Ultra320 SCSI Cables: Ensuring Data Integrity of the Ultra320 Bus

Introduction

Historically, cables have been viewed simply as wiring that connects a peripheral to the host bus adapter. But as data transfer rates rise, the complexity of ensuring data signal integrity across the entire SCSI bus – from ASIC to peripheral – increases and, at Ultra320 SCSI rates, cables begin to behave more like transmission lines and suffer from associated problems, such as attenuation and reflections, that tend to degrade electrical signals and lower the margin of error for data integrity. Because of this unprecedented bus sensitivity to signaling errors, a properly designed cable is crucial to ensuring data integrity.

The Solution

Doubling the maximum frequency in Ultra320 SCSI from Ultra160 SCSI has pushed the SCSI bus into a frequency range with more signal attenuation in SCSI bus cables and faster rise time. The doubled signal frequency has resulted in attenuated and reflected signals on the SCSI bus. To minimize signal loss, Adaptec® has introduced an improved cable technology that addresses electromagnetic interference (EMI) and other electrical noises that cause signal loss. The round cable improves impedance uniformity on the cable to minimize reflections, which causes most of the signal degradation.

Testing

Adaptec has a unique understanding of the complete solution for interconnect characterization – from ASIC to peripheral – enabling it to ensure the integrity of the entire Ultra320 SCSI bus. Adaptec validates the Ultra320 signal path by rigorously testing cables in both theoretical and real-world environments. Adaptec's integrated Ultra320 features such as Training Pattern, Pre-compensation, and Adjusted Active Filter minimize transmission line inhibitors such as skew, propagation delay, and attenuation.

Understanding the Change

Characterizing and modeling of high-speed interconnects in a digital system are critical in achieving an accurate representation of system performance. By coupling the signal characteristics with real-world applications, Adaptec has certified the Ultra320 SCSI bus for maximum throughput.

Securing the Ultra320 SCSI Bus

Adaptec has switched from the standard twist and flat internal cable with active termination to a more secure internal round cable with shielding and active termination. A snapshot of the signal integrity of twist and flat versus round cables will illustrate how Adaptec is protecting the Ultra 320 signal.
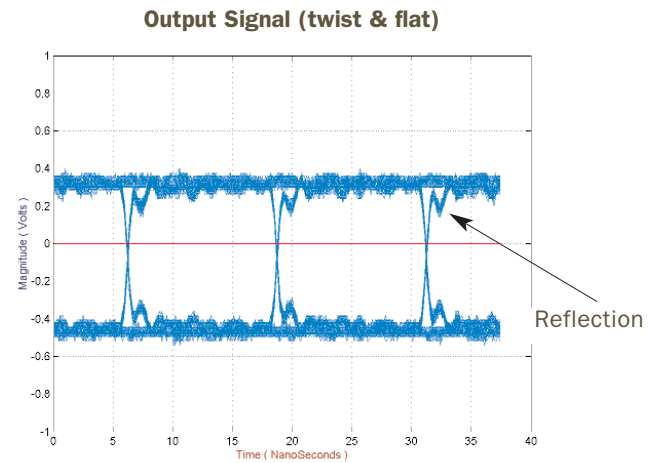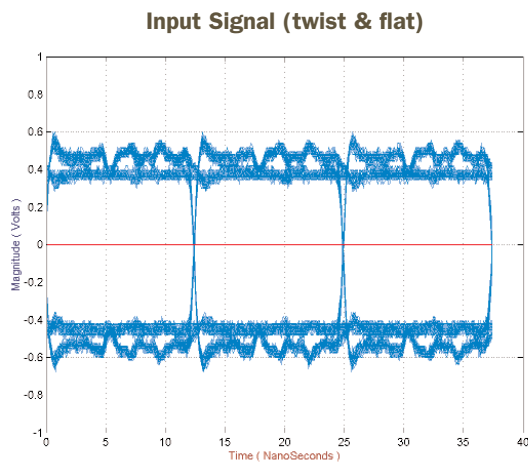
Ultra320 and Ultra160 Data Signals – A Comparative Analysis

A comparison of Ultra160 and Ultra320 SCSI illustrates differences in signaling with different cable designs.

