

Title: Understanding Twisted Pair Cable Technology**No: GEN17-1****Date: Saturday, 25 June, 2005****SUMMARY:**

This Connectivity Information Sheet will explain some of the more important factors on how twisted pair cables work.

MORE INFORMATION:

In the late 1970s, twisted pair cabling originated in the computer industry as a means of transmitting digital data over computer networks. This cable was designed to be a medium for relatively slow computer data communication. Digital data signals are relatively forgiving and can tolerate considerable interference and degradation before affecting the integrity of the signal. It is only recently that twisted pair cable began to be used to carry analog video signals, which are much more demanding.

As this trend continues to gain acceptance and become more common, we must gain the knowledge necessary to deploy it consistently in a professional environment. It is important to understand known twisted pair cable issues and testing methods so we know how to recognize and resolve installation performance issues. Using the highest quality cable, proper installation techniques, and thorough testing will maximize the quality of the image being displayed in a presentation environment and minimize expensive and time consuming troubleshooting.

There have been significant changes in the technology and performance of twisted pair cable since its inception. The development of high-speed data transfer rates for network applications and bandwidth-consuming multimedia signals has necessitated significant improvements in the overall performance of twisted pair cable. Twisted pair cable is being used for data applications for networks such as 10baseT; 100baseT; Gigabit Ethernet; and multimedia video and audio. The most common names for these cables are Category 5 (CAT 5), Category 5e, and much higher performance cable like Category 6 and Category 7. In the data world Category 5e presently supports Local Area Networks (LANs) for 100 Mbps.

Category 6 supports up to 250 Mbps and some manufacturers now claim to support up to 350 Mbps and higher. These cables support Gigabit Ethernet and many multimedia applications.

This paper will explain some of the more important factors on how twisted pair cables work; specifically it will cover the following:

Clarify and explain some of the issues involving twisted pair cable

- Electromagnetic Emissions
- Common Mode Noise

Describe some of the tests used for meeting Category 5 and Category 6 requirements and testing for performance results that pertain to the use of Minicom products

- Wiremap
- Length
- Attenuation

- Return Loss
- Near-End Crosstalk
- Equal Level Far-End Crosstalk.

Any system – whether it uses coaxial cable or twisted pair cable – that integrates source materials and a display device for the purpose of sharing information is a presentation system. Optimal image quality in a presentation environment requires special attention to all components and factors, including the type and quality of cable used as well as the cable transmission method. Maximizing the advantages of using Category 5, 5e, or 6 systems to run analog video signals while minimizing the disadvantages, requires understanding twisted pair technology, potential installation issues, and cable tests.

Electromagnetic Emissions and Common Mode Noise

Let's take a look at how twisted pair works and what issues should be considered when selecting it for your multimedia application. This twisted pair cable we are going to discuss is made of four twisted pair wires. One problem with twisted pair wire is electromagnetic emissions at high frequencies. These emissions can couple into adjacent twisted pairs. The second issue is the ability of the cable to eliminate common mode noise. Common mode noise is electrical interference induced into the cable with equal amounts of energy, in the same polarity, on both wires of a twisted pair.

This can come from sources like electric motors, air-conditioners, power transformers, fluorescent lighting ballasts, etc.

The cable designer will optimize the common mode noise rejection and the reduction of transmitted signal electromagnetic emissions by maintaining certain twist ratios (twists per foot), which are in the form of different twist ratios between pairs, and clockwise and counter-clockwise twisting between pairs within a common sheath. Each wire is covered with a dielectric insulation, and the diameter of the center conductor and its centering within the dielectric insulator are very important in maintaining uniform impedance. It is also important to note that the twisting action helps keep the wires as close together as possible.

