System Connection™

Understanding Cabling Basics

Table of Contents

Section 1 - Computer Cables & Computer Communication

Basic Communication Concepts

Computer cables generally can be classified in one of two ways; cables that handle data for a single computer and its peripherals (such as printers, monitors, modems) and those used to connect one or more computers and associated peripherals into networks. First, lets examine how computer cables are used to communicate or exchange data between a single computer and its peripherals.

Computers communicate using on and off electrical pulses known as computer binary language. To make the on and off pluses of computer binary language useful, the ASCII code was developed to relate characters (numbers, letters, and symbols) to groups of on and off pulses. For example, "0" is off and "1" is on. Each zero or one is called a bit. A group of 8 bits is called a byte, and each byte has an ASCII character assigned to it.

Computers use something known as an interface to send data to each other. There are three common types of interfaces; Input only, Output only, and Input-Output. We will focus on the Input-Output (I/O) interface type in this paper. Most standard personal computer systems use one or more of the following I/O interfaces: **serial, parallel, ethernet or SCSI.**

I/O Interfaces - The Basics

Serial

In a serial interface, all of the data travels along one wire. The eight bits in a byte are sent one after another down the wire. In general, serial cables will operate properly in lengths of up to 100 feet without significant distortion or loss of data. It is possible, however, to extend the limit up to 200 feet further using specially shielded, "low capacitance" cabling or serial extenders. Newer serial technologies such as Universal Serial Bus (USB) or IEEE 1394 (Firewire) extend the capabilities of the serial bus, including the number of devices that can be connected..

Parallel

In a parallel interface data is sent down eight parallel lines simultaneously. Parallel interfaces allow faster data transfer rates but are restricted to the use of much shorter cable lengths than serial cables. The higher data transfer rates of the parallel interface has made it suitable for use in SCSI systems.

In printer applications, using standard 18 conductor, single shielded wire, parallel cables will work properly in lengths up to 50 feet depending upon the amount of radio frequency interference (RFI) in the area where they are used. Parallel printer cable lengths of up to 150 feet can be achieved using low capacitance, twisted pair, double shielded wire. For applications where bi-directional communication is desired, 25 conductor, double shielded wire or 12.5 pair, IEEE 1284 wire is required.

Most computers today have enhanced parallel ports (EPP) or IEEE 1284 ports that allow data transfer rates of 16.5 megabytes per second when connected to another EPP/IEEE 1284 compliant device. These EPP/IEEE 1284 ports also provide two-way communication between the computer and connected device requiring 12.5 pair, IEEE 1284 compliant wire or rated cables.

SCSI

Many computers, especially Apple Macintosh computers, use the SCSI or Small Computer Systems Interface. The SCSI bus (internal circuit board, connected devices, and all cables) can connect up to 8 devices. Each device is connected to the next in the chain by a separate cable. Most SCSI devices have an incoming and outgoing port, with the next device in the chain being connected by cable via the outgoing port. Hooking devices together in this manner is called "daisy chaining."

In a SCSI environment, signals are sent to every device connected to the chain. Each connected device has a unique address or ID assigned to it. These IDs are assigned when the system is configured or a new device is added to the chain. Using the device's SCSI ID, the bus can address specific data requests to that device. For a more detailed discussion of how the SCSI bus works, see Section 4.

New Technologies

Serial technology offers cost and technical advantages over parallel technology. For those reasons many of the new interface technologies are serial based. The new universal serial bus is a good example. Using two versions of a four position connector, 2 pair wire, and sophisticated software it is possible to connect up to 127 devices (high and low speed) to a single computer. IEEE 1394, another serial technology, can connect computers and consumer electronic products such as camcorders and TVs at speeds up to 400 Mb/sec.

Section 2 - Factors to Consider When Choosing a Computer Cable

Just as a Mercedes and a Chevrolet are both automobiles but differ in quality and performance, the performance of an interface can be affected by the materials and manufacturing techniques used to build a cable.

Shielding

Foil Shielding

Shielding is necessary to eliminate the effects of noise or interference in a computer cable. Cable shielding is accomplished in several different ways. The most common method used for computer cables running at relatively low data transfer speed is to use a single layer of aluminum mylar foil material wrapped around the bundle of individual wires inside the cable. A good example of a single shielded cable would be a keyboard cable.

