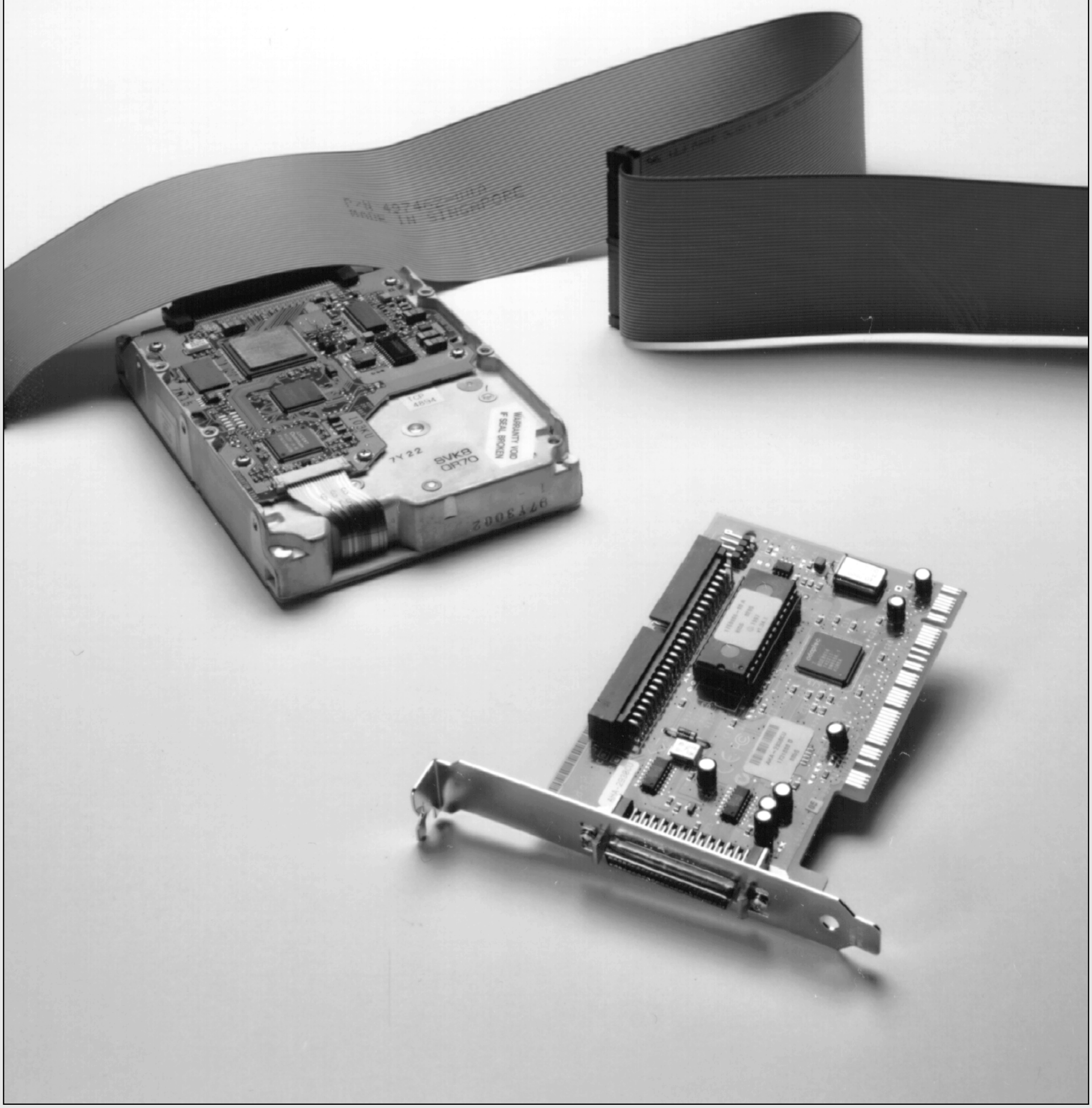
CHAPTER 8

The SCSI Interface



Small Computer System Interface

SCSI (pronounced "scuzzy") stands for Small Computer System Interface and is a general-purpose interface used for connecting many types of devices to a PC. This interface has its roots in SASI, the Shugart Associates System Interface. SCSI is the most popular interface for attaching high-speed disk drives to higher-performance PCs, such as workstations or network servers. SCSI is also very flexible; it is not only a disk interface, but is also a systems-level interface allowing many types of devices to be connected. SCSI is a bus that supports as many as 7 or 15 total devices. Multichannel adapters exist that can support up to 7 or 15 devices per channel.

The SCSI controller, called the *host adapter*, functions as the gateway between the SCSI bus and the PC system bus. Each device on the bus has a controller built in. The SCSI bus does not talk directly with devices such as hard disks; instead, it talks to the controller that is built into the drive.

A single SCSI bus can support as many as 8 or 16 physical units, usually called SCSI *IDs*. One of these units is the SCSI host adapter card in your PC; the other 7 or 15 can be other peripherals. You could have hard disks, tape drives, CD-ROM drives, a graphics scanner, or other devices attached to a single SCSI host adapter. Most systems can support up to four host adapters, each with up to 15 devices, for a total of 60 devices! There are even dual channel adapters that could double that figure.

SCSI is a fast interface, generally suited to high-performance workstations, servers, or anywhere the ultimate in performance for a storage system interface is needed. The latest Ultra4 (Ultra320) SCSI version supports transfer speeds of up to 320MB/sec!

When you purchase a SCSI device such as a SCSI hard disk, you usually are purchasing the device, controller, and SCSI adapter in one circuit; as such the device is ready to connect directly to the SCSI bus. This type of drive usually is called an *embedded* SCSI device—the SCSI interface is built in. For example, most SCSI hard drives are technically the same as their IDE counterparts except for the addition of the SCSI bus adapter circuits (normally a single chip) added to the controller board. You do not need to know what type of controller is inside the SCSI drive because your system cannot talk directly to the controller as though it were plugged into the system bus, like on a standard IDE drive. Instead, communications go through the SCSI host adapter installed in the system bus. You can access the drive only with the SCSI protocols.

Apple originally rallied around SCSI as being an inexpensive way out of the bind in which it put itself with the Macintosh. When the engineers at Apple realized their mistake in making the Macintosh a closed system (with no expansion slots), they decided that the easiest way to gain expandability was to build a SCSI port into the system, which is how external peripherals were originally added to the slotless Macs. Of course, in keeping with Apple tradition, they used a nonstandard SCSI connector. Now that Apple is designing systems with expansion slots, Universal Serial Bus (USB), and FireWire (iLINK or IEEE-1394), SCSI has been dropped from most Macs as a built-in option. Because PC systems always have been expandable, the push toward SCSI has not been as urgent. With up to eight or more bus slots supporting various devices and controllers in PC-compatible systems, it seemed as though SCSI was not as necessary for system expansion. In fact, with modern PCs sporting inexpensive built-in USB ports for external expansion, in most cases SCSI devices are necessary only when top performance is a critical issue.

SCSI has become popular in the PC-based workstation market because of the performance and expandability it offers. One block that stalled acceptance of SCSI in the early PC marketplace was the lack of a real standard; the SCSI standard originally was designed by one company and then turned into a committee-controlled public standard. Since then, no single manufacturer has controlled it.

Note

Most SCSI host adapters bundled with hardware, such as graphics scanners or SCSI CD-ROM, CD-R, or CD-RW drives, will not include all the features needed to support multiple SCSI devices or bootable SCSI hard drives. This has nothing to do with any limitations in the SCSI specification. The situation is simply that the manufacturer has included the most stripped-down version of a SCSI adapter available to save money. It has all the functionality necessary to support the device it came with, but nothing else. Fortunately, with the right adapter and drivers, one SCSI card could support all the SCSI devices in a system from hard drives to optical drives, scanners, tape drives, and more.

