

Exploring the WORLD of SCSI

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How SCSI Began

Starting as an interface specifically developed for disk drives, SCSI (Small Computer Systems Interface) has quickly grown to become one of the most often-used interfaces for connecting to and optimizing the performance of a wide variety of peripherals. Originally developed to bring more intelligence into storage peripherals, SCSI has progressed from a storage-only interface into one capable of streamlining the transmission of predominantly larger imaging files between one workstation or server and another. Because it has faster data transmission capability than serial and parallel technologies, SCSI was initially the interface of choice for storage peripherals such as hard drives and tape backup systems. With the growth in PC peripherals and SCSI capability to support multiple devices from one port, SCSI has become the

interface of choice for peripherals that require high-speed data transfer. Peripherals such as hard drives, scanners, tape backup drives, and communication devices utilize SCSI's fast capabilities to interface with a workstation. The connection is made using a SCSI card that is installed inside the computer or, in some cases, is embedded on the main logic board.



Figure 1-1 - An internal view of a standard SCSI drive.

SCSI has a rich and long history in the relatively short time span of the computing industry's existence. The standard recognizes virtually every peripheral type and takes advantage of newer hardware and more

intelligent controllers. The data path has been widened and transfer speeds have been increased to keep pace with system requirements while maintaining backward compatibility from version to version. Table 1-1 provides a sequence of enhancements that have evolved within the SCSI market.

Table 1-1 - SCSI Interface Evolution and Features, 1986-1999

SCSI Type	Year Introduced	Maximum Speed	Cable Length	Number of Devices
SCSI-1	1986	5MBps	6 meters	7
SCSI-2	1988	10MBps	3 meters	7
Ultra SCSI	1992	20MBps	1.5 meters	7
Wide Ultra SCSI	1996	40MBps	3 meters	15
Ultra 2 SCSI	1998	80MBps	12 meters	15
Ultra-3 SCSI	1999	160MBps	12 meters	15

SCSI-1

The original standard, now called SCSI-1, had only one flavor so there is little confusion about it. It is the 8-bit wide, 5MBps (maximum) stuff most of us know as the standard Mac SCSI interface. It supports 8 SCSI IDs, 0-7, one of which must be a host computer. Its great advantage is the 6 meters (20 feet) maximum SCSI chain length it supports and the large number of devices available, particularly scanners and small removable media drives.

SCSI-2, Fast and Wide

SCSI-2 started the trend toward multiple implementations of the same standard – and multiple (and confusing!) names. SCSI-2 implementations are known as **Fast** because the maximum transfer rate was doubled to 10 MB per second. A **MegaTransfer** is one MB transfer without regard to bus width.

This was important, because SCSI-2 introduced bus widths wider than one byte to the SCSI standard. (While 32-bit wide transfers are a part of the standard, only 8- and 16-bit implementations have been marketed.) Thus, we get **Fast SCSI**, an 8-bit data interface with a maximum transfer rate of 10 MBps, and **Wide SCSI**, a 16-bit version with a maximum of 20 MBps – the same electrical characteristics and limitations, but twice the number of data lines for twice the throughput. Wide SCSI sometimes goes by the name **Fast and Wide SCSI**, but that usage is dying out.

The addition of the wider data path made it simple to add an address line to the standard, so **all Wide SCSI implementations support 16 IDs (0-15)**. The SCSI-2 standard supports all the IDs, so Wide SCSI can support up to 15 devices plus a host.

The improved transfer rate came with the penalty of reduced SCSI chain length, limited to 3 meters (9.8 feet). It is important to understand that ribbon and simple twisted pair cables, while cheap, are not optimum transmission devices for high-speed digital signals. These signal pulses bounce back along wires whenever they encounter any change in the construction of the wiring and generate crosstalk, ghost signals in adjacent wires. The longer the cable and the faster the pulse rate, the more these effects degrade the signal, placing limits on cable length and/or transfer speed.

SCSI-3, Ultra SCSI

By the time SCSI-3 came along, inexpensive electronics that could resolve faster pulses were practical in consumer gear. This let engineers double the internal clock rate of SCSI processors, and Ultra SCSI was born with 20 MB per second performance. In theory, both narrow (8-bit) and wide (16-bit) Ultra SCSI interfaces are defined, but it is rare to see a device with narrow Ultra SCSI fitted to it. Thus, Ultra SCSI devices operating on a wide bus can do 40 MBps. If they are included on a narrow chain, they max out at 20 MBps, just like Wide SCSI.

Unfortunately, increasing the clock rate doesn't change the behavior of the cables, so **Ultra SCSI is sensitive to cable length**. Three meters (9.8 feet) Ultra SCSI chains will work reliably, but only when no more than five total devices (including the host) are attached. Limiting the chain length to 1.5 meters (4.9 feet) allows six to eight total devices on the chain. For reasons I won't go into here, eight total devices is the practical limit for Ultra SCSI.