Foil and Braid Shielding

For devices running at higher data transfer speeds or supporting bi-directional communication, an additional level of shielding is required. The copper tinned braid is applied over the foil shielding in a woven pattern or mesh. The shielding properties of this mesh can be improved by tightening the weave of the mesh. The less space in between strands in the mesh, the better the shielding. Measurement of the shielding effectiveness is a percentage of the area covered completely by the braid. For example, a loose weave might offer a 65% overall coverage of the foil shielding beneath it. A good example of a double shielded cable are our premium Macintosh SCSI drive cables.

Foil, Braid and Twisted Pair

Most applications requiring a double shielded cable will probably also require the use of twisted pair wire. Interference and the free flow of electrons in a cable called "inductance" can be significantly reduced by wrapping or twisting a ground wire around each individual data conductor or wire. The combination of foil, braid, and twisted pair shielding provides an effective barrier against interference and is used in most SCSI, IEEE 1284, USB, Firewire, and other high speed applications or where bi-directional communication is required.

Full vs. Partial Shielding

Up to this point we have been talking about the shielding of the actual wire used in the cable. Complete or full shielding requires the connector also to be shielded. An unshielded connector negates any benefit gained from shielding in the wire. Some cables, particularly inexpensive cables, do not shield the connector. This is known as "partial shielding" and in many lower speed applications it will not effect system performance. However, for higher speed applications where the data travels in the same frequency range as common electronic interference or noise a connector with a copper or aluminum foil shield is essential. SCSI cables typically use a copper shield with solder applied around the edges to seal the shield to the connector shell and foil braid to insure a complete shield.

Molded vs. Assembled Cables

Computer cables are generally manufactured in one of two ways; molded or assembly type. Since almost all wire material has a molded jacket of some plastic material, we will focus here on the protective hoods that cover the connectors at each end of the cable.

Molded

Molded cables are manufactured by a process where a protective plastic, in most cases PVC, hood is permanently attached or molded over the connector. The first step in the process is the premold. In the premold, a milky white PE material is injected into a mold cavity holding the terminated cable. The PE material completely encapsulates the connector and the individual data wires or conductors, ensuring electrical isolation between contact pins and eliminating stress on the individual data wires or conductors. Typically both ends of the cable are premolded at the same type.

The next step in the process is to apply the post mold or overmold to the cable. The premolded ends are both inserted into a mold tool where the PVC material is then injected. For most of our standard products the overmold mold tool has a removable section that can be modified in a variety of ways to include customer specific requirements like part number, logo insertion, etc. The finished cable is then cleaned up, removing burrs, etc., has thumbscrews or thumbpads installed, is inspected, re-tested, bagged and labeled. Post molded or overmolded cables have better cable strength, durability, more resistance to interference, and are more visually appealing. All System Connection molded cables have a lifetime warranty.

Assembled

Assembly type or cables with assembled hoods usually have a two-piece hood or slide up boot to protect the connector and associated data wires. Hoods are usually snapped or fastened with screws and can be made of plastic, metal, or nonconductive plastic material. In many cases, the hood provides little or no strain relief and in the case of snap together plastic hoods, provides no shielding. Metal and nonconductive plastic hoods provide more effective shielding than snap together plastic hoods and can be just as efficient at eliminating interference if combined with proper cable manufacturing techniques. Lack of effective strain relief and ineffective shielding makes the overall cable assembly more susceptible to outside damage and interference. Plastic hooded cables are usually less expensive than molded equivalents. Assembled cables usually do not come with a guarantee.

Premium vs. Standard Grade Cables

Premium Grade

The term premium is one of the most overused words in our industry. To System Connection, "premium" is defined as computer cables that either by the construction method and/or the components used meets the highest specifications set by a manufacturer, the industry or a standards organization. In general, premium cables use a better grade of wire, have higher levels of shielding, or connectors from a major name brand manufacturer. Premium cables are also built using specific construction techniques like isolating sensitive timing and signal lines in the center of the data wire core or bundle.

Standard Grade

Our definition of a standard grade cable is a cable that uses off the shelf components, offshore or domestic, and is produced offshore. These cables may be shielded or unshielded, use molded or assembled hoods, and lesser gauge wire or fewer data conductors than a premium cable. Our parallel printer cables are a good example of a standard grade cable.