In the beginning, SCSI adapters lacked the capability to boot from hard disks on the SCSI bus. Booting from these drives and using a variety of operating systems was a problem that resulted from the lack of a software interface standard. The standard BIOS software in PC systems is designed to talk to ST-506/412, ESDI, or ATA (IDE) hard disks and devices. SCSI is so different from ATA/IDE that a new set of ROM BIOS routines is necessary to support the system so it can self-boot. Also, this BIOS support is unique to the SCSI host adapter you are using; so, unless the host adapter is built into your motherboard, this support won't be found in your motherboard BIOS. Instead, SCSI host adapters are available with BIOS support for SCSI hard disk drives right on the SCSI host adapter itself.

Note

For more information about the ST-506/412 Interface and the ESDI Interface, see "ST-506/412 Interface" and "ESDI Interface," respectively, in the Technical Reference section of the CD accompanying this book. An expanded discussion of both technologies can be found in *Upgrading and Repairing PCs, 6th Edition*, which is included in its entirety in PDF format on the CD with this book.

Because of the lead taken by Apple in developing systems software (operating systems and ROM) support for SCSI, peripherals connect to Apple systems in fairly standard ways. Until recently, this kind of standard-setting leadership was lacking for SCSI in the PC world. This situation changed dramatically with Windows 95 and later versions, which include drivers for most popular SCSI adapters and peripherals on the market. These days, Windows 98/Me and Windows 2000 include even more drivers and support for SCSI adapters and devices built in.

Many PC manufacturers have standardized SCSI for high-end systems. In these systems, a SCSI host adapter card is placed in one of the slots, or the system has a SCSI host adapter built into the motherboard. This arrangement is similar in appearance to the IDE interface because a single cable runs from the motherboard to the SCSI drive. SCSI supports as many as 7 or 15 additional devices per bus (some of which might not be hard disks), whereas IDE supports only 4 devices (2 per controller). Additionally, SCSI supports more types of devices other than hard disks than IDE supports. IDE devices must be a hard disk, an IDE-type CD-ROM drive, a tape drive, an LS-120 SuperDisk drive, a Zip drive, and so on. Systems with SCSI drives are easy to upgrade because virtually any third-party SCSI drive will plug in and function.

ANSI SCSI Standards

The SCSI standard defines the physical and electrical parameters of a parallel I/O bus used to connect computers and peripheral devices in daisy-chain fashion. The standard supports devices such as disk drives, tape drives, and CD-ROM drives. The original SCSI standard (ANSI X3.131-1986) was approved in 1986, SCSI-2 was approved in January 1994, and the first portions of SCSI-3 were approved in 1995. Note that SCSI-3 has evolved into an enormous standard with numerous sections and is an evolving, growing standard still very much under development. Because it has been broken down into multiple standards, there really is no single SCSI-3 standard.

The SCSI interface is defined as a standard by ANSI (American National Standards Institute), specifically by a committee currently known as T10. T10 is a technical committee of the National Committee on Information Technology Standards (NCITS, pronounced "insights"). NCITS is accredited by ANSI and operates under rules approved by ANSI. These rules are designed to ensure that voluntary standards are developed by the consensus of industry groups. NCITS develops information-processing system standards, whereas ANSI approves the process under which they are developed and publishes them. Working draft copies of all SCSI-related standards can be downloaded from the T10 Technical Committee site at `http://www.t10.org`.

One problem with the original SCSI-1 document was that many of the commands and features were optional, and there was little or no guarantee that a particular peripheral would support the expected commands. This problem caused the industry as a whole to define a set of 18 basic SCSI commands called the Common Command Set (CCS) to become the minimum set of commands supported by all peripherals. CCS became the basis for what is now the SCSI-2 specification.

Along with formal support for CCS, SCSI-2 provided additional definitions for commands to access CD-ROM drives (and their sound capabilities), tape drives, removable drives, optical drives, and several other peripherals. In addition, an optional higher speed called Fast SCSI-2 and a 16-bit version called Wide SCSI-2 were defined. Another feature of SCSI-2 is *command queuing*, which enables a device to accept multiple commands and execute them in the order that the device deems to be most efficient. This feature is most beneficial when you are using a multitasking operating system that could be sending several requests on the SCSI bus at the same time.

The X3T9 group approved the SCSI-2 standard as X3.131-1990 in August 1990, but the document was recalled in December 1990 for changes before final ANSI publication. Final approval for the SCSI-2 document was finally made in January 1994, although it has changed little from the original 1990 release. The SCSI-2 document is now called ANSI X3.131-1994. The official document is available from Global Engineering Documents or the ANSI committee—both are listed in the Vendor List on the CD. You can also download working drafts of these documents from the T10 Technical Committee home page as listed previously.

Most companies indicate that their host adapters follow both the ANSI X3.131-1986 (SCSI-1) and the X3.131-1994 (SCSI-2) standards. Note that because virtually all parts of SCSI-1 are supported in SCSI-2, virtually any SCSI-1 device is also considered SCSI-2 by default. Many manufacturers advertise that their devices are SCSI-2, but this does not mean they support any of the additional optional features that were incorporated in the SCSI-2 revision.

For example, an optional part of the SCSI-2 specification includes a fast synchronous mode that doubles the standard synchronous transfer rate from 5MB/sec to 10MB/sec. This Fast SCSI transfer mode can be combined with 16-bit Wide SCSI for transfer rates of up to 20MB/sec. An optional 32-bit version was defined in SCSI-2, but component manufacturers have shunned this as too expensive. In essence, 32-bit SCSI was a stillborn specification, as it was withdrawn from the SCSI-3 standard. Most SCSI implementations are 8-bit standard SCSI or 16-bit Fast/Wide SCSI. Even devices that support none of the Fast or Wide modes can still be considered SCSI-2.

SCSI-3 is broken down into a number of standards. The SCSI Parallel Interface (SPI) standard controls the parallel interconnection between SCSI devices, which is mostly what we are talking about here. So far several versions of SPI have existed, including SPI, SPI-2, SPI-3, and SPI-4. Versions through SPI-3 have been published, whereas SPI-4 is still in draft form.

What can be confusing is that several terms can be used to describe the newer SPI standards, as shown in Table 8.1.

Table 8.1 SPI (SCSI Parallel Interface) Standards

SCSI-3 Standard	Also Known As	Speed	Throughput
SPI	Ultra SCSI	Fast-20	20/40MB/sec
SPI-2	Ultra2 SCSI	Fast-40	40/80MB/sec
SPI-3	Ultra3 SCSI	Fast-80DT	160MB/sec
SPI-4	Ultra4 SCSI	Fast-160DT	320MB/sec

To add to the confusion, SPI-3 or Ultra3 SCSI is also called Ultra160 or Ultra160+, and SPI-4 or Ultra4 SCSI is also called Ultra320 or Ultra320+ by some companies. The Ultra160/320 designation refers to any device that includes the first three of the five main features from the Ultra3/4 SCSI specification. Ultra160/320+ refers to any device that supports all five main features of Ultra3/4 SCSI.

Table 8.2 shows the maximum transfer rates for the SCSI bus at various speeds and widths and the cable type required for the specific transfer widths.

Note

The A cable is the standard 50-pin SCSI cable, whereas the P cable is a 68-pin cable designed for 16-bit transfers. High Voltage Differential (HVD) signaling was never popular and is now considered obsolete. LVD (Low Voltage Differential) signaling is used in the Ultra2 and Ultra3 modes to increase performance and cabling lengths. Pinouts for the cable connections are listed in this chapter in Tables 8.3–8.6.

