

INTRODUCTION

SCSI is actually an acronym for Small Computer System Interface and it is pronounced as “skuzzy”. It is the second-most popular hard disk interface used in PCs today. It's a high-speed, intelligent peripheral I/O bus with a device independent protocol for transferring data between different types of peripheral devices. The SCSI bus connects all parts of a computer system so that they can communicate with each other. The bus frees the host processor from the responsibility of I/O internal tasks. A SCSI bus can be either internal, external, or cross the boundary from internal to external. The SCSI protocol is a peer-to-peer relationship: one device does not have to be subordinated to another device in order to perform I/O activities. Only two of these devices can communicate on the bus at any given time.

Each SCSI bus can connect up to 8 or up to 16 peripherals; one of those devices will always be the computer or the SCSI card, because they too are devices on the SCSI. SCSI devices are designated as either initiators (drivers) or targets (receivers) and the interface to the host computer is called the host adapter. Every device connected to the bus will have a different SCSI ID, ranging from 0 to 7. The host adapter takes up one ID leaving 7 ID's for other hardware. SCSI hardware typically consists of hard drives, tape drives, CD-ROMs, printers and scanners. .

The reason for the slow taking 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 been. The end result is that each piece of SCSI hardware has its own host adapter. 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.

HISTORY AND EVOLUTION

In the beginning, one couldn't even use a hard drive on the bus. This was mainly because the BIOS in those systems were designed to use the ST506/412 controller. With the IDE, the BIOS was easily changed because of the similarity to ST506/412 on the WD1003 controller. At the register level, though, SCSI was very different, and would have required an entirely new set of BIOS in the PC.

What we currently know of as the SCSI interface had its beginnings back in 1979. Shugart Associates, led by storage industry pioneer Alan Shugart (who was a leader in the development of the floppy disk, and later founded Seagate Technology) created the Shugart Associates Systems Interface (SASI). This very early predecessor of SCSI was very rudimentary in terms of its capabilities, supporting only a limited set of commands compared to even fairly early "true" SCSI, and rather slow signaling speeds of 1.5 Mbytes/second. For its time, SASI was a great idea, since it was the first attempt to define an intelligent storage interface for small computers. The limitations must be considered in light of the era: we are talking about a time when 8" floppy drives were still being commonly used.

Shugart wanted to get SASI made into an ANSI standard, presumably to make it more widely-accepted in the industry. In 1981, Shugart Associates teamed up with NCR Corporation, and convinced ANSI to set up a committee to standardize the interface. In 1982, the X3T9.2 technical committee was formed to work on standardizing SASI. A number of changes were made to the interface to widen the command set and improve performance. The name was also changed to SCSI; I don't know the official reason for this, but I suspect that having Shugart Associates' name on the interface would have implied that it was proprietary and not an industry standard. The first "true" SCSI interface standard was published in 1986, and evolutionary changes to the interface have been occurring since that time.

It's important to remember that SCSI is, at its heart, a system interface, as the name suggests. It was first developed for hard disks, is still used most for hard

disks, and is often compared to IDE/ATA, which is also used primarily for hard disks. For those reasons, SCSI is sometimes thought of as a hard disk interface. However, SCSI is not an interface tied specifically to hard disks. Any type of device can be present on the bus, and the very design of SCSI means that these are "peers" of sorts--though the host adapter is sort of a "first among equals". SCSI was designed from the ground up to be a high-level, expandable, high-performance interface. For this reason, it is frequently the choice of high-end computer users. It includes many commands and special features, and also supports the highest-performance storage devices.

Of course, these features don't come for free. Most PC systems do not provide native, "built in" support for SCSI the way they do for IDE/ATA, which is one of the key reasons why SCSI isn't nearly as common as IDE/ATA in the PC world. Implementing SCSI on a PC typically involves the purchase of a storage device of course, but also a special card called a host adapter. Special cables and terminators may also be required. All of this means that deciding between SCSI and IDE/ATA is an exercise in tradeoffs.