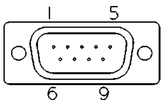
Section 3 - Connector Types and Uses

Each of the I/O interfaces we reviewed in Section 1 use a different cable and/or connector type. Often the wire will be the same among the various applications, the difference being the way the connectors are wired together or pinned out and/or the connectors used. We will focus on the various connector types in this section.

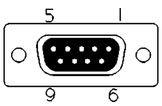
A connector is defined as the component at the end of a cable into which the individual data wires in the cable are connected or terminated. Connectors come in many sizes and shapes, but all connectors come in male and female genders. Typically, male connectors have pins that stick out, while female connectors have sockets or holes. Each pin or socket is either connected directly to or jumpered to an individual data wire that is either Connector soldered, twisted, crimped, or pressure fit on. Each pin or socket is numbered to identify it. These numbers usually appear on the connector face. Although the numbering scheme for any given connector is fixed, the wire assigned to that pin can change. A pinout diagram shows how the individual pins or sockets in a connector are connected to the data wires in a cable.

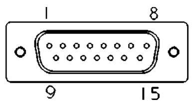
D Series

D sub miniature or D sub connectors are identified by the "D" shape formed by the ridge of metal surrounding the pins or sockets on the connector face. Usually referred to as DB connectors, the most common type is the "DB25" or "RS232" connector. The 25 in DB25 refers to the number of pins or sockets in the connector. See DB25 drawing below. The DB25 connector is widely used in applications ranging from printer cables to modems to SCSI cables. These connectors usually have jacks or thumbscrews built into the connector shell for attaching the cable to a similar mating connector on the device. Other common "D" connectors are the DB9 (9 pin) used for mice, the DB15 (15 pin) used as a video connector on Macintosh computers, the high density DB15 (15 pin) used with VGA monitor ports on PCs. Less common but also widely used is the DB26 (26 pin) used in Sun workstations as the printer port.

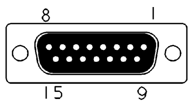


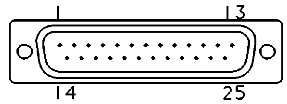
DB9 Male & Female



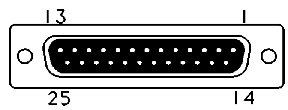


DB15 Male & Female



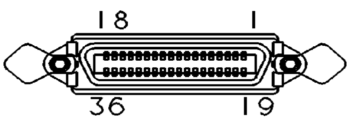


DB25 Male & Female

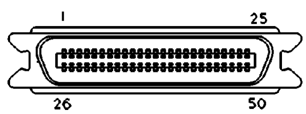


Centronics

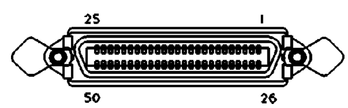
Centronics connectors are named after the manufacturer who popularized them. Centronics male connectors have a central ridge into which the contacts are molded. Female connectors have a depression with contacts molded in as well. Centronics used bail locks, wire clips to connect cable end connectors to similar connectors on the device. The most familiar use of a Centronics connector is the 36 pin style connector on the back of a printer. The 50 pin style is most commonly found on Macintosh and other SCSI-1 type devices. Centronics connectors with smaller spacing between contacts are called mini centronics style. Typical mini centronics connectors come in 26, 36, and 50 pin styles.



Centronics 36 Female



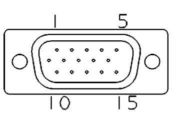
Centronics 50 Male



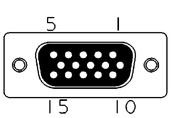
Centronics 50 Female

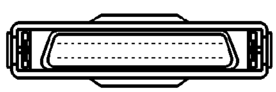
High Density Connectors

The spacing between connector pins or sockets can be measured in inches or millimeters. The standard spacing of the pins/sockets in a connector like a DB25 is .10 inches. Pins or sockets with spacing of less than .10 inches are considered high density. Examples of high density connectors are the .050 50 pin used typically for external SCSI-2 applications, the .050 68 pin used in external SCSI-3 applications, and 2mm 44 position header type used for notebook drive applications.