SCSI is both forward and backward compatible, meaning one can run faster devices on buses with slower host adapters or vice versa. In each case, the entire bus will run at the lowest common denominator speed. In fact, as was stated earlier, virtually any SCSI-1 device can also legitimately be called SCSI-2 (or even SCSI-3) because most of the improvements in the later versions are optional. Of course, you can't take advantage of the faster modes on an older, slower host adapter. By the same token, you can purchase an Ultra3 capable SCSI host adapter and still run older standard SCSI devices. You can even mix standard 8-bit and wide 16-bit devices on the same bus using cable adapters.

SCSI-1

SCSI-1 was the first implementation of SCSI. It was officially known as ANSI X3.131-1986. The major features of SCSI-1 were

- 8-bit parallel bus
- 5MHz asynchronous or synchronous operation
- 4MB/sec (asynchronous) or 5MB/sec (synchronous) throughput
- 50-pin cables with low-density pin-header internal and Centronics-style external connectors
- Single-ended (SE) unbalanced transmission
- Passive termination
- Optional bus parity

SCSI-1 is now considered obsolete; in fact, the standard has been withdrawn by ANSI and replaced by SCSI-2.

Table 8.2 SCSI Types, Data-Transfer Rates, and Cables

SCSI Standard	SCSI Technology	Marketing Term	Clock Speed (MHz)	Transfer Width
SCSI-1	Async	Asynchronous	5	8-bit
SCSI-1	Fast-5	Synchronous	5	8-bit
SCSI-2	Fast-5/Wide	Wide	5	16-bit
SCSI-2	Fast-10	Fast	10	8-bit
SCSI-2	Fast-10/Wide	Fast/Wide	10	16-bit
SPI (SCSI-3)	Fast-20	Ultra	20	8-bit
SPI (SCSI-3)	Fast-20/Wide	Ultra/Wide	20	16-bit
SPI-2 (SCSI-3)	Fast-40	Ultra2	40	8-bit
SPI-2 (SCSI-3)	Fast-40/Wide	Ultra2/Wide	40	16-bit
SPI-3 (SCSI-3)	Fast-80DT	Ultra3 (Ultra160)	40[3]	16-bit
SPI-4 (SCSI-3)	Fast-160DT	Ultra4 (Ultra320)	80[3]	16-bit

**Not including the host adapter.*

Cable Lengths are in meters: 25M = 80ft., 12M = 40ft., 6M = 20ft., 3M = 10ft., 1.5M = 5ft.

SE = Single-ended signaling;

HVD = High Voltage Differential signaling, obsolete

LVD = Low Voltage Differential signaling

SPI = SCSI Parallel Interface, part of SCSI-3

SCSI-2

SCSI-2 is officially known as ANSI X3.131-1994. The SCSI-2 specification is essentially an improved version of SCSI-1 with some parts of the specification tightened and several new features and options added. Normally, SCSI-1 and SCSI-2 devices are compatible, but SCSI-1 devices ignore the additional features in SCSI-2.

Some of the changes in SCSI-2 are very minor. For example, SCSI-1 allowed SCSI bus parity to be optional, whereas parity must be implemented in SCSI-2. Parity is an extra bit that is sent as a verification bit to ensure that the data is not corrupted. Another requirement is that initiator devices, such as host adapters, provide terminator power to the interface; most devices already did so.

SCSI-2 also added several optional features:

- Fast SCSI (10MHz)
- Wide SCSI (16-bit transfers)
- Command queuing
- New commands
- High-density, 50-pin cable connectors
- Active (Alternative 2) termination for improved single-ended (SE) transmission
- High Voltage Differential (HVD) transmission (incompatible with SE on the same bus) for longer bus lengths

Transfer Speed (MB/s)	Max. No. of Devices*	Cable Type	Max. Length (SE)	Max. Length (HVD)	Max. Length (LVD)
4	7	A (50-pin)	6M	25M	-
5	7	A (50-pin)	6M	25M	-
10	15	P (68-pin)	6M	25M	-
10	7	A (50-pin)	3M	25M	-
20	15	P (68-pin)	3M	25M	-
20	7	A (50-pin)	3/1.5M[1]	25M	-
40	7	P (68-pin)	3/1.5M[1]	25M	-
40	7	A (50-pin)	-	-	12M[2]
80	15	P (68-pin)	-	-	12M[2]
160	15	P (68-pin)	-	-	12M[2]
320	15	P (68-pin)	-	-	12M[2]

DT = Double transition, or two transfers per clock cycle, 16-bit only

1 = Ultra SCSI cable total length is restricted to 1.5M if more than 3 devices exist on the bus (not including the host adapter). A maximum of 7 devices is allowed.

2 = A 25M cable may be used if only one device exists (point-to-point interconnect).

3 = Ultra3 (Ultra160) and Ultra4 (Ultra320) SCSI transfer twice per clock cycle and are 16-bit only.

Wide SCSI enables parallel data transfer at a bus width of 16 bits. The wider connection requires a new cable design. The standard 50-conductor, 8-bit cable is called the A cable. SCSI-2 originally defined a special 68-conductor B cable that was supposed to be used in conjunction with the A cable for 32-bit wide transfers. However, because of a lack of industry support and the added expenses involved, 32-bit SCSI was never actually implemented and was finally removed as a part of the SCSI-3 specifications. Therefore, two different types of SCSI cables are now available, called the A cable and the P cable. A cables are any SCSI cables with 50-pin connectors, whereas P cables are any SCSI cables with 68-pin connectors. You need a P cable if you are connecting a Wide SCSI device and want it to work in 16-bit mode. The P cable was not officially included in the standard until SCSI-3.

Fast SCSI refers to high-speed synchronous transfer capability. Fast SCSI achieves a 10MB/sec transfer rate on the standard 8-bit SCSI cabling. When combined with a 16-bit Wide SCSI interface, this configuration results in data-transfer rates of 20MB/sec (called Fast/Wide).

The high-density connectors enable smaller, more efficient connector and cable designs.

In SCSI-1, an initiator device, such as a host adapter, was limited to sending one command per device. In SCSI-2, the host adapter can send as many as 256 commands to a single device, which will store and process those commands internally before responding on the SCSI bus. The target device even can resequence the commands to allow for the most efficient execution or performance possible. This is especially useful in multitasking environments, such as OS/2 and Windows NT, which can take advantage of this feature.

SCSI-2 took the Common Command Set that was being used throughout the industry and made it an official part of the standard. The CCS was designed mainly for disk drives and did not include specific commands designed for other types of devices. In SCSI-2, many of the old commands are reworked, and several new commands have been added. New command sets have been added for CD-ROMs, optical drives, scanners, communications devices, and media changers (jukeboxes).

The single-ended SCSI bus depends on very tight termination tolerances to function reliably. Unfortunately, the original 132-ohm passive termination defined in the SCSI-1 document was not designed for use at the higher synchronous speeds now possible. These passive terminators can cause signal reflections to generate errors when transfer rates increase or when more devices are added to the bus. SCSI-2 defines an active (voltage-regulated) terminator that lowers termination impedance to 110 ohms and improves system integrity. Note that LVD SCSI requires special LVD terminators. If you use SE terminators on a bus with LVD devices, they either won't work or, if they are multimode devices, will default to SE operation.

These features are not required; they are optional under the SCSI-2 specification. If you connect a standard SCSI host adapter to a Fast SCSI drive, for example, the interface will work, but only at standard SCSI speeds.