SCSI began as a parallel interface, allowing the connection of devices to a PC or other systems with data being transmitted across multiple data lines. Today, parallel or "regular" SCSI is still the focus of most SCSI users, especially in the PC world. SCSI itself, however, has been broadened greatly in terms of its scope, and now includes a wide variety of related technologies and standards, as defined in the SCSI-3 standard. 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. Their example was followed by many manufacturers. As a result, SCSI integration is becoming very easy to work with and will get easier as technology progresses.

SCSI STANDARDS

SCSI-1

SCSI-1 supports transfer rates of up to 5 Mbps and up to 7 devices on an 8-bit bus (not including the host adapter). The most common types of connectors for SCSI-1 are the Amphenol 50-pin for external connectivity and 50-pin Dual-Row Socket F (IDC) connectors for internal connections.

SCSI-2

Approved by ANSI in 1994, SCSI-2 raised the bar to 10 Mbps on a 16 bit bus. Using the 32 bit bus from the standard, known as "Wide SCSI", the rate increases to 20 Mbps. SCSI-2 can run as high as 40 Mbps when combining both the Fast and Wide specifications of the SCSI-2 standard. SCSI-2 usually uses a Micro-D subminiature 50-pin connector for external cables. Internally, like SCSI-1, it connects with the same 50-pin IDC connector.

SCSI-3

Primarily implemented in high-end systems, SCSI-3 commonly uses a 68-pin ribbon cable for in-cabinet connections, and a 68-pin shielded twisted-pair for external connections. Unlike SCSI-1 and SCSI-2, the internal and external 68-pin connectors can be interconnected. Although the most common bus width for SCSI-3 is 16-bit with transfer rates of 20 Mbps, SCSI-3 has specifications for 80 Mbps (Ultra2) and 160 Mbps (Ultra160) throughputs. The Ultra2 and Ultra160 use a technology called Low Voltage Differential (LVD) to achieve higher speeds at nominal cable distances.



The first SCSI standard was approved by ANSI in 1986 as standard X3.131-1986. To avoid confusion when subsequent SCSI standards came out, the original specification was later renamed "SCSI-1". SCSI-1 defines the basics of the first SCSI buses, including cable length, signaling characteristics, commands and transfer modes. Devices corresponding to the SCSI-1 standard use only a narrow (8-bit) bus, with a 5 MB/s maximum transfer rate. Only single-ended transmission was supported, with passive termination. The most common types of connectors for SCSI-1 are the Amphenol 50-pin for external connectivity and 50-pin Dual-Row Socket F (IDC) connectors for internal connections.

LIMITATIONS OF SCSI 1

It was quite limited, especially by today's standards, and defined only the most fundamental of SCSI features and transfer modes. It did not include definitions of a device independent interface. So it wasn't guaranteed that any device can be connected. SCSI-1 is now obsolete, and the standard has in fact been withdrawn by ANSI.

Devices that adhere to the SCSI-1 standard can in most cases be used with host adapters and other devices that use the higher transfer rates of the more advanced SCSI-2 protocols, but they will still function at their original slow speed. Since all SCSI-1 devices are single-ended, they may cause performance degradation if placed onto a multimode LVD SCSI bus. If you want to run LVD devices to their full potential, you will want to avoid mixing them with single-ended devices



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In 1985, a year before the SCSI-1 standard was formally approved; work began on the SCSI-2 specification. Important goals of this evolution of the SCSI standard were to improve performance, enhance reliability, and add features to the interface. However, the most important objective was to formalize and properly standardize SCSI commands. After the confusion that arose from the non-standardized implementations of original SCSI, a working paper was created to define a set of standard commands for SCSI hard disks, called the common command set or CCS. This paper eventually formed the basis for the new SCSI-2 standard. SCSI-2 was approved by ANSI in 1994 and released as document X3.131-1994. SCSI-2 is an extensive enhancement of the very limited original SCSI. The command set used for SCSI devices was standardized and enhanced, and several confusing "options" removed. In addition, the standard defines the following significant new features as additions to the original SCSI-1 specification:

There were also several other minor changes to the standard, mostly low-level technical changes. It is important to note that one of the major design criteria in the creation of SCSI-2 was backward compatibility with SCSI-1. SCSI-2 devices will in most cases work with older SCSI-1 devices on a bus. This is not always done, however, because the older devices have no ability to support the SCSI-2 enhancements and faster transfer protocols.