In a well-designed and balanced multi-pair Category 5/5e/6/7 cable with consistent twist ratios and matched pair lengths, the electromagnetic interference (EMI) being emitted from the pair is reduced significantly. In addition, common mode noise from external interference and adjacent pair crosstalk is significantly improved. To see how this is important, we first must understand what happens when a balanced signal is applied to a twisted pair of wires. When a transmitter applies a balanced analog audio or video signal to a twisted pair wire, the signal is the same amplitude (voltage level) on both wires, but the signal on one of the wires is inverted to the opposite polarity. When the signal on one wire is going in a positive direction, the signal on the other wire is going in a negative direction. This is referred to as differential mode. See Figure 1.

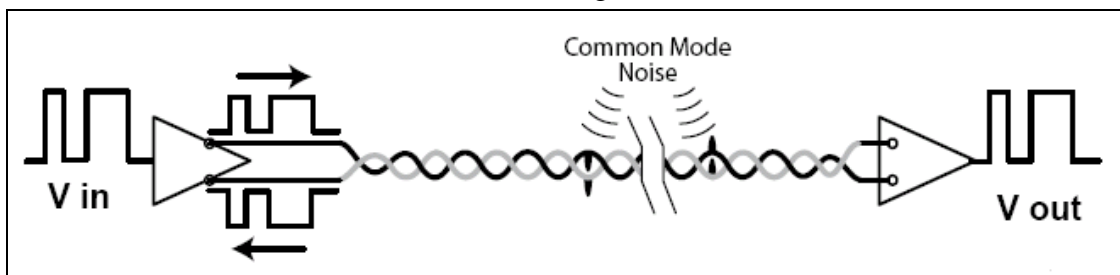


Figure 1. Common mode noise: The noise is at the same level traveling in the same direction at the same time. The noise will cancel at the receiver.

All induced common mode noise from adjacent wire pairs, as well as from other external sources such as motors, transformers, and other external sources, will cause the same noise signal to be induced into both wires equally and of the same polarity. This will cause electrons to flow in the same direction through both wires of the twisted pair, and the noise will cancel at the receiver. In balanced transmissions, the receiver is operating in a differential mode. This means it is looking for a difference between the two input signals to form an output signal. The receiver has a positive and negative input, sometimes referred to as the Tip and Ring inputs, respectively. The differential receiver performs a simple math function: it inverts the sign (polarity) of the signal at the negative input to a positive value and adds the value of the two input signals together.

Let's try it out with a signal value of +0.35 volts at the positive input and a signal value of -0.35 volts at the negative input. Now change the sign of the negative input to a +0.35 and add the two inputs together – the result is a +0.7 volts. See Figure 2.

When common mode noise is present on the twisted pair, the noise is equal in amplitude and always of the same polarity on both wires. The differential receiver processes this common mode noise in the same way as it did the signal. If we have +0.015 volts of common mode noise at both inputs, change the sign of the common mode noise at the negative input to -0.015 volts, and add the two inputs together. They will cancel out and only the original signal will be present at the output of the receiver. This would still be true if the common mode noise were negative at both inputs

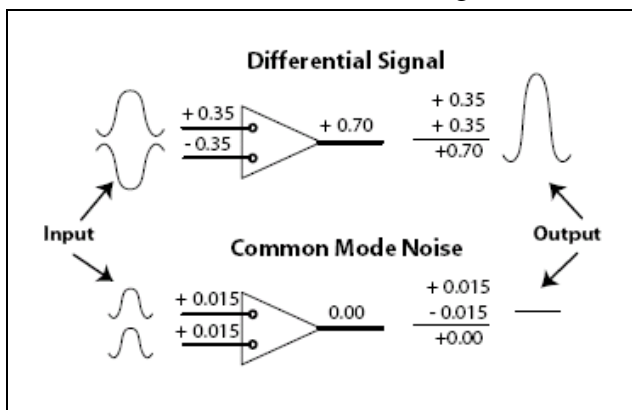


Figure 2. How common mode noise is cancelled at the receiver.

If for any reason the wires in a twisted pair were to become separated – like from a sharp bend during installation – the noise will strike the wires at slightly different angles, causing the induced signals (noise) to be slightly different in each wire. This difference will not cancel out at the receiver and, thus, will become part of the signal. At the same time, this separation will form a loop (See Figure 3) and will act as a loop antenna, picking up additional unwanted noise/crosstalk.