SCSI-3

SCSI-3 is a term used to describe a set of standards currently being developed. Simply put, it is the next generation of documents a product conforms to. Unlike SCSI-1 and SCSI-2, SCSI-3 is not one document that covers all the layers and interfaces of SCSI, but is instead a collection of documents that covers the primary commands, specific command sets, and electrical interfaces and protocols. The command sets include hard disk interface commands, commands for tape drives, controller commands for RAID (Redundant Array of Inexpensive Drives), and other commands as well. There is also an overall SCSI Architectural Model (SAM) for the physical and electrical interfaces, as well as a SCSI Parallel Interface standard that controls the form of SCSI most commonly used. Each document within the standard is now a separate publication with its own revision level—for example, within SCSI-3 three different versions of the SCSI Parallel Interface have been published. Normally we don't refer to SCSI-3 anymore as a specific interface and instead refer to the specific subsets of SCSI-3, such as SPI-3 (Ultra3 SCSI).

The main additions to SCSI-3 include

- Ultra2 (Fast-40) SCSI
- Ultra3 (Fast-80DT) SCSI
- Ultra4 (Fast-160DT) SCSI
- New Low Voltage Differential signaling
- Elimination of High Voltage Differential signaling

Breaking up SCSI-3 into many smaller individual standards has enabled the standard as a whole to develop more quickly. The individual substandards can now be published rather than waiting for the entire standard to be approved.

Figure 8.1 shows the main parts of SCSI-3.

The primary changes being seen in the marketplace from SCSI-3 are the new Fast-40 (Ultra2) and Fast-80DT (Ultra3) high-speed drives and adapters. These have taken the performance of SCSI up to 160MB/sec. Also new is the LVD electrical standard, which allows for greater cable lengths. The older High Voltage Differential signaling has been removed from the standard.

A number of people are confused over the speed variations in SCSI. Part of the problem is that speeds are quoted as either clock speeds (MHz) or transfer speeds. With 8-bit transfers, you get one byte per transfer, so if the clock is 40MHz (Fast-40 or Ultra2 SCSI), the transfer speed is 40MB/sec. On the other hand, if you are using a Wide (16-bit) interface, the transfer speed doubles to 80MB/sec, even though the clock speed remains at 40MHz. With Fast-80DT, the bus speed technically remains at 40MHz; however, two transfers are made per cycle, resulting in a throughput speed of 160MB/sec. The same is true for Ultra4 SCSI, which runs at 80MHz and transfers 2 bytes at a time and two transfers per cycle. Ultra4 is also called Ultra320 and is the fastest form of parallel SCSI today.

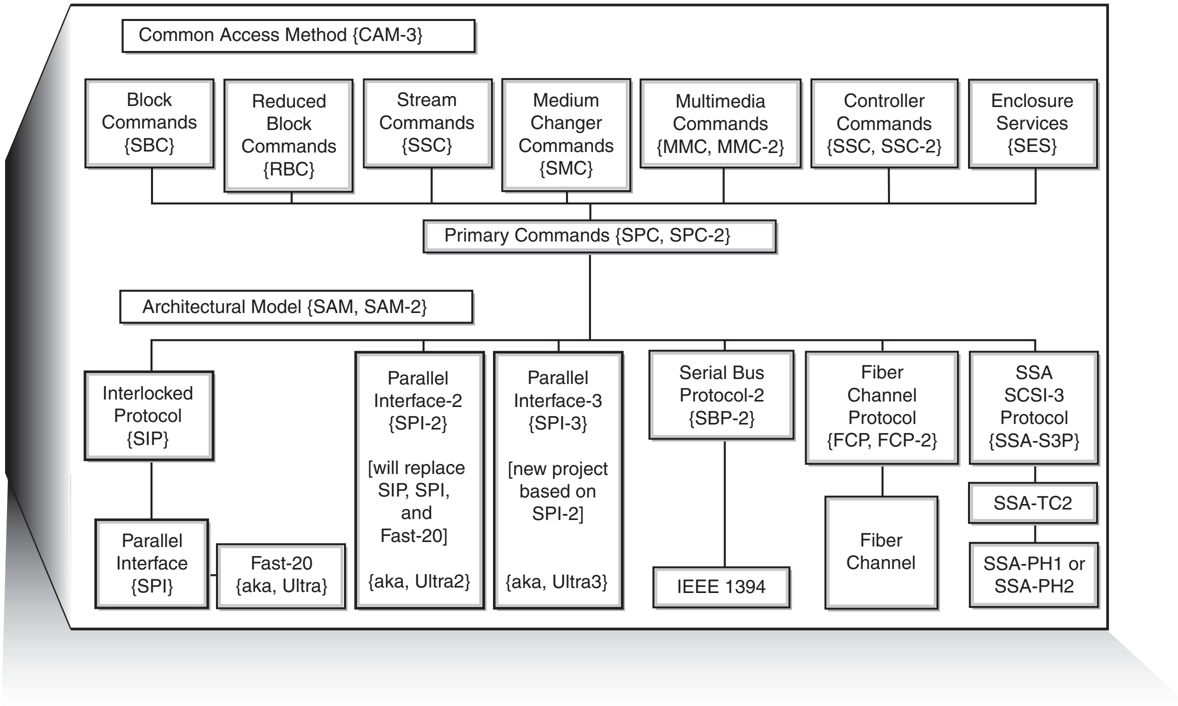


Figure 8.1 The SCSI-3 architecture.

Finally, confusion exists because SCSI speeds or modes are often discussed using either the official terms, such as Fast-10, Fast-20, Fast-40, and Fast-80DT, or the equivalent marketing terms, such as Fast, Ultra, Ultra2, and Ultra3 (also called Ultra160). Refer to Table 8.2 for a complete breakdown of SCSI official terms, marketing terms, and speeds.

The further evolution of the most commonly used form of SCSI is defined under the SPI standards within SCSI-3. The SPI standards are detailed in the following sections.

SPI or Ultra SCSI

The SCSI Parallel Interface standard was the first SCSI standard that fell under the SCSI-3 designation and is officially known as ANSI X3.253-1995. SPI is also called Ultra SCSI by most marketing departments and defines the parallel bus electrical connections and signals. A separate document called the SCSI Interlock Protocol (SIP) defines the parallel command set. SIP was included in the later SPI-2 and SPI-3 revisions and is no longer carried as a separate document. The main features added in SPI or Ultra SCSI are

- Fast-20 (Ultra) speeds (20MB/sec or 40MB/sec)
- 68-pin P-cable and connectors defined for Wide SCSI

SPI initially included speeds up to Fast SCSI (10MHz), which enables transfer speeds up to 20MB/sec using a 16-bit wide bus. Later, Fast-20 (20MHz), commonly known as Ultra SCSI, was added through an addendum document (ANSI X3.277-1996), allowing a throughput of 40MB/sec on a 16-bit wide bus (commonly called Ultra/Wide).

SPI-2 or Ultra2 SCSI

SPI-2 is also called Ultra2 SCSI, officially published as ANSI X3.302-1998, and adds several features to the prior versions:

- Fast-40 (Ultra2) speeds (40MB/sec or 80MB/sec)
- Low Voltage Differential signaling
- Single Connector Attachment (SCA-2) connectors
- 68-pin Very High Density Connector (VHDC)

The most notable of these is a higher speed called Fast-40, which is commonly called Ultra2 SCSI and runs at 40MHz. On a narrow (8-bit) bus, this results in 40MB/sec throughput, whereas on a wide bus (16-bit), this results in 80MB/sec throughput and is commonly referred to as Ultra2/Wide.

To achieve these speeds, a new electrical interface called LVD must be used. The slower single-ended electrical interface is only good for speeds up to Fast-20. Fast-40 mode requires LVD operation. The LVD signaling also enables longer cable lengths up to 12 meters with multiple devices or 25 meters with only one device. LVD and SE devices can share the same cable, but in that case the bus will run in SE mode and be restricted in length to as little as 1.5 meters in Fast-20 mode. LVD operation requires special LVD-only or LVD/SE multimode terminators. If multimode terminators are used, the same terminators will work on either SE or LVD buses.