Advantages of SCSI 2

Fast SCSI: This higher-speed transfer protocol doubles the speed of the bus to 10 MB/s transfer rate with 8-bit regular SCSI cabling

Wide SCSI: The width of the original SCSI bus was increased to 16 (or even 32) bits.

More Devices per Bus: On buses that are running with Wide SCSI, 16 devices are supported (as opposed to 8 with regular SCSI).

Improved Cables and Connectors: SCSI uses a large number of different cable and connectors. SCSI-2 defined new higher-density connections, extending the basic 50-pin connectors defined in SCSI-1.

Active Termination: Termination is an important technical consideration in setting up a SCSI bus. SCSI-2 defined the use of active termination, which provides more reliable termination of the bus.

Differential Signaling: To allow longer cable lengths, differential signaling was introduced. This was later renamed "high-voltage differential".

Command Queuing: A SCSI-2 feature that is used when the initiator wants to send multiple commands to the same SCSI address. Tagged queues allow the target to store up to 256 commands per initiator

Additional Command Sets: SCSI-2 added new command sets to support the use of more devices such as CD-ROMs, scanners and removable media. The older command set focused more on hard disks.



SCSI-3 changes the complete SCSI document structure and are no longer one document but a collection of documents, each with its own revision number.

Some of these documents are the

1. SCSI Primary Command (SPC) set layer,
2. SCSI Block Commands (SBC) for hard disk interface
3. SCSI Stream Commands (SSC) for tape drives
4. SCSI Controller Commands (SCC) for RAID arrays
5. Multimedia Commands (MMC)
6. Media Changer Commands (MCC)
7. The SCSI Enclosure Services (SES) commands.

Let's take a look at some other important SCSI-3 documents:

SPI

The SCSI Parallel Interface (SPI) defines the electrical signals and connections for parallel SCSI. A very quickly adapted new feature defined in SCSI-3 is the 68-pin, high density, micro-D connector for 16-bit Wide SCSI (termed the Alternative 3, P-connector). This connector eliminates the necessity of using two cables for 16-bit SCSI and gave a tremendous boost to the growth of Wide SCSI.

There are several revisions of the SPI document.

Fast SCSI: data transfer speeds up to 10 Megatransfers (20 Mbytes/sec for 16-bit).

The Ultra SCSI: (Fast-20) modification of SPI includes doubling the data throughput to 20 Megatransfers/sec (40 Mbytes/sec for 16-bit).

SPI-2

SPI-2 doubles bus speed again to the Ultra 2 (Fast-40) SCSI data throughput of 40 Megatransfers/s (80 Mbytes/s for 16-bit).

To attain this speed, a new electrical interface is defined. This interface uses 3 V logic instead of TTL voltage levels and is known as Low Voltage Differential (LVD) SCSI. The older TTL based differential SCSI is now called High Voltage Differential (HVD) and it is not compatible with LVD signals.

SPI-3

SPI-3 again doubles the SCSI bus speed to Ultra 3 (also known as Ultra160 and Fast-80) providing SCSI bus speeds up to 80 Megatransfers/sec (160 Mbytes/sec for 16-bit). Double Transition (DT) clocking is used to double the data transfer rate from Ultra 2 (Fast-40) to Ultra 3 (Ultra 160 or Fast-80) SCSI without having to increase the clock speed. For this speed, clocking on both the rising and falling edges of the REQ and ACK clock is required. This is called Double Transition (DT) clocking and is defined for the 16-bit bus only.