The following Eye Diagrams illustrate Ultra160 signal behavior with both an Ultra160 twist and flat cable and an Ultra320 round cable.
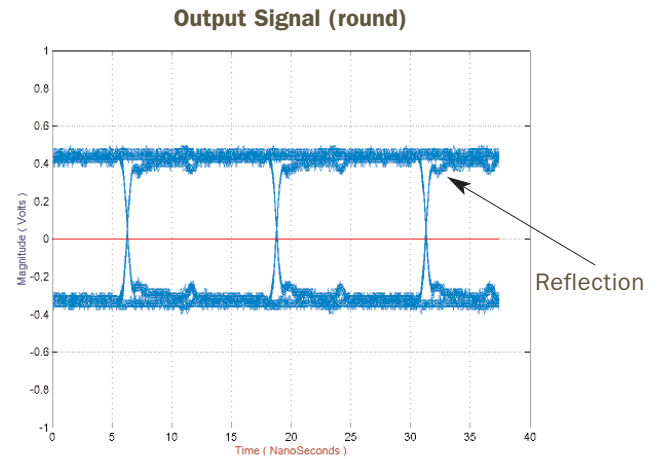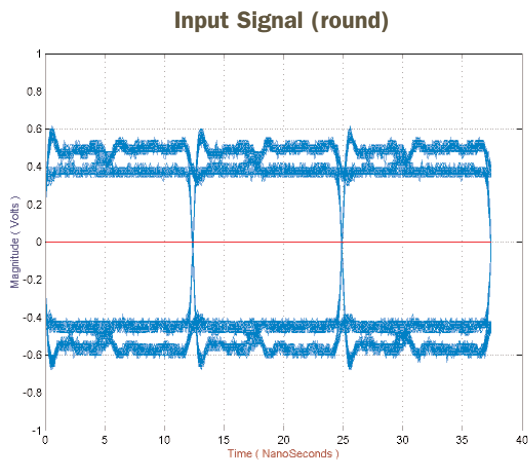
The top two Eye Diagrams show the input signal (top left) and the output signal (top right) of the twist and flat Ultra160 SCSI cable on an Ultra160 signal. The lower two Eye Diagrams show the input signal (lower left) and the output signal (lower right) of the Ultra320 SCSI round cable on an Ultra160 signal.

There are fewer reflections on the round cable at Ultra160 signaling. The signal input is similar for both cables, but the Ultra320 round cable produces a cleaner output signal.

Ultra160 SCSI Eye Diagram of incoming signal for twist & flat cable, 5-position, 4-ft with active termination

Ultra160 SCSI Eye Diagram of signal to peripheral for twist & flat cable, 5-position, 4-ft with active termination
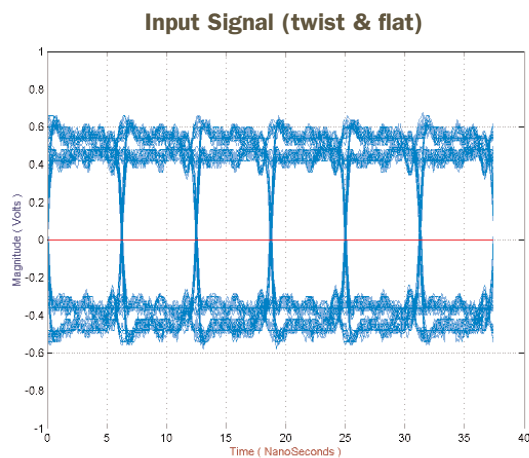

Ultra160 SCSI Eye Diagram of incoming signal for round cable, 5-position, 4-ft with active termination