The SPI-2 standard also includes SIP (SCSI Interlink Protocol) and defines the Single Connector Attachment (SCA-2) 80-pin connector for hot-swappable drive arrays. There is also a new 68-pin Very High Density Connector (VHDC), which is smaller than the previous types.

SCSI Signaling

“Normal,” or standard, SCSI uses a signaling technique called single-ended signaling. SE signaling is a low-cost technique, but it also has performance and noise problems.

Single-ended signaling is also called unbalanced signaling. Each signal is carried on a pair of wires, normally twisted to help reduce noise. With SE one of the pair is grounded, often to a common ground for all signals, and the other carries the actual voltage transitions. It is up to a receiver at the other end of the cable to detect the voltage transitions, which are really just changes in voltage.

Unfortunately, this type of unbalanced signaling is very prone to problems with noise, electromagnetic interference, and ground leakage; these problems get worse the longer the cable is. This is the reason Ultra SCSI was limited to such short maximum bus lengths—as little as 1 1/2 meters or 5 feet.

When SCSI was first developed, a signaling technique called High Voltage Differential signaling was also introduced into the standard. Differential signaling, also known as *balanced signaling*, is still done with a pair of wires. In fact, the first in the pair carries the same type of signal that single-ended SCSI carries. The second in the pair, however, carries the logical inversion of that signal. The receiving device detects the difference between the pair (hence the name differential). By using the wires in a balanced pair, the receiver no longer needs to detect voltage magnitude, only the differential between voltage in two wires. This is much easier for circuits to do reliably, which makes them less susceptible to noise and enables greater cable length. Because of this, differential SCSI can be used with cable lengths of up to 25 meters, whereas single-ended SCSI is good only for 6 meters maximum, or as little as 1 1/2 meters in the faster modes.

Figure 8.2 shows the circuit differences between balanced (differential) and unbalanced (single-ended) transmission lines.

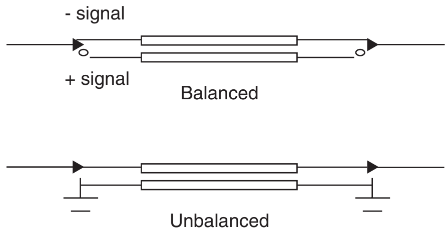


Figure 8.2 Balanced (differential) versus unbalanced (single-ended) signaling.

Unfortunately, the original standard for HVD signaling called for high voltage differentials between the two wires. This means that small, low-power, single-chip interfaces using HVD signaling could not be developed. Instead, circuits using several chips were required. This works at both ends, meaning both the host adapter and device circuitry had to be larger and more expensive.

Another problem with HVD SCSI is that although the cables and connectors look (and are) exactly the same as for SE SCSI, both types of devices cannot be mixed on the same bus. If they are, the high voltage from the HVD device will burn out the receiver circuits on all SE devices attached to the bus. In other words, the result will be smoked hardware—not a pretty sight.

Because SE SCSI worked well enough for the speeds that were necessary up until recently, HVD SCSI signaling never really caught on. It was used only in minicomputers and very rarely, if at all, in PCs. Because of this, the extra cost of this interface, and the fact that it is electrically incompatible with standard SE SCSI devices, HVD signaling was removed from the SCSI specification in the latest SCSI-3 documents. So, as far as we are concerned, it is obsolete.

Still, a need existed for a more reliable signaling technique that would allow for longer cable lengths. The answer came in the form of LVD signaling. By designing a new version of the differential interface, it can be made to work with inexpensive and low-power SCSI chips. Another advantage of LVD is that because it uses low voltage, if you plug an LVD device into an SE SCSI bus, nothing will be damaged. In fact, as an optional part of the LVD standard, the LVD device can be designed as a multimode device, which means it works on both SE and LVD buses. In the case of installing a multimode LVD device into an SE bus, the device detects that it is installed in an SE bus and defaults to SE mode.

This means that all multimode LVD/SE SCSI devices can be used on either LVD or SE SCSI buses. However, when on a bus with even one other SE device, all the LVD devices on the bus run only in SE mode. Because SE mode supports only SCSI speeds of up to 20MHz (Fast-20 or UltraSCSI) and cable lengths of up to 1 1/2 or 3 meters, the devices also work only at that speed or lower; you also might have problems with longer cables. Although you can purchase an Ultra3 SCSI multimode LVD/SE drive and install it on a SCSI bus along with single-ended devices, you will certainly be wasting the capabilities of the faster device.

Note that all Ultra2 and Ultra3 devices support LVD signaling because that is the only way they can be run at the Ultra2 (40MHz) or Ultra3 (80MHz) speeds. Ultra SCSI (20MHz) or slower devices can support LVD signaling, but in most cases LVD is synonymous with Ultra2 or Ultra3 only.

Table 8.2, shown earlier, lists all the SCSI speeds and maximum lengths for each speed using the supported signaling techniques for that speed.

Because the connectors are the same for SE, HVD, LVD, or multimode SE/LVD devices, and because putting an HVD device on any bus with SE or LVD devices causes damage, it would be nice to be able to tell them apart. One way is to look for a special symbol on the unit; the industry has adopted different universal symbols for single-ended and differential SCSI. Figure 8.3 shows these symbols.

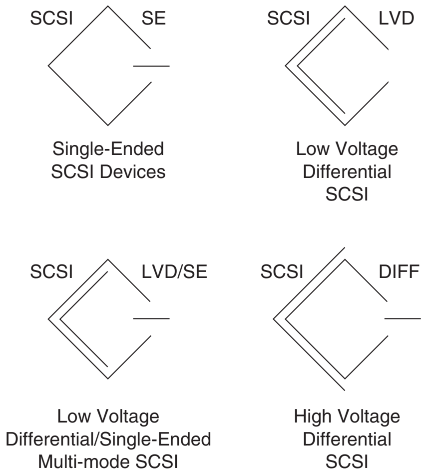


Figure 8.3 Universal symbol icons identifying SE, LVD, multimode LVD/SE, and HVD devices.

If you do not see such symbols, you can tell whether you have a High Voltage Differential device by using an ohmmeter to check the resistance between pins 21 and 22 on the device connector:

- On a single-ended or Low Voltage Differential device, the pins should be tied together and also tied to the ground.
- On a High Voltage Differential device, the pins should be open or have significant resistance between them.

Although you will blow up stuff if you plug HVD devices into LVD or SE buses, this generally should not be a problem because virtually all devices used in the PC environment are SE, LVD, or LVD/SE. HVD has essentially been rendered obsolete because it has been removed from the SCSI standard with Ultra3 SCSI (SPI-3).

SPI-3 or Ultra3 SCSI (Ultra160)

SPI-3, also known as Ultra3 or Ultra160 SCSI, builds on the previous standard and doubles the speed again to Fast-80DT (double transition). This results in a maximum throughput of 160MB/sec. The main features added to SPI-3 (Ultra3) are

- DT (double transition) clocking
- CRC (Cyclic Redundancy Check)
- Domain validation
- Packetization
- Quick Arbitrate and Select (QAS)

Double transition clocking sends data on both the rising and falling edges of the REQ/ACK clock. This enables Ultra3 SCSI to transfer data at 160MB/sec, while still running at a bus clock rate of 40MHz. This mode is defined for 16-bit wide bus use only.

Cyclic Redundancy Checking (CRC) is a form of error checking incorporated into Ultra3 SCSI. Previous versions of SCSI used simple parity checking to detect transmission errors. CRC is a much more robust form of error-detection capability that is far superior for operation at higher speeds.