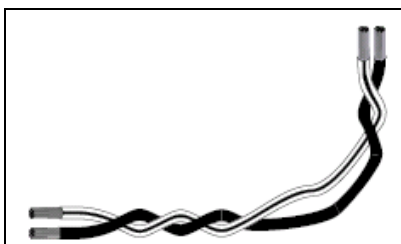


Figure 3. Twisted pair showing damaged twist pattern.

Cable Testing

Now that we have an understanding of how this cable works, we'll talk about how we're going to be sure that our new multimedia twisted pair cable installation is going to work, after we hook up Minicom CAT5 Transmitter and Receiver to display device. Just wait a minute, this is not a coax cable; it is not a "just crimp on some BNC connectors and turn everything on" type of application. As people in the data world know, it is very important that this cable run be tested to meet the stringent requirements of the CAT6 specification (the higher the quality of cable is, the higher the performance that results). To do this, we're going to use a hand-held Level Three cable tester and verify that the installation meets the requirements of Category 6. (Level Three tests for parameters up to the Category 6 standard, while Level Two tests for parameters up to the Category 5e standard.) This test will automatically perform a series of tests we're going to discuss.

The main tests that we need to be concerned with for our applications are the following:

- Wiremap
- Length
- Attenuation
- Return Loss
- Near-End Crosstalk
- Equal Level Far-End Crosstalk.

Wiremap Test

The Wiremap Test is used to identify installation-wiring errors:

- Proper pin termination at each end
- Continuity to the remote end
- Shorts between any two or more conductors
- Crossed pairs
- Split pairs
- Reversed pairs
- Any other mis-wiring.

Attenuation Test

The loss of signal strength (or voltage) in the cable is called attenuation. The more attenuation there is, the less signal there will be present at the receiver. The attenuation is measured in decibels (dB). Attenuation increases with distance and frequency. For every 6dB of loss, the original signal will be half the original amplitude. See table below.

Decibels vs. Voltage					
dB	Voltage Ratio	dB	Voltage Ratio	dB	Voltage Ratio
0	1V	-9	0.355	-18	0.125
-1	0.891	-10	0.316	-19	0.112
-2	0.794	-11	0.282	-20	0.100
-3	0.707	-12	0.250	-30	0.032
-4	0.631	-13	0.224	-40	0.010
-5	0.562	-14	0.200	-50	0.003

-6	0.500	-15	0.178	-60	0.001
-7	0.447	-16	0.158	-80	0.000
-8	0.398	-17	0.141		

Length Test

Structured cable systems for the data world have a length limit of 100 meters (328 feet) total. (Note: this restriction does not directly apply to the transmission of analog signals.)

The length test will provide us with the physical length of each pair and the delay time in nanoseconds. The delay is the time it takes for the signal to travel the entire length of the cable. This delay is a percentage of the speed of light called the Nominal Velocity of Propagation (NVP). Typical NVP varies from 60-90 percent of the speed of light from cable to cable. The delay skew is the difference in time it takes for a signal to travel down the shortest pair to the time it takes to travel down the longest pair. Lengths of wire pairs often vary within the same twisted pair cable due to small differences in twist tension and rates. The delay skew is measured in nanoseconds (ns) and feet.

For most data network applications, the delay skew limit is 45 ns; this is not acceptable for analog RGB signals. The delay skew information is very important when sending analog RGB signals over twisted pair wires and needs to be as close to zero as possible.

Depending on the resolution, the delay skew resulting from a length difference of three feet will most likely need compensation. Measurements of a typical 1024 x 768 signal with a refresh rate of 60 Hz (pixel clock of 65 MHz) showed the pixel duration to be approximately 15 ns.

For an image running at 1280 x 1024 pixels, with a refresh rate of 60 Hz (pixel clock of 135 MHz), the pixel duration was approximately 8 ns.

