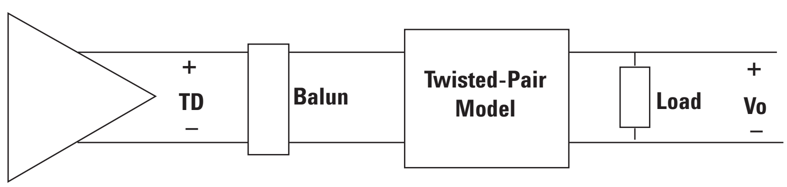

Figure 2b. The 10BASE-T TD circuit connected to the load through the twisted-pair model (TPM).

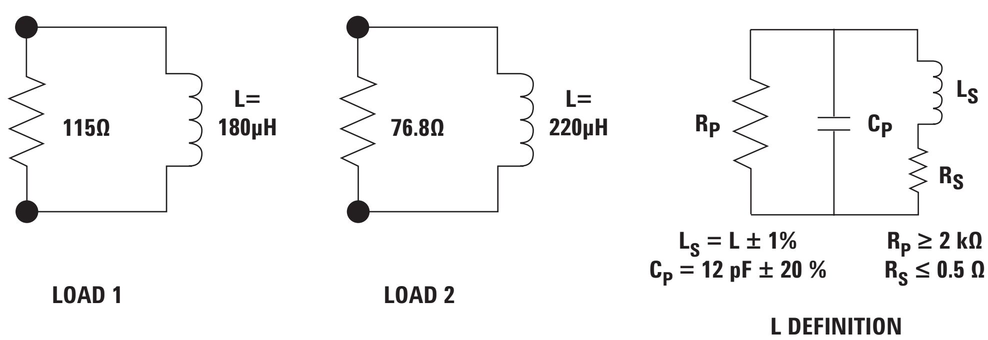

Figure 3. Loads 1 and 2, which are used to test 10BASE-T.

First is the LTP or link test pulse, also known as the NLP or normal link pulse. The LTP is the first signal transferred by the 10BASE-T transmitter and is used to indicate the presence of an active transmitter. If there is an active device at the end of the link, it responds with its own LTP. The LTP is also used in bursts to form data words where device capability data is exchanged during auto-negotiation. In all cases, the LTP has to fit within a defined template with all combinations of loads with and without the twisted-pair model.

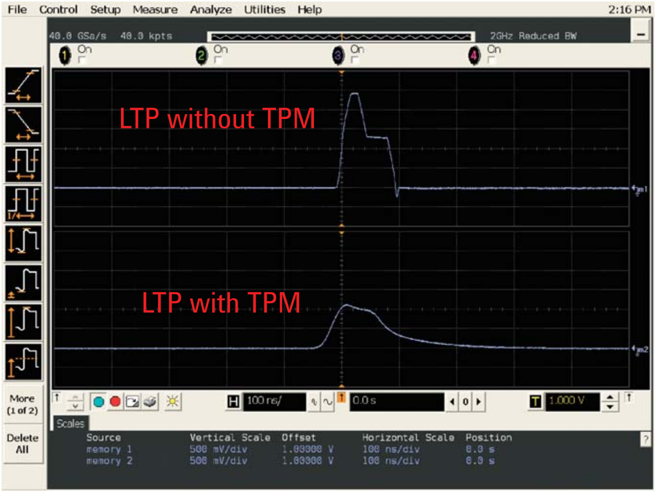

Figure 4. The link test pulse (LTP) waveform with and without the twisted-pair model.

Figure 5. LTP signal with TPM in the LTP template.

The next signal of interest is the TP_IDL signal. 10BASE-T data is transmitted in Manchester-encoded (transition indicates logical "1") data packets with a period of idle in between known as the interframe gap. The TP_IDL signal indicates the start of the idle period, and is therefore found at the end of each data packet. As with the LTP, the TP_IDL waveform also has to fit within a defined template with all combinations of loads with and without the twisted-pair model.

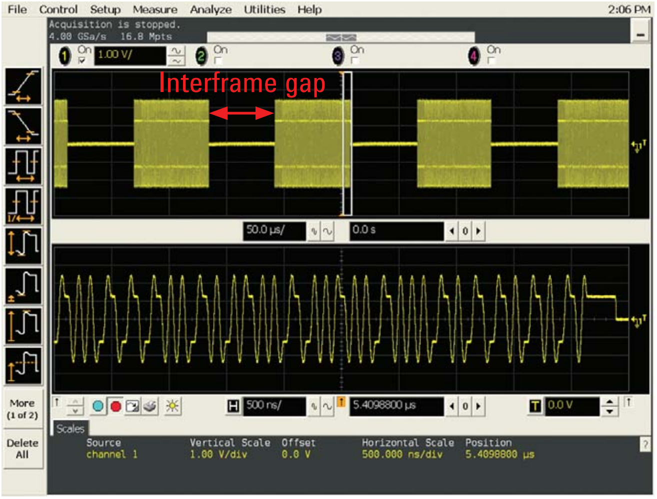

Figure 6. Manchester-encoded random data packets. The waveform displayed in the lower half of the screen is the zoomed-in area contained in the white box on the waveform in the upper half.

Figure 7. The TP_IDL is a positive-going pulse with a width of 300 ns or 350 ns depending on whether the last bit was one or zero respectively.

Figure 8. The TP_IDL

The signaling rate for 10BASE-T is nominally 10 MHz. An all-1's Manchester-encoded signal will result in a 10-MHz waveform. This all-1's waveform is used to test that all harmonics measured on the transmitting circuit are at least 27 dB below the fundamental. This is easily achieved, as most modern digitizing oscilloscopes come with an FFT function. Through the use of FFTs made with the Hanning window function for frequency accuracy, it is easy to measure the magnitude of the spectrum at 10 MHz and its harmonics.

Apart from the template tests and the test for harmonic content, the other parameters that can be tested are the peak differential output voltage and common-mode voltage. These tests are performed with random data signals, as shown in Figure 6, and are relatively straightforward measurements.

Figure 9. All-1's Manchester-encoded signal.

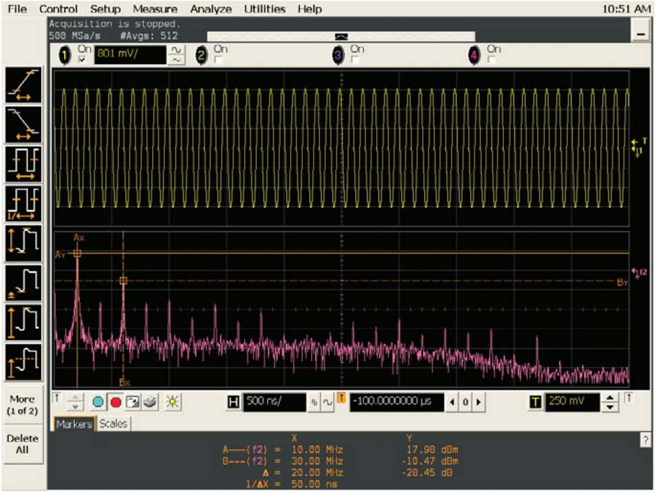

Figure 10. The oscilloscope display is divided into two, with the trace on the upper portion displaying the all-'1's Manchester-encoded signal. The trace on the lower portion uses the oscilloscope FFT function to measure harmonic content of the all-1's Manchester-encoded signal. This example shows a marker at the fundamental frequency of 10 MHz and another marker on the third harmonic (30 MHz). The magnitude of the third harmonic shown here is –28.45 dB from the fundamental.

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