Domain validation allows better negotiation of SCSI transfer speeds and modes. With prior SCSI versions, when the bus is initialized, the host adapter sends an `INQUIRY` command at the lowest 5MHz speed to each device to determine which data-transfer rate the device can use. The problem is that even though both the host adapter and device might support a given speed, there is no guarantee that the interconnection between the devices will reliably work at that speed. If a problem occurs, the device becomes inaccessible. With domain validation, after a maximum transfer speed is negotiated between the host and the device, it is then tested at that rate. If errors are detected, the rate is stepped down until the connection tests error-free. This is similar to how modems negotiate transmission speeds before communicating and will go a long way toward improve the flexibility and perceived reliability of SCSI.

Packetization is a protocol that enables information to be transferred between SCSI devices in a much more efficient manner. Traditional parallel SCSI uses multiple bus phases to communicate different types of information between SCSI devices: one for command information, two for messages, one for status, and two for data. In contrast, packetized SCSI communicates all this information by using only two phases: one for each direction. This dramatically reduces the command and protocol overhead, especially as higher and higher speeds are used.

Packetized SCSI is fully compatible with traditional parallel SCSI, which means packetized SCSI devices can reside on the same bus as traditional SCSI devices. As long as the host adapter supports the packetization, it can communicate with one device using packets and another using traditional protocol. Not all Ultra3 or Ultra160 SCSI devices include packetization support. Ultra3 devices that support packetization normally are referred to as Ultra160+ SCSI.

Quick Arbitrate and Select (QAS) is a feature in Ultra3 SCSI that reduces arbitration time by eliminating bus free time. QAS enables a device to transfer control of the bus to another device without an intervening BUS FREE phase. SCSI devices that support QAS report that capability in the `INQUIRY` command.

Ultra160 and Ultra160+

Because the five main new features of Ultra3 SCSI are optional, drives could claim Ultra3 capability and not have a consistent level of functionality. To ensure truth in advertising and a minimum level of performance, a group of manufacturers got together and created a substandard within Ultra3 SCSI that requires a minimum set of features. These are called Ultra160 and Ultra160+ because both indicate 160MB/sec throughput. These new substandards are not an official part of SCSI—they are not an official part of the standard. Even so, they do guarantee that certain specifications will be met and certain performance levels will be attained.

Ultra160 is a specific implementation of Ultra3 (SPI-3) SCSI that includes the first three additional features of Ultra3 SCSI:

- Fast-80DT clocking for 160MB/sec operation
- CRC
- Domain validation

Ultra160 SCSI runs in LVD mode and is backward compatible with all Ultra2 SCSI (LVD) devices. The only caveat is that no SE devices must be on the bus. When Ultra2 and Ultra160 (Ultra3) devices are mixed, each device can operate at its full-rated speed independent of the other. The bus will dynamically switch from single- to double-transition mode to support the differences in speeds.

Ultra160+ adds the other two features, ensuring a full implementation of Ultra3:

- Packetization
- Quick Arbitrate and Select

With Ultra160 and Ultra160+, you have a known level of functionality to ensure that a minimum level of performance will be met. Ultra160+ SCSI is the highest-performance PC-level storage interface and is best suited for high-traffic environments, such as high-end network servers or workstations. The adaptability and scalability of the interface enables high performance with high reliability.

SPI-4 or Ultra4 SCSI (Ultra320)

SPI-4, also known as Ultra4 or Ultra320 SCSI, is basically an update on the previous Ultra3 (Ultra160) SCSI. It has all the same features, except it doubles the speed again to Fast-160DT. This results in a maximum throughput of 320MB/sec, the current fastest form of parallel SCSI.

The SPI-4 standard is still in development, although products running at Ultra320 speeds will likely be available before the standard is officially published.

Fiber Channel SCSI

Fiber Channel SCSI is a specification for a serial interface using a fiber channel physical and protocol characteristic, with a SCSI command set. It can achieve 100MB/sec over either fiber or coaxial cable of several kilometers in length. Fiber Channel is designed for long-distance connectivity (such as several kilometers) and connecting multiple systems. Standard parallel SCSI will continue to be the I/O choice for inside the box or external close proximity connectivity for some time to come. Due to compatibility problems between various manufacturers' Fiber Channel devices and the fact that Ultra3 (Ultra160) and Ultra4 (Ultra320) SCSI are significantly faster, Fiber Channel is unlikely to become popular in the PC environment. Ultra160/320 SCSI is also far less expensive to implement and remains backward compatible with Ultra2 SCSI devices.

SCSI Cables and Connectors

The SCSI standards are very specific when it comes to cables and connectors. The most common connectors specified in this standard are the 50-position unshielded pin header connector for internal SCSI connections and the 50-position shielded Centronics latch-style connectors for external connections. The shielded Centronics-style connector also is called Alternative 2 in the official specification. Passive or Active termination (Active is preferred) is specified for both single-ended and differential buses. The 50-conductor bus configuration is defined in the SCSI-2 standard as the A cable.

Older narrow (8-bit) SCSI adapters and external devices use a full-size Centronics-type connector that normally has wire latches on each side to secure the cable connector. Figure 8.4 shows what the low-density, 50-pin SCSI connector looks like.

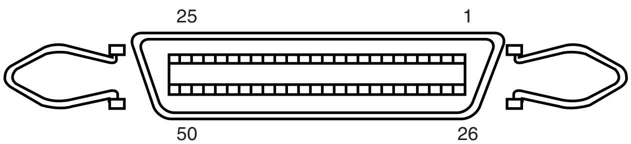


Figure 8.4 Low-density, 50-pin SCSI connector.

The SCSI-2 revision added a high-density, 50-position, D-shell connector option for the A-cable connectors. This connector now is called Alternative 1. Figure 8.5 shows the 50-pin, high-density SCSI connector.

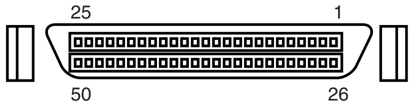


Figure 8.5 High-density, 50-pin SCSI connector.

The Alternative 2 Centronics latch-style connector remains unchanged from SCSI-1. A 68-conductor B-cable specification was added to the SCSI-2 standard to provide for 16- and 32-bit data transfers; the connector, however, had to be used in parallel with an A cable. The industry did not widely accept the B-cable option, which has been dropped from the SCSI-3 standard.

To replace the ill-fated B cable, a new 68-conductor P cable was developed as part of the SCSI-3 specification. Shielded and unshielded high-density D-shell connectors are specified for both the A and P cables. The shielded high-density connectors use a squeeze-to-release latch rather than the wire latch used on the Centronics-style connectors. Active termination for single-ended buses is specified, providing a high level of signal integrity. Figure 8.6 shows the 68-pin, high-density SCSI connector.

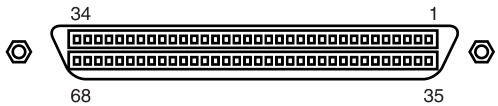


Figure 8.6 High-density, 68-pin SCSI connector.

Drive arrays normally use special SCSI drives with what is called an 80-pin Alternative-4 connector, which is capable of Wide SCSI and also includes power signals. Drives with the 80-pin connector are normally *hot-swappable*—they can be removed and installed with the power on—in drive arrays. The 80-pin Alt-4 connector is shown in Figure 8.7.

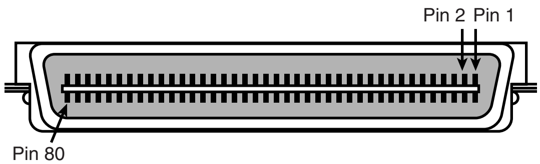


Figure 8.7 80-pin Alt-4 SCSI connector.

Apple and some other nonstandard implementations from other vendors used a 25-pin cable and connector for SCSI devices. They did this by eliminating most of the grounds from the cable, which unfortunately results in a noisy, error-prone connection. I don't recommend using 25-pin cables and connectors; you should avoid them if possible. The connector used in these cases was a standard female DB-25 connector, which looks exactly like a PC parallel port (printer) connector.