High Density (.050)
50 Pin SCSI-2 Male



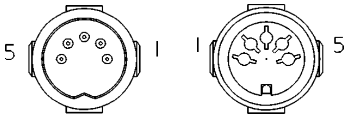


High Density DB15
Male & Female

High Density (.050)
68 Pin SCSI-3 Male

DIN

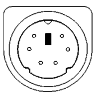
The DIN connector is a circular in shape and used in a variety of applications from PCs to laboratory testing equipment. The most common DIN is the 5 pin type used on most PC keyboards before 1993. Below are examples of DIN 5 position connectors:

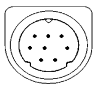


Din 5 Pin Male & Female

Mini Din

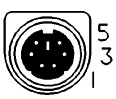
As the name implies, the "mini din" is a miniature version of the DIN connector. First widely used on Macintosh computers, the mini din 6 pin type now appears on most PCs and workstations such as Sun Microsystems. Typical mini din configurations include 3,4,6,8 or 9 pin versions.

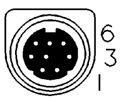




Mini Din 6 Pin
Male & Female

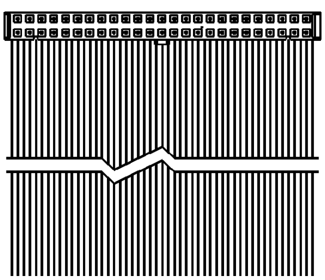
Mini Din 8 Pin
Male & Female



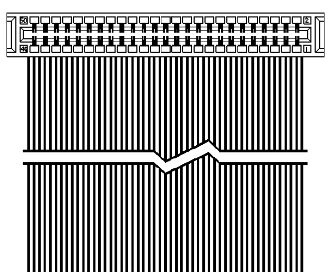


Ribbon Cable Connectors

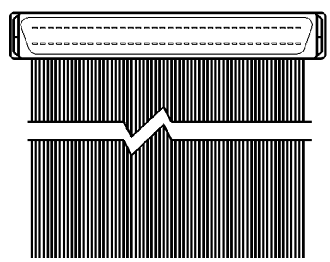
Ribbon cable connectors are rectangular in shape with typical configurations having 34, 40, 44,50,68, 80 or 100 pins or sockets. Ribbon connectors are also called IDC type connectors since the ends of each pin or socket contact have a blade system that cuts through the outer jacket or insulation of the cable to make contact with the individual data wire or conductor. Since ribbon wire comes in stranded or solid core versions, connectors should be carefully chosen for suitability with the wire type to be used. Not all ribbon connectors will work well with solid core wire.



IDC50 (header) Position Socket



IDC50 (card edge) Position Socket



.050 68 Pin Male (.025 ribbon)

Section 4 - SCSI - a more in depth look

SCSI - Small Computer System Interface, usually pronounced "scuzzy" is a method of interconnecting multiple components in a computer system to provide fast and versatile data transfer. SCSI can be both parallel and serial, with parallel being the more common method at present. The focus of this section is on parallel SCSI unless otherwise mentioned.

Many Devices Share the Same Bus

SCSI enables many devices (peripherals) to share a common Input/Output (I/O) bus. A SCSI bus is defined as all the elements from the SCSI controller card in the computer to the last connected device, including all internal and external cabling and terminators. The heart of a SCSI bus is the controller card. The controller card is usually located in one of the expansion slots (bays) of a computer simplifying configuration since one card can interface with a wide variety of device types. The function of the SCSI controller is to regulate the flow of information between all internal and external SCSI devices. Examples of Typical SCSI devices are; hard drives, raids, tape back up devices, CD ROM drives, DVD drives, Removable media drives (Zip, Jaz) and scanners.

Common Command Set

SCSI uses a software control system called the common command set or CCS. The CCS is a set of commands that allows different types of SCSI compatible devices from various vendors to communicate on the SCSI bus. The CCS makes generic requests to devices such as read, write, print a file, etc. The CCS provides an easy way for all devices to talk to each other. One of the benefits of the CCS is that it allows SCSI devices to function independently of the computer's processor and each other. For example, a tape drive on the SCSI bus could backup a hard disk drive on the bus independently of the system processor. This frees the system processor for other important tasks and improves the overall speed of the system.

SCSI Arbitration

Each SCSI device has its own built in intelligence or firmware in a chipset in the device. The firmware allows the device to arbitrate use of the SCSI bus. Since arbitration is essential to how a SCSI system work, we will take a few minutes and review it here. Each device on the bus has it own address, much like homes have an individual street address to identify them. Each device must take a turn using the bus. The process of asking for and receiving permission to use the bus is called arbitration. SCSI devices can make a request of any other bus device or the SCSI controller. The device that makes the request is called the initiator while the device to whom the request is addressed is called the target.