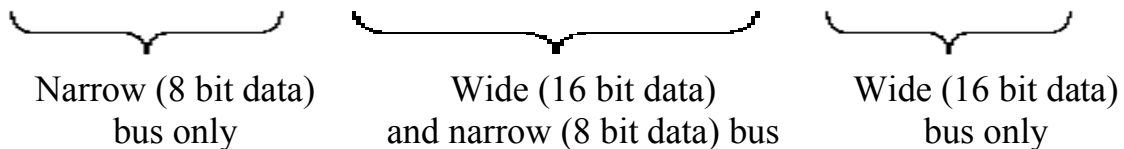
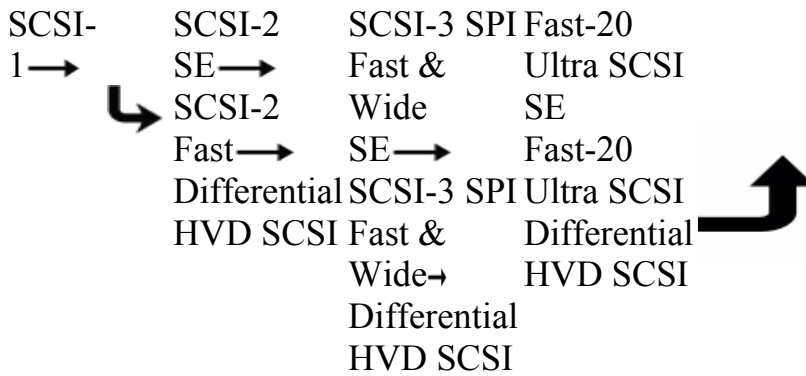
SPI-4

Spi-3 is again modified by increasing the bus speed to Ultra 4(Ultra 320) providing bus speed up to 160 Megatransfers/sec (320 Mbytes/sec for 16-bit).

7 GENERATIONS OF SCSI

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|---------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|---|---|
| Up to 5 Megabytes Per Second | Up to 10 Megabytes Per Second | Up to 20 Megabytes Per Second | Up to 40 Megabytes Per Second | Up to 160 Megabytes Per Second | Up to 320 Megabytes Per Second |
|---------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|---|---|

| | | |
|--------------------------------------|----------------------------------|----------------------------------|
| Ultra2 SCSI | Ultra3 or Ultra160 SCSI | Ultra320 SCSI |
| Fast-40 SPI- 2→ LVD SCSI | Fast-80 SPI-3→ LVD SCSI | Fast-160 SPI-4 LVD SCSI |



The Three electrical levels of SCSI:

SE = Single Ended

HVD SCSI or Differential SCSI = High voltage differential SCSI,

LVD SCSI = Low voltage differential SCSI

ROLE OF T10 COMMITTEE

There was a time that SCSI standards were relatively few, and not that difficult to understand. That time is now long past. In some ways, the best way I could describe the current situation regarding SCSI standards, feature sets and marketing terms is that it makes the standards and terms associated with IDE/ATA seem simple by comparison. That would really be a rather strong indictment, however, so I won't say that. Still, understanding all of the documents and labels associated with SCSI can be very baffling at times.

It's not that the standards are poorly written, or that the technology is all that hard to understand. The main issue with SCSI today is that it has become so broad, and includes so many different protocols and methods, that it's hard to get a handle on all of it. The confusion surrounding SCSI standards has increased since the creation of SCSI-3, which is really a collection of different standards, some of them rather different from each other. The situation is made worse by manufacturers that like to create funky new "unofficial names" for transfer modes or feature sets, or apply overly-broad labels to specific hardware.

The first organization that was charged with developing the first SCSI standard was ANSI technical committee X3T9.2. Today, SCSI standards are developed, maintained and approved by a number of related organizations, each playing a particular role.

Here's how they all fit together:

- **American National Standards Institute:** ANSI is usually thought of as an organization that develops and maintains standards, but in fact they do neither. They are an oversight and accrediting organization that facilitates and manages the standards development process. As such, they are the "high level management" of the standards world. They qualify other organizations as Standards Developing Organizations or SDOs. ANSI also publishes standards once they have been developed and approved.

- **Information Technology Industry Council:** ITIC is a group of several dozen companies in the information technology (computer) industry. ITIC is the SDO approved by ANSI to develop and process standards related to many computer-related topics.
- **National Committee for Information Technology:** NCITS is a committee established by ITIC to develop and maintain standards related to the information technology world. NCITS was formerly known under the name "Accredited Standards Committee X3, Information Technology", or more commonly, just "X3". It maintains several sub-committees that develop and maintain standards for various technical subjects.
- **T10 Technical Committee:** T10 is the actual technical standards committee responsible for the SCSI interface.