Unfortunately, you can damage equipment by plugging printers into DB-25 SCSI connectors or by plugging SCSI devices into DB-25 printer connectors. So, if you use this type of SCSI connection, be sure it is marked well because there is no way to tell DB-25 SCSI from DB-25 parallel printer connectors by looking at them. The DB-25 connector is shown in Figure 8.8.

Again, I recommend you avoid making SCSI connections using this type of cable or connector.

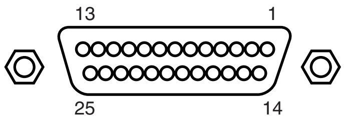


Figure 8.8 DB-25 SCSI connector.

SCSI Cable and Connector Pinouts

The following section details the pinouts of the various SCSI cables and connectors. Two electrically different versions of SCSI exist: single-ended and differential. These two versions are electrically incompatible and must not be interconnected; otherwise, damage will result. Fortunately, very few differential SCSI applications are available in the PC industry, so you will rarely (if ever) encounter one. Within each electrical type (single-ended or differential), there are basically two SCSI cable types:

- A cable (Standard 8-bit SCSI)
- P cable (16-bit Wide SCSI)

The 50-pin A-cable is used in most SCSI-1 and SCSI-2 installations and is the most common cable you will encounter. SCSI-2 Wide (16-bit) applications use a P cable instead, which has 68 pins. You can intermix standard and Wide SCSI devices on a single SCSI bus by interconnecting A and P cables with special adapters. SCSI-3 applications that are 32-bit wide would have used an additional Q cable, but this was finally dropped from the SCSI-3 standard after it was never implemented in actual products.

SCSI cables are specially shielded with the most important high-speed signals carried in the center of the cable and less important, slower ones in two additional layers around the perimeter. A typical SCSI cable is constructed as shown in Figure 8.9.

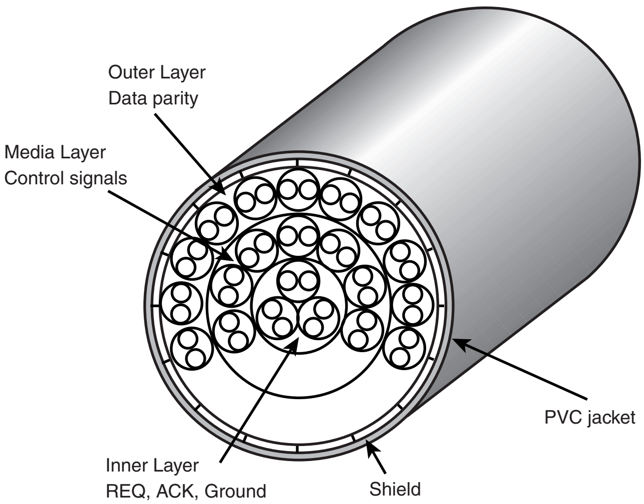


Figure 8.9 Cross section of a typical SCSI cable.

This specialized construction is what makes SCSI cables so expensive, as well as thicker than other types of cables. Note this specialized construction is necessary only for external SCSI cables. Cables used to connect devices inside a shielded enclosure (such as inside a PC) can use much less expensive ribbon cables.

The A cables can have pin-header–type (internal) connectors or external shielded connectors, each with a different pinout. The P cables feature the same connector pinout on either internal or external cable connections.

Single-Ended SCSI Cables and Connectors

The single-ended electrical interface is the most popular type for PC systems. Tables 8.3 and 8.4 show all the possible single-ended cable and connector pinouts. The A cable is available in both internal unshielded and external shielded configurations. A hyphen preceding a signal name indicates the signal is Active Low. The RESERVED lines have continuity from one end of the SCSI bus to the other. In an A cable bus, the RESERVED lines should be left open in SCSI devices (but may be connected to ground) and are connected to ground in the bus terminator assemblies. In the P and Q cables, the RESERVED lines are left open in SCSI devices and in the bus terminator assemblies.

Table 8.3 A-Cable (Single-Ended) Internal Unshielded Header Connector

Signal	Pin	Pin	Signal
GROUND	1	2	-DB(0)
GROUND	3	4	-DB(1)
GROUND	5	6	-DB(2)
GROUND	7	8	-DB(3)
GROUND	9	10	-DB(4)
GROUND	11	12	-DB(5)
GROUND	13	14	-DB(6)
GROUND	15	16	-DB(7)
GROUND	17	18	-DB(Parity)
GROUND	19	20	GROUND
GROUND	21	22	GROUND
RESERVED	23	24	RESERVED
Open	25	26	TERMPWR
RESERVED	27	28	RESERVED
GROUND	29	30	GROUND
GROUND	31	32	-ATN
GROUND	33	34	GROUND
GROUND	35	36	-BSY
GROUND	37	38	-ACK
GROUND	39	40	-RST
GROUND	41	42	-MSG
GROUND	43	44	-SEL
GROUND	45	46	-C/D
GROUND	47	48	-REQ
GROUND	49	50	-I/O

Table 8.4 A-Cable (Single-Ended) External Shielded Connector

Signal	Pin	Pin	Signal
GROUND	1	26	-DB(0)
GROUND	2	27	-DB(1)
GROUND	3	28	-DB(2)
GROUND	4	29	-DB(3)
GROUND	5	30	-DB(4)
GROUND	6	31	-DB(5)
GROUND	7	32	-DB(6)
GROUND	8	33	-DB(7)
GROUND	9	34	-DB(Parity)
GROUND	10	35	GROUND
GROUND	11	36	GROUND
RESERVED	12	37	RESERVED
Open	13	38	TERMPWR
RESERVED	14	39	RESERVED
GROUND	15	40	GROUND
GROUND	16	41	-ATN
GROUND	17	42	GROUND
GROUND	18	43	-BSY
GROUND	19	44	-ACK
GROUND	20	45	-RST
GROUND	21	46	-MSG
GROUND	22	47	-SEL
GROUND	23	48	-C/D
GROUND	24	49	-REQ
GROUND	25	50	-I/O

IBM used the SCSI interface in virtually all PS/2 systems introduced after 1990. These systems use a Micro-Channel SCSI adapter or have the SCSI Host Adapter built into the motherboard. In either case, IBM's SCSI interface uses a special 60-pin, mini-Centronics–type external shielded connector that is unique in the industry. A special IBM cable is required to adapt this connector to the standard 50-pin

Centronics-style connector used on most external SCSI devices. The pinout of the IBM 60-pin, mini-Centronics–style external shielded connector is shown in Table 8.5. Notice that although the pin arrangement is unique, the pin-number–to–signal designations correspond with the standard unshielded internal pin header type of SCSI connector. IBM has discontinued this design in all its systems because after the PS/2 series, all have used conventional SCSI connectors.

The P cable (single-ended) and connectors are used in 16-bit Wide SCSI-2 applications (see Table 8.6 for the pinout).