Ultra160 SCSI Eye Diagram of signal to peripheral for round cable, 5-position, 4-ft with active termination
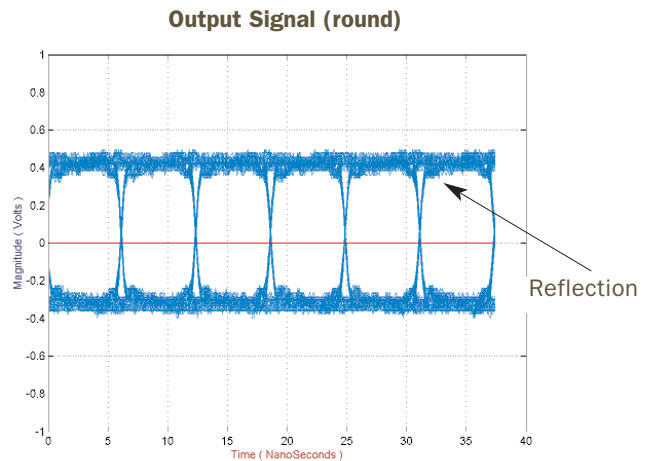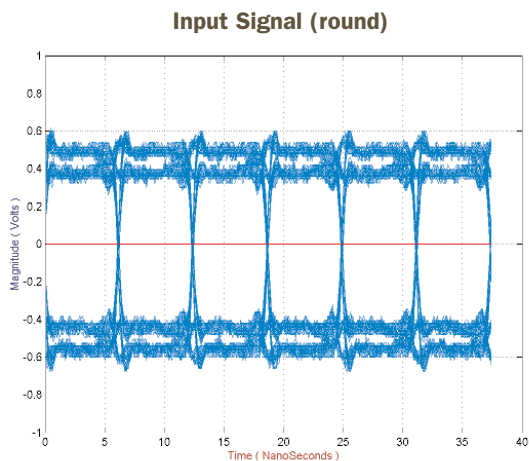
The top two Eye Diagrams show the input signal (top left) and the output signal (top right) of the twist and flat Ultra160 SCSI cable on an Ultra320 signal. The lower two Eye Diagrams show the input signal (lower left) and the output signal (lower right) of the Ultra320 round cable on an Ultra320 signal.

There are fewer reflections on the round cable at Ultra320 signaling. The signal input is similar for both cables, but the Ultra320 round cable secures a cleaner output signal. The round cable also has a cleaner signal at Ultra320 than at Ultra160 data transfer rates.

Input Signal (twist & flat)

Ultra320 SCSI Eye Diagram of incoming signal for twist & flat cable, 5-position, 4-ft with active termination

Output Signal (twist & flat)

Ultra320 SCSI Eye Diagram of signal to peripheral for twist & flat cable, 5-position, 4-ft with active termination

Input Signal (round)
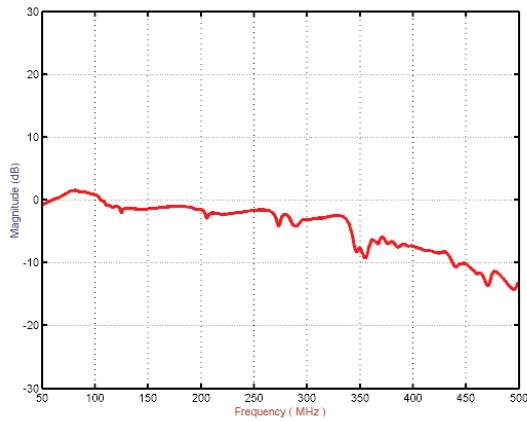
Ultra320 SCSI Eye Diagram of incoming signal for round cable, 5-position, 4-ft with active termination
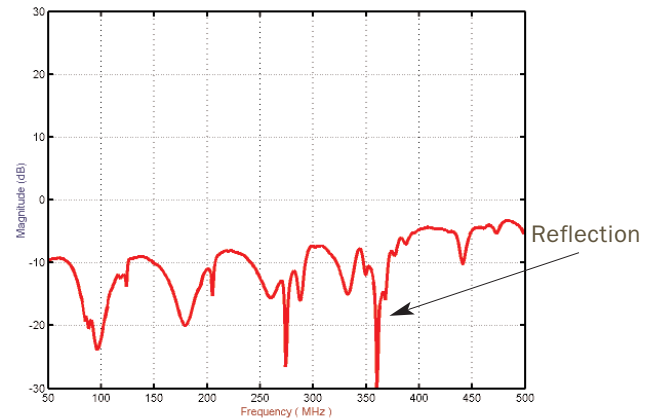
Output Signal (round)