If you boil all of this down, T10 is the group that actually does the work of developing new SCSI standards. The other organizations support their activities. The T10 group is comprised primarily of technical people from various hard disk and other technology companies, but the group (and the development process itself) is open to all interested parties. Comments and opinions on standards under development are welcomed from anyone, not just T10 members. The standards development process is intended to create consensus, to ensure that everyone who will be developing hardware and software agrees on how to implement new technology.

Once the T10 group is done with a particular version of a standard, they submit it to NCITS and ANSI for approval. This approval process can take some time; which is why the official standards are usually published several years after the technology they describe is actually implemented. While approval of the standard is underway, companies develop products using technology described in the standard, confident that agreement has already been reached. Meanwhile, the T10 group starts work on the next version of the standard. With SCSI-3 now including a number of different "sub-standards", it is in some ways constantly "under development".

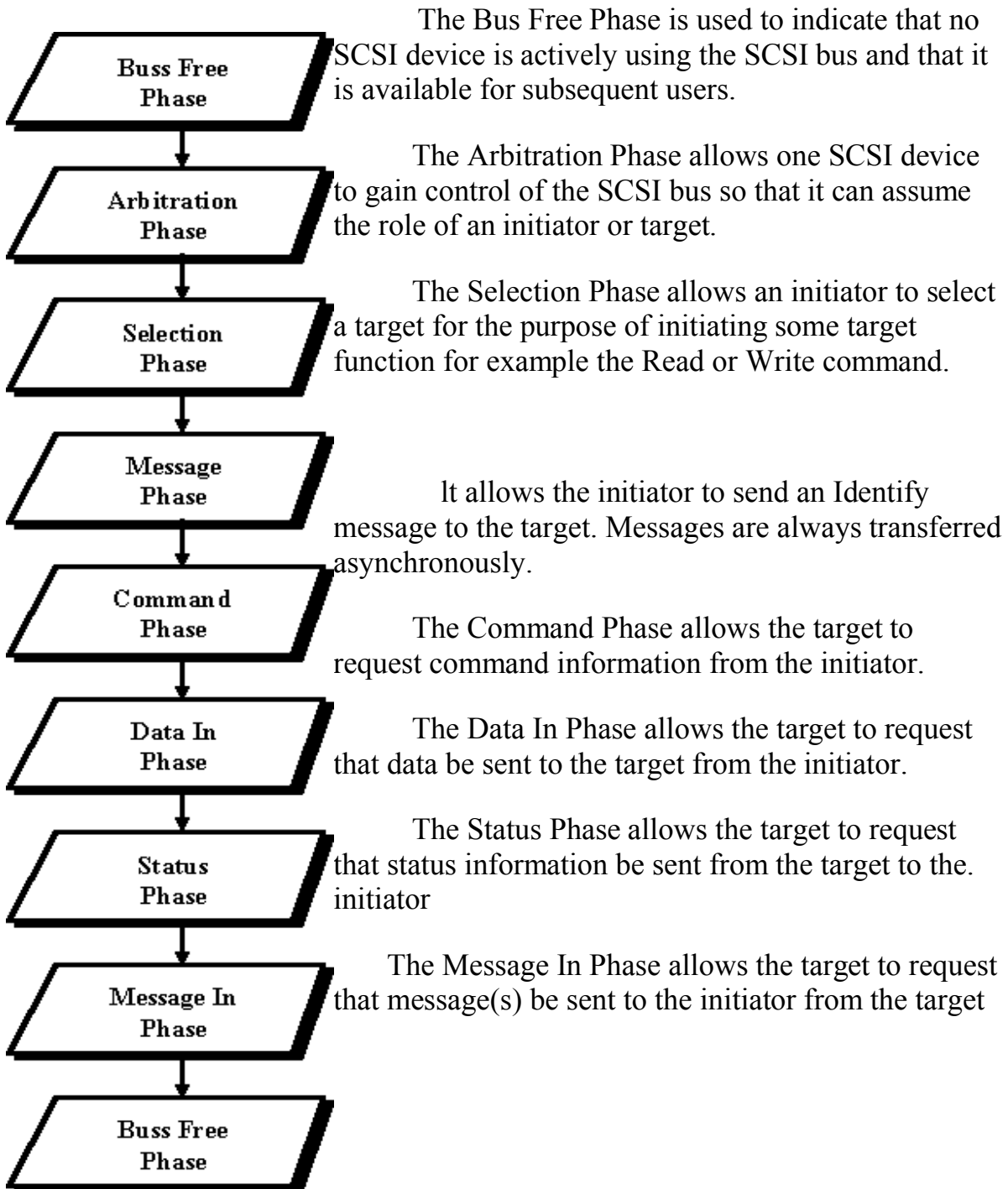
There are also other organizations that are involved in the creation and maintenance of SCSI-related standards. Since SCSI-3 has a broad scope, it defines and structures certain standards that are in fact "owned" by other groups. In particular, the documents describing the physical layer for Fibre Channel are developed by the T11 technical committee, and the IEEE-1394 interface is of course an IEEE standard.