Table 8.5 IBM PS/2 SCSI External

Signal Name	Pin	Pin	Signal Name
GROUND	1	60	Not Connected
-DB(0)	2	59	Not Connected
GROUND	3	58	Not Connected
-DB(1)	4	57	Not Connected
GROUND	5	56	Not Connected
-DB(2)	6	55	Not Connected
GROUND	7	54	Not Connected
-DB(3)	8	53	Not Connected
GROUND	9	52	Not Connected
-DB(4)	10	51	GROUND
GROUND	11	50	-I/O
-DB(5)	12	49	GROUND
GROUND	13	48	-REQ
-DB(6)	14	47	GROUND
GROUND	15	46	-C/D
-DB(7)	16	45	GROUND
GROUND	17	44	-SEL
-DB(Parity)	18	43	GROUND
GROUND	19	42	-MSG
GROUND	20	41	GROUND
GROUND	21	40	-RST
GROUND	22	39	GROUND
RESERVED	23	38	-ACK
RESERVED	24	37	GROUND
Open	25	36	-BSY
TERMPWR	26	35	GROUND
RESERVED	27	34	GROUND
RESERVED	28	33	GROUND
GROUND	29	32	-ATN
GROUND	30	31	GROUND

Table 8.6 P-Cable (Single-Ended) Internal or External Shielded Connector

Signal Name	Pin	Pin	Signal Name
GROUND	1	35	-DB(12)
GROUND	2	36	-DB(13)
GROUND	3	37	-DB(14)
GROUND	4	38	-DB(15)
GROUND	5	39	-DB(Parity 1)
GROUND	6	40	-DB(0)
GROUND	7	41	-DB(1)
GROUND	8	42	-DB(2)
GROUND	9	43	-DB(3)
GROUND	10	44	-DB(4)
GROUND	11	45	-DB(5)
GROUND	12	46	-DB(6)
GROUND	13	47	-DB(7)
GROUND	14	48	-DB(Parity 0)
GROUND	15	49	GROUND
GROUND	16	50	GROUND
TERMPWR	17	51	TERMPWR
TERMPWR	18	52	TERMPWR
RESERVED	19	53	RESERVED
GROUND	20	54	GROUND
GROUND	21	55	-ATN
GROUND	22	56	GROUND
GROUND	23	57	-BSY
GROUND	24	58	-ACK
GROUND	25	59	-RST
GROUND	26	60	-MSG
GROUND	27	61	-SEL
GROUND	28	62	-C/D
GROUND	29	63	-REQ
GROUND	30	64	-I/O
GROUND	31	65	-DB(8)
GROUND	32	66	-DB(9)
GROUND	33	67	-DB(10)
GROUND	34	68	-DB(11)

High Voltage Differential SCSI Signals

High Voltage Differential SCSI is not normally used in a PC environment but is very popular with minicomputer installations because of the very long bus lengths that are allowed. This has changed with the introduction of Low Voltage Differential signaling for SCSI, bringing the benefits of differential signaling to lower-end and more mainstream SCSI products.

Differential signaling uses drivers on both the initiator and target ends of the bus and makes each signal work in a push/pull arrangement, rather than a signal/ground arrangement as with standard single-ended SCSI. This enables much greater cable lengths and eliminates some of the problems with termination.

Almost all PC peripherals produced since the beginning of SCSI have been SE types. These are incompatible with HVD devices, although HVD devices can be used on an SE bus with appropriate (and expensive) adapters. The LVD devices, on the other hand, can be used on an SE bus if they are multimode devices, in which case they switch into SE mode. If all devices—including the host adapter—support LVD mode, all the devices switch into that mode and much longer cable lengths and higher speeds can be used. The normal limit for an SE SCSI bus is 1.53 meters maximum (about 5–10 feet) and up to 20MHz. If run in LVD mode, the maximum bus length goes up to 12 meters (about 40 feet) and speeds can go up to 80MHz. HVD SCSI supports bus lengths of up to 25 meters (about 80 feet).

Note that almost all modern SCSI hard disks are Ultra2 or Ultra3 devices, which means by default they are also LVD or multimode LVD/SE devices.

Expanders

SCSI expanders separate a SCSI bus into more than one physical segment, each of which can have the full SCSI cable length for that type of signaling. They provide a complete regeneration of the SCSI bus signals, allowing greater cable lengths and incompatible devices to essentially share the same bus. An expander also can be used to separate incompatible parts of a SCSI bus—for example, to keep SE and HVD SCSI devices in separate domains.

Expanders are transparent to the software and firmware on the bus, and they don't take up a device ID. They are normally capable of providing termination if located at the end of a bus segment, or they can have termination disabled if they are in the middle of a bus segment.

Because of their expense, expanders are not normally used except in extreme situations in which no other alternative remains. In most cases it is better to stick within the recommended cable and bus length requirements and keep incompatible devices, such as HVD devices, off a standard SE or LVD bus.

Termination

Because a SCSI bus carries high-speed electrical signals, it can be affected by electrical reflections that might occur within any transmission line system. A terminator is designed to minimize the potential for reflections or noise on the bus, as well as to create the proper load for the bus transmitter circuits. Terminators are placed at each end of the bus to minimize these problems.

Despite the simple rules that only two terminators must be on the bus and they must be at each end, I still see improper termination as the most common cause of problems in SCSI installations.

Several kinds of SCSI terminators are available, dependent on the bus signaling and speed requirements:

- Passive
- Active (also called Alternative 2)
- Forced Perfect Termination (FPT): FPT-3, FPT-18, and FPT-27

- HVD termination
- LVD termination

The first three are used on single-ended SCSI buses only. Passive terminators use a passive network of 220ohm and 330ohm resistors to control bus termination. They should be used only in narrow (8-bit) SCSI buses running at 5MHz. Passive terminators allow signal fluctuations in relation to the terminator power signal on the bus. Usually, passive terminating resistors suffice over short distances, such as 2 or 3 feet, but for longer distances or higher speeds, active termination is a real advantage. Active termination is required with Fast SCSI.

Figure 8.10 shows the schematic of a typical passive terminator.

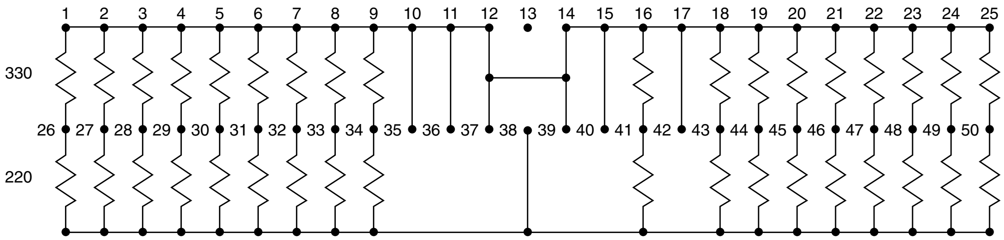


Figure 8.10 Passive SCSI terminator schematic.

Active terminators use built-in voltage regulator ICs combined with 110ohm resistors. An active terminator actually has one or more voltage regulators to produce the termination voltage, rather than resistor voltage dividers alone. This arrangement helps ensure that the SCSI signals always are terminated to the correct voltage level. Active terminators often have some sort of LED indicating the termination activity. The SCSI-2 specification recommends active termination on both ends of the bus and requires active termination whenever Fast or Wide SCSI devices are used. Most high-performance host adapters have an "auto-termination" feature, so if it is the end of a chain, it terminates itself. Figure 8.11 shows a typical active terminator.

A variation on active termination is available for single-ended buses: *forced perfect termination (FPT)*. Forced perfect termination is an even better form of active termination, in which diode clamps are added to eliminate signal overshoot and undershoot. The trick is that instead of clamping to +5 and ground, these terminators clamp to the output of two regulated voltages. This arrangement enables the clamping diodes to eliminate signal overshoot and undershoot, especially at higher signaling speeds and over longer distances. Forced perfect termination is technically not found in the SCSI specifications but is the superior type of termination for single-ended applications that experience high levels of electrical noise. Figure 8.12 shows the schematic of a typical FPT-18 type terminator (18 lines forced perfect, designed for 50-pin connections).

FPT terminators are available in several versions. FPT-3 and FPT-18 versions are available for 8-bit standard SCSI, whereas the FPT-27 is available for 16-bit (Wide) SCSI. The FPT-3 version forces perfect the three most highly active SCSI signals on the 