Ultra320 SCSI Eye Diagram of signal to peripheral for round cable, 5-position, 4-ft with active termination

The twist and flat cable has a more jagged attenuation curve (top left) and more signal loss at higher frequencies. The round cable has a smoother attenuation curve (bottom left) with less signal loss at higher frequencies.
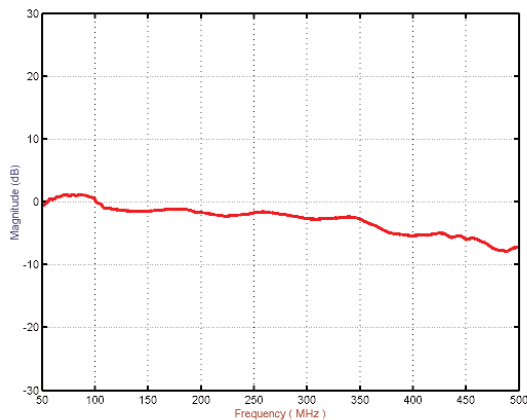
The twist and flat cable has jagged disturbances (top right) when measuring reflections. The more jagged the edges, the more reflections in the signal, a characteristic that causes more signal loss. The round cable has a smoother curve, indicating fewer signal reflections.

Attenuation Curve Measuring signal output at different frequencies. Mixed mode S-parameter twist & flat cable, 5-position, 4-ft

Attenuation Curve Measuring reflections back to originating signal. Mixed mode S-parameter twist & flat cable, 5-position, 4-ft
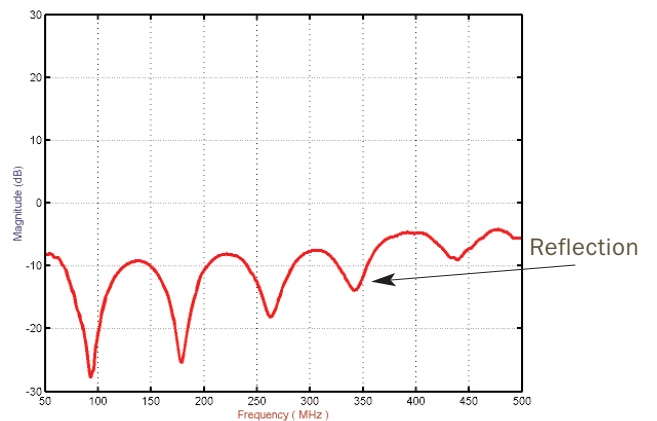
Attenuation Curve Measuring signal output at different frequencies. Mixed mode S-parameter round cable, 5-position, 4-ft

Attenuation Curve Measuring reflections back to originating signal. Mixed mode S-parameter round cable, 5-position, 4-ft

Key Cabling Terms and Concepts

Transmission line characteristics

Much of Adaptec's research and development is devoted to understanding the characteristics that may affect cable signal integrity. These characteristics include impedance, attenuation, crosstalk, time delay, and time delay skew. Transmission characteristics show how the transmission line will perform under a given set of circumstances. Transmission characteristics are a result of the interaction of all the cable characteristics.

Characteristic impedance

Characteristic impedance is the combined effect of resistance, conductance, inductance and capacitance in a transmission line.

The characteristic impedance of cables must match the impedance of the transmitting and receiving circuits. Otherwise, reflections will occur, causing signal loss and distortion.

Effects on impedance

Impedance is affected by conductor size, insulation material, insulation thickness, shield proximity and frequency.

Capacitance

Capacitance is the property of an electric circuit that opposes any change in voltage. Capacitance distorts the signal as it passes through the transmission line. The lowest possible capacitance is preferred. Capacitance is frequency dependent.