Ultra2, LVD SCSI

But there is more to the SCSI standards than discussed so far. One of the specs is the electrical transmission method that defines voltages and other characteristics on each wire in the interface. Without getting into a long discussion, suffice it to say other implementations that sacrificed cost and compatibility for longer cable lengths have been around since SCSI-2, but they don't apply to the desktop systems most users will encounter.

However, under SCSI-3 a new, relatively inexpensive and completely compatible electrical standard allowing long cable lengths was defined. This is known as **Ultra2**, also called **LVD SCSI**. By devoting two wires to each

signal and only looking at the difference between them, the limitations of cable effects on signal integrity is greatly reduced. This doesn't double the numbers of wires in the cable, because conventional designs pair each signal wire with a common ground wire, but it does double the number of line drivers required, so it is more expensive.

Ultra2 takes advantage of this connection standard to produce a bus with a 40 MegaTransfer per second maximum transfer rate, a maximum cable length of 12 meters (29.4 feet), and support for 16 device IDs on the SCSI chain. Since it is invariably offered only in a wide version, the maximum transfer rate is 80 MBps.

To sum it all up, here's a list of the major characteristics of each SCSI level:

SCSI-1	5MBps <6 meter (19.6 feet) cables 8 IDs, 8 supported
SCSI-2	Fast SCSI 10 MBps <3 meter (9.8 feet) cables 8 IDs, 8 supported Wide SCSI 20 MBps <3 meters (9.8 feet) cables 16 IDs, 16 supported
SCSI-3, Ultra SCSI (specs vary by cable length and bus width, but no separate naming conventions)	Narrow Ultra 20 MBps 8 IDs

Wide Ultra

40 MBps

16 IDs

5 devices supported on <3 meter
(9.8 feet) cables, six to eight devices
supported on <1.5 meter cables

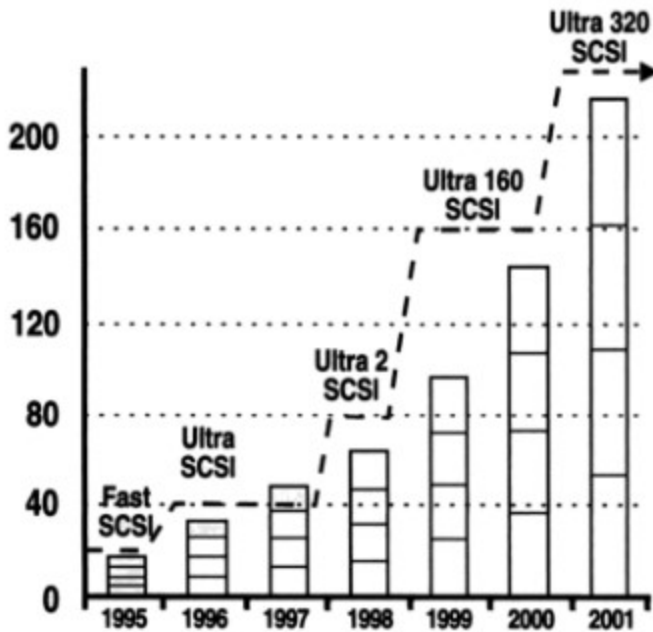
Ultra2 SCSI

80 MBps

<12 meter (29.4 feet) cables

16 devices supported in wide

Figure 1-2 - Chart of sustained transfer rate for one hard-disk drive. Each block within a column represents the sustained transfer rate for one hard disk.



SCSI Design Objectives

The capability of connecting seven devices via one SCSI port, has been available from the first revision of SCSI technology. Most interfaces were initially designed for a specific application, which still limits the type of equipment they support. For example, the parallel port was initially designed for printer use only and has subsequently been enhanced to support other peripherals. Because it was not initially designed for multiple devices, there are still many compatibility issues when connecting more than one device to a parallel port.

SCSI Features and Benefits

In addition to SCSI's large number of available peripherals, SCSI provides some unique features and benefits not available on other interfaces. Table 2 displays SCSI features and their benefits.

SCSI is an entirely different interface than IDE or the enhanced AT disk interface. It is more of a system-level interface, meaning that it does not only deal with disk drives. It is not a controller, like IDE, but a separate bus that is hooked to the system bus via a host adapter. A single SCSI bus can hold up to eight units, each with a different SCSI ID, ranging from 0 to 7. The host adapter takes up one ID, leaving seven IDs for other hardware. SCSI hardware typically consists of hard drives, tape drives, CD-ROMs as well as scanners.

And SCSI's popularity is increasing. Speed seems to be the main reason for this, although it will be shown later on in the book that this isn't necessarily anything to get excited about. One advantage is that there are a multitude of hardware types that can use a SCSI bus. The interface is very expandable, whereas IDE is pretty much limited to hard drives and CD-ROMs.

The reason for the slow acceptance of SCSI is the lack of standard. Each company seems to have its own idea of how SCSI should work. While the connections themselves have been standardized, the actual driver specs used for communication have not. The end result is that each SCSI peripheral has its own host adapter, and the software drivers for the device cannot work with an adapter made by someone else. So, due to the lack of an adapter standard, a standardized software interface, and a standard BIOS for hard drives attached to the SCSI adapter, SCSI can be a mess for the end user.