BUS PHASES

The Small Computer System Interface bus can be time-shared, which results in greater usage of bus bandwidth. This is how it works: while one device is using the bus, other devices may be active and performing internal activities. Devices do not use the bus unless they are involved in data transfer or have status to report. Devices may disconnect from the bus while time-consuming activities internal to the device are occurring. As soon as a device is ready to resume communication, the device can arbitrate for the bus (when the bus is free) to reattach to the host. System performance is significantly increased when devices disconnect and reconnect to the bus. During the bus phases (Figure 2), devices must first contend for access to the bus. Then a physical path is established between the initiator and target. Remember, the SCSI bus cannot be in more than one phase at a time.

On a busy system, the SCSI bus may be free. For as little as 1.2ps while there is no device requesting the bus. Or, it could remain in the bus free state indefinitely.

A device can arbitrate and win the bus in 3.6ps or less. Devices that lose arbitration can try again when the bus is free. The Selection phase can occur in 580 ns. If the target does not respond, the bus is free in about 250ms. The target controls the bus after the selection phase. This is the first information transfer phase in the connection. It allows the initiator to send an Identify message to the target. Messages are always transferred asynchronously. Six Inquiry command bytes are transferred asynchronously from the initiator to the target. The target responds with Inquiry data. The data is transferred synchronously if both the target and the initiator have previously established a synchronous data Transfer. The target sends a single status byte asynchronously. The last information that is transferred in the connection is typically the Command Complete message. The target releases all signals within 10ls of the initiator's acknowledgement of the previous message. The initiator releases any signals it may be driving within 800ns of its detection of the BSY signal.



SCSI V/S IDE

SCSI can connect devices both inside and outside the box with up to 7 drives on a narrow bus or up to 15 drives on a wide bus versus IDE is limited to an 18 inch bus, inside the box with 2 devices per bus. IDE buses execute one command at a time versus SCSI allows queuing to each of the devices on the bus. IDE takes up to 95% of the CPU during data transfers, SCSI only uses about 5% of the CPU for buffer management.

SCSI is a much higher-level protocol than IDE is. In fact, while IDE is an interface, SCSI is really a system-level bus, with intelligent controllers on each SCSI device working together to manage the flow of information on the channel. SCSI supports many different types of devices, and is not at all tied to hard disks the way IDE/ATA is--ATAPI supports non-hard-disk IDE devices but it is really a kludge of sorts. Since it has been designed from the ground up as almost an additional bus for peripherals, SCSI offers performance, expandability and compatibility unmatched by any other current PC interface.

SCSI is an entirely different interface than the more popular IDE. 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

CONCLUSION

From the beginning the SCSI standard was carefully planned and evolved over some years before being defined as an official ANSI standard. Because of this the SCSI architecture is much more mature than competing interfaces and can evolve and expand further. This is obvious by looking at the SCSI-3 family of standards which quickly has adopted new technologies. It will undoubtedly continue to do so in the future.

Because it is used in more demanding applications SCSI devices usually have a lot of "intelligent" logic to increase performance and are usually of better build quality and this makes them the obvious choice for the high-performance aware that requires reliability and state of the art performance. SCSI devices usually have a higher price tag than their counterparts in the market place but we'd like to point out that *you get what you pay for*. SCSI will always have niche in the computer business because of this.