Effects on capacitance

Many variables in the cable design affect capacitance including insulation materials and thickness.

Dielectric

The dielectric is the material between conductors in a cable. A dielectric material is a substance that is a poor conductor of electricity, but an efficient supporter of electrostatic fields, property that is useful in capacitors. An important property of a dielectric is its ability to support an electrostatic field while dissipating minimal energy in the form of heat. The lower the dielectric loss (the proportion of energy lost as heat), the more effective a dielectric material. And changes in the dielectric constant of the insulating material will affect the cable characteristics.

Inductance

Inductance is the property of an electric circuit that opposes current. The lowest possible inductance is preferred and any conductor possesses this property with a current flowing through it. Inductance distorts the signal as it passes through the transmission line. Inductance is frequency dependent.

Effects on inductance

Inductance is affected by many variables in cable design, chief among them conductor size, insulation thickness and shield proximity.

Inductor

An inductor is a passive electronic component that stores energy in the form of a magnetic field. Cables are examples of straight wire inductors with low inductive characteristics.

Resistance

Resistance is the opposition to the flow of current in an electric circuit. All metallic conductors have resistance, and the lowest possible resistance is desired. Resistance wastes transmission line energy in the form of heat.

Skin effect also affects resistance. At higher frequencies, skin effect increases, causing the signal to concentrate at the outer edge of the conductor.

Effects on resistance

Many variables in cable design affect resistance, including conductor size, conductor material, plating material, temperature, and length impact resistance.

Attenuation or insertion loss

Attenuation, usually measured in dB/ft, is a natural consequence of signal transmission over long distances. It causes the signal to shrink or shorten in amplitude, where the wasted signal is lost in the form of heat or reflections. Attenuation occurs with any type of signal. The lowest possible attenuation is preferred.

Effects on attenuation

Attenuation is affected by conductor size, conductor/plating material, insulation material, impedance, and frequency.

Crosstalk

Crosstalk is the effect of a signal traveling in one cable component on the signal of another cable component. It is a major contributor to noise for cables. Noise from the signals will affect other signals, producing skew – the difference between two signals at the same location.

Crosstalk is a disturbance caused by the electric or magnetic fields of one signal on another. The phenomenon that causes crosstalk is called electromagnetic interference (EMI).

Effects on crosstalk

Cable characteristics such as conductor type, twisting, shielding and frequency affect crosstalk.

Attenuation to crosstalk Ratio

Attenuation-to-crosstalk ratio (ACR) is the difference, measured in decibels, between the signal attenuation produced by a wire or cable transmission medium and the far end crosstalk.

For a signal to be received with an acceptable bit error rate, the attenuation and the crosstalk must both be minimized. In practice, the attenuation depends on the length and gauge of the wire or cable transmission medium, and is a fixed quantity. However, crosstalk can be reduced by ensuring that twisted-pair wiring is tightly twisted but not crushed, and by ensuring that connectors between wire and cable media are properly rated and installed.

The ACR is a quantitative indicator of how much stronger the attenuated signal is than the crosstalk at the destination (receiving) end of a communications circuit. The ACR figure must be at least several decibels for proper performance. If the ACR is not large enough, errors will be frequent. In many cases, even a small improvement in ACR can cause a dramatic reduction in the bit error rate.

Time and propagation delay

Associated with skew, time delay is the interval required for a signal to pass through a transmission line. Skew is the difference between the earliest and latest signals' arrival time at the target or initiator. A cable's propagation delay measures the travel time of a signal down the transmission line.

Effects on time and propagation delay

Time delay and skew are affected by the insulation material and twisting of conductors. Unequal wire length in pairs due to twisting, deformation of dielectric due to twisting, variance in the dielectric constant, air gaps between conductor and dielectric, unequal pair lengths due to cabling also adversely impact skew. The likelihood of data clocking errors rises as time delay and skew increase.

Propagation delay is affected by inductance and capacitance. The velocity factor measures signal speed as a percentage of the speed of light. The higher the velocity factor, the lower the propagation delay.

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