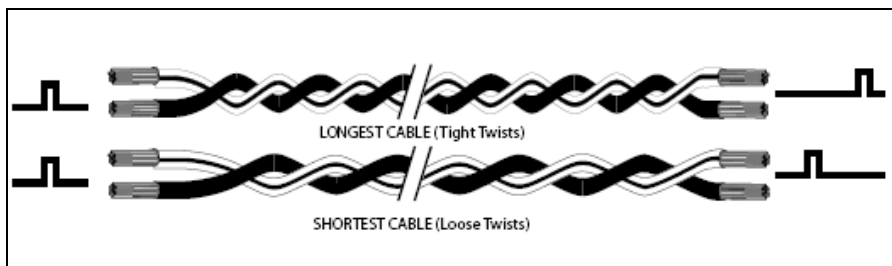


Figure 4. Delay skew: The signal traveling on the longest cable will arrive later than the signal traveling on the shortest cable, so the signals will arrive at different times.

Using Belden Media Twist cable for our reference, each foot has a delay of 1.451 ns. If there were a delay skew of five feet between a pair of wires, the delay in nanoseconds would be 7.255 (5 feet x 1.451 ns). This would be very close to one pixel width off at the 1280 x 1024 rate and half a pixel width off at the 1024 x 768 rate. If this delay skew is not compensated for, the image will appear to be out of convergence because the red, green, and blue signals will arrive at different times. See Figure 4. Delay skew is caused by differences in length between one or more of the pairs.

When transmitting multimedia analog information, we are not limited to the 100 meters (328 feet) maximum length specification for data networks (data networks are digital and have different standards). However, we need to understand that when performing a Level Three test on cable lengths that are much longer, certain tests will fail. The Length Test will always fail, and the Attenuation Test will also fail at some point. This is because these testers were designed to be used for data communications signals instead of analog signals.

The important information we need from these measurements is the delay skew in feet between the pairs in order to make the necessary compensation.

Twisted pair cable test equipment measures and reports wire pair length. (Test results on the various pair lengths can be used in equalizing pair skew.) The NVP is very close to that of conventional coax. The similarities in NVP mean that an additional length of coax equal to the length of pair skew (a 1:1 ratio), placed on the receiver's output, equalizes the effects of pair skew. For example, if there are two pairs, one with a length of 100 meters, the second with a length of 102 meters, then a 2-meter length of coaxial cable may be added at the end of the first pair's original cable run of 100 meters.

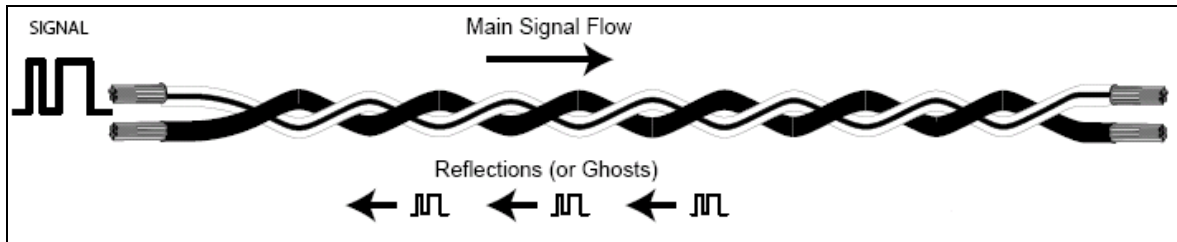


Figure 5. Reflected energy caused by impedance variations.

Return Loss Test

Return loss is a measurement of the reflected signal back toward the transmitter. This reflected energy is caused by variations of impedance in the cable and connectors. See Figure 5. This would be the equivalent of an electrical echo of the original signal. It is like when your TV is switched to a weak station and you see that the image is full of ghosts. These ghosts are nothing more than reflections of the original image. This same problem can happen with poorly terminated or damaged coax cables. The greater the variations in impedance, the greater the return loss readings. When running this test, it is important to verify that the return loss reading from all four pairs not only pass the return loss test, but also have nearly the same results. If three pairs pass with a substantial margin and the fourth pair barely passes, this might indicate a poor crimp or contact on an RJ45 connector along the transmission path. Other high return loss might be caused by damage made to the cable during installation.