In a SCSI system there can be multiple initiators and targets. However, only two devices can "talk" to each other at any given time. If an initiator requests, say, a hard drive (target) to begin formatting, the hard drive can disconnect itself from the bus while formatting to keep from tying up the bus. Once the formatting process is complete, the hard drive, now the initiator, arbitrates again for use of the bus, with the original initiator device now becoming the target. Since the arbitration process does not involve the use of the system processor, the processor is free to do other tasks making the entire system very efficient.

If two devices (initiators) make a request or arbitrate to use the bus at the exact same time, the device with the highest ID bit or best address gets first priority to use the bus. For example, if a device with an address of "1" and a device with an address of "7" arbitrate for the bus at the exact same time, the device with the address of "1" would receive first priority to use the bus. The second device would have to arbitrate for the bus again until access is granted.

Multiprocessing

One of the big bottlenecks in today's computer systems is the difference in processing speed between the solid state microprocessor, the CPU (Central processing Unit or system processor) and the mechanical hard disk. A disk head can find data in .01 seconds, which is fast by mechanical standards, but is an eternity to a solid state CPU which can perform millions of operations in that time.

This bottleneck effect becomes even more severe in multi-tasking operating systems like Windows NT that may have several open applications making requests of the hard drive at the same time. The same is true in a file server environment where several different workstations making requests of the server at the same time.

The SCSI protocol provides for multitasking. The SCSI controller can process more than one task at a time. When you need more speed in a SCSI system you add more hard drives. This is probably exactly opposite of what most people would expect. Since the controller can handle more than one task, it simultaneously issues requests to several hard drives. When a disk finds a piece of requested data, the controller transfers the data back to the CPU and operating system while the other hard drives continue searching.

Single Ended and Differential

There are two basic types of electrical connections associated with SCSI: single ended and differential. In single ended connections, the voltage on one data wire (line) inside the cable determines that lines' signal state, i.e., whether it is carrying a signal or not. In differential connections, the difference in voltage between two data wires (lines) determines the lines' state.

The number of individual data wires inside a cable is the same whether it is single ended or differential, the difference lies in how those wires are used. Each data wire inside the cable is paired with another wire. In single ended connections, each data or signal line is paired with a ground wire or line. Whereas in a differential connection, both lines of the twisted pair are signal lines, one is positive while the other is negative electrically.

Single ended is the most popular connection used since it requires less pins for signal transmission, uses less expensive wire, and simpler electronics. But single ended connections are more prone to noise and interference, making cable lengths shorter. Although differential requires twice as many signal lines for the same number of signals, it allows much longer cable or segment lengths.

Single Ended, Differential or LVD? - The Choice

The choice of SCSI transceivers (also called drivers and receivers) determines the maximum bus length and number of devices that can be supported. The majority of existing SCSI devices use single-ended transceivers, which have been adequate for most applications. However, increasing the bus speed has decreased the maximum bus length when single-ended transceivers are used. High-powered differential transceivers overcome the bus length limitations imposed by single-ended transceivers, however their use is limited to those applications that can bear the added expense.

A new transceiver technology, Low-Voltage Differential (LVD), will combine the best features of single-ended and high-power differential transceivers. LVD will also enable higher speeds. To ease the migration to LVD, most new devices will support Universal transceivers which include both single-ended and LVD transceivers. The STA (SCSI Trade Association) recommends the use of Universal transceivers.

Cable Construction - SCSI -1

Cables for SCSI-1 applications can be effectively divided into two wire types: 19 twisted pair and 25 twisted pair. Both wire types are shielded with aluminum mylar foil and copper tinned braid shielding. 19 twisted pair wire is traditionally associated with Macintosh SCSI systems, although Mac SCSI cables will work in many PC SCSI applications. The individual data conductors can be either 26 or 28 gauge. Apple's original SCSI specifications call for 26 AWG wire, however, wire impedance and the location of key signals lines request and acknowledge in the cable core are more important that the wire gauge. The correct impedance for Macintosh SCSI applications is 105 Ohms. 25 twisted pair wire is the most commonly used wire for most SCSI-1 applications. System Connection 25 pair wire is built with the important acknowledge and request signal lines being located in the center of the wire bundle.