Table 2 - SCSI Interface Features and Benefits

Features	Benefits
Single connection	Simple to add additional devices
Up to 15 devices	More choices and capabilities
Internal and/or external	Connection flexibility
Highest performance	Faster data transfer between computer and peripheral
Compatibility	Backward compatibility from one version to the other
Intelligent interface	Uses fewer system resources
Multitasking	Simultaneous access by multiple applications
High MTBF	Increase value of investment

SCSI Evolution

SCSI has become increasingly the interface of choice for workstation, server, and computer designers as well as users who need a bus-based storage solution. SCSI also was developed mainly because the BIOS in those systems were designed to use the ST506/412 controller. At the register level though, SCSI was very different, and would have required an entirely new set of BIOS in the PC. When this feature first started, hard drives could only be used with DOS. Later, Adaptec and Future Domain designed adapters that could be used with non-DOS operating systems.

Many high-end systems have built-in SCSI support. There is usually an adapter card or an adapter built in to the motherboard. This native support for SCSI was set in motion by IBM. Many manufacturers followed this example. As a result, SCSI integration is becoming very easy to work with and will get easier as technology progresses.

SCSI Standards

SCSI-1 was standardized by ANSI in 1986. While this outlined the physical and electrical traits of SCSI, it failed to outline a common set of commands so that all manufacturers' hardware would work together. The industry then decided to agree on a minimum set of 18 basic commands called the Common Command Set (CCS). All SCSI hardware supported the CCS.

CCS became the basis for SCSI-2, a more advanced version of the original SCSI that provided extra commands for other types of devices. SCSI-2 also provided extra speed with options called Fast SCSI and a 16-bit version called Wide SCSI. A feature called command queuing gave the SCSI device the ability to execute commands in an order that would be most efficient. This is most useful on hard drives using OSes that multitask.

The standard for SCSI-1 and SCSI-2 is somewhat clouded. Almost all features and commands of SCSI-1 are supported in SCSI-2, and most SCSI-1 hardware is called SCSI-2. Many manufacturers boast that their equipment is SCSI-2. This makes it seem better, but in reality it may not support the extra features that were included in the true SCSI-2 revision. Of course this also means that SCSI-1 adapters will work with SCSI-2 hardware. SCSI-1 and SCSI-2 compliant hardware is the same.

A SCSI-3 standard is being worked on, although features of this new standard are already in use by some manufacturers. Such drives run in Fast-20 mode or an Ultra-SCSI mode. These speed rates are defined below.

Data Transfer Rates

Below is a quick reference table describing the data transfer rates.

Bus Width	Standard	Fast SCSI	Ultra SCSI	Cable
8-bit	5 MB/sec	10 MB/sec	20 MB/sec	50-pin
16-bit	10 MB/sec	20 MB/sec	40 MB/sec	68-pin

Fast SCSI delivers a 10 MB/sec transfer rate. When combined with the 16-bit bus, this doubles to 20 MB/sec. This is called Fast-Wide SCSI.

Ultra-SCSI, also called Fast-20 SCSI, is twice as fast as Fast SCSI. It is part of the SCSI-3 setup, which has not been standardized but is still being sold in high-speed drives. Ultra SCSI delivers 20MB/sec over the 8-bit bus. Ultra-Wide SCSI incorporates the 16-bit bus, and the speed raises to 40MB/sec.

Benefits of SCSI

The benefits of SCSI are probably best identified by listing the reasons why someone would use SCSI.

- SCSI makes it much easier to add new peripheral devices to a computer system.
- Because the development cycle for SCSI devices is very short, the latest generation of SCSI peripherals keeps pace with the latest generation of computer systems.
- SCSI maintains high performance standards which is why SCSI is still the dominant interface for medium and large systems.
- Because SCSI is an intelligent interface (the intelligence about I/O operations is moved from the host to the peripheral device), computer systems can use a standard set of commands to accomplish moving data between the host and device.
- Along with the simplicity of the SCSI interface, it is possible to connect a new peripheral device to an existing system with no hardware changes or additional hardware parts.
- SCSI has a demonstrated track record of keeping pace with the growing and evolving requirements of desktop and server systems.

Figure 1-3

	Capacity	Data Protection/ Backup	Distribution	Archiving	TECHNICAL	
					Transfer Rate (sustained)	Disk Capacity
Hard Drive	★★★★	★★	n/a	★	15 to 17 MB/sec	2 GB to 18 GB
Large-capacity removable drive	★★★★★	★★★★★	★★★★	★	6.6 MB/sec	1 GB to 4.7 GB
CD-R CD-RW	★	★	★★★★★	★★★★★	1.8 MB/sec**	650 MB
Tape	n/a	★★★★	★	★★	83 KB/sec to 917 KB/sec	2 GB to 10 GB