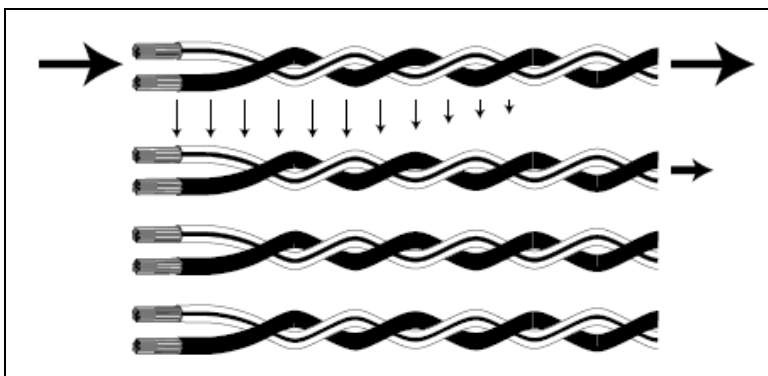


Figure 6. How Near-End Crosstalk is created.

Near-End Crosstalk (NEXT)

The NEXT measurement is the amount of signal that is induced into an adjacent twisted pair at the transmission end by the electromagnetic field created by the signal being transmitted through an adjacent pair at the same end. See Figure 6. The induced signal is strongest at this end partially because the transmitted signal is strongest at the transmitter

end. The transmitted signal gets attenuated as it travels through the cable and is weakest at the receiver, or far end. The untwisting of the cable that is required to make the termination makes this the most vulnerable part of the assembly process. Electromagnetic emissions become greater with increases in the frequency of the signal, and thus, crosstalk increases with increases in frequency. During the operation of 100-megabit and one-gigabit data systems, both ends are required to transmit and receive data simultaneously. This means that where the electromagnetic emissions are the strongest – at the transmitter – they are also very close to a receiver. With Minicom products, all signals are sent from the near end and received at the far end.

The near-end crosstalk gets attenuated somewhat by the impedance of the cable, prior to reaching the receiver. Proper termination practices and high quality cable and connectors play a very important part in keeping NEXT to a minimum.

ELFEXT (Equal Level Far-End Crosstalk)

ELFEXT is a very important measurement for our application. This is the crosstalk that reaches the receiver and has automatically had its results compensated for by variations in cable length. A short run will have less attenuation and therefore have a higher Far-End Crosstalk (FEXT) reading than a longer cable. The ELFEXT measurement automatically adjusts the FEXT results for the difference in cable lengths. If you were to test one cable of 30 meters and another at 70 meters, you would want to know how much crosstalk is reaching the receivers.

It is increasingly important for system contractors, designers, and installers to maintain skills and knowledge of system and infrastructure options. Many of the alternatives available, including twisted pair cable, have significant pitfalls that can be expensive or even disastrous to discover during a system installation. Twisted pair cable is a very attractive technology that enables unique and interesting interconnections when understood and deployed correctly.

In this paper we have discussed the workings of twisted pair cable technology. Problems such as electromagnetic emissions and common mode noise can be reduced with the use of well designed twisted pair cables and installation techniques that properly maintain a cable's twists and form. Rigorous cable testing verifies that the cable at hand meets the requirements of the standard required, Category 5, 5e, 6 or 7.

Understanding the capabilities and characteristics of twisted pair cable is only part of the system. It is equally important to carefully select the transmitter and receiver equipment and understand the effect they can have on system performance. Minicom manufactures a complete line of twisted pair cable extension and distribution equipment and makes available knowledgeable staff prepared to assist in the understanding and deployment of this and other technologies.

COMMENTS:

See Connectivity Information Sheet GEN18-1 for explanation of the skew and how to compensate it.