Shielding is critical at the connector ends as well. Molded SCSI-1 cables have a copper foil shield placed over the premold that is then soldered completely on all edges to either the connector or the cable braid. Cables with assembled hoods have copper tape and a cable clamp over the exposed cable shielding. A drain wire is also soldered to each connector. Occasionally, the connector backshell itself can also be shielded.

Cable Construction - SCSI-2 (Fast SCSI, Fast Wide SCSI)

The bulk wire used for SCSI-2 (Fast SCSI, Fast Wide SCSI) is the same as that used in SCSI-1 applications. The wire gauge used for most SCSI-2 applications is 28 AWG. SCSI-2 cables come in both single ended and differential versions. Single ended impedance should be 90 Ohms, while differential impedance should be 135 Ohms. Basic construction techniques are the same as for SCSI-1 cables, with the acknowledge and request signal lines located in the center of the cable core, how the drain wire is attached, and how assembled cables are shielded. From April 1997 forward, all 25 twisted pair wire will conform to the higher Ultra SCSI specification. For ribbon cable, the center line of the wire can be either .050 or .025 PVC material.

Connectors used include all the SCSI-1 connectors plus .050 50 pin with latches , .050 60 pin and .050 68 pin mini centronics types for RS/6000 type systems, and .050 50 pin mini centronics types used mainly in Japan.

Cable Construction - SCSI-3 (Ultra, Wide Ultra, Ultra 2, Wide Ultra 2 SCSI)

SCSI-3 applications use either 34 twisted pair or 25 twisted pair wire. The same construction techniques used in SCSI-2 applications are used.
SCSI-3 supports single-ended, differential and low voltage differential connection types. The higher speeds of Ultra and Ultra 2 translate into greater susceptibility to inductance and interference from outside sources. Ultra wire has a higher impedance value, and there are other differences, such as data wire insulation etc. that make it better suited for the higher transmission speeds.

Ultra specification cables can be 28 or 30 AWG wire. With an impedance of 90 Ohms +/- 6 Ohms for single ended. Ultra SCSI differential impedance is with Low Voltage Differential impedance being 135 Ohms. Ultra cables that use SCSI-1 or SCSI-2 type connectors need to specify if the cable should be built with the upper 8 bytes (single lines) open (unterminated), or terminated with resistor packs. Ultra 2 cables typically use 30 AWG Ultra-2 wire, do not typically support single ended type of connections and operate ideally with LVD type connections. Hoods for these cables are usually powder coated metal.

Ribbon cables for both Ultra and Ultra 2 applications are built with TPE or FEP solid core wire with solid core compatible connectors. Connectors used include all SCSI-1 and SCSI-2 connectors plus .050 68 pin and .8mm 68 pin VHDCI .

SCSI Terminology

At this point, it would be helpful to define some SCSI terminology. The following is an excerpt from A SCSI Trade Association white paper titled "Terminology for SCSI Parallel Interface Technology". Parallel SCSI's long and successful evolution has resulted in the proliferation of terminology. To minimize the resulting confusion over SCSI terms, the SCSI Trade Association (STA) has endorsed the following terminology for defining SCSI bus widths and speeds:

STA Term	SCSI Bus Width in Bits	Max. SCSI Bus Speed (Megabytes)
SCSI-1	8	5
Fast SCSI	8	10
Fast Wide SCSI	16	20
Ultra SCSI	8	20
Wide Ultra SCSI	16	40
Ultra 2 SCSI	8	40
Wide Ultra 2 SCSI	16	80

	Maximum Bus Length, Meters (1)			
	Single-Ended	Differential	LVD	Maximum Devices
SCSI-1	6	25	12	8
Fast SCSI	3	25	12	8
Fast Wide SCSI	3	25	12	16
Ultra SCSI	1.5	25	12	8
Ultra SCSI	3	-	-	4
Wide Ultra SCSI	-	25	12	16
Wide Ultra SCSI	1.5	-	-	8
Wide Ultra SCSI	3	-	-	4
Ultra2 SCSI	(2)	(2)	12	8
Wide Ultra2 SCSI	(2)	(2)	12	16

Notes:

1. This parameter may be exceeded in point-to-point and engineered applications.
2. Single-ended and high-power differential are not defined at Ultra2 speeds.

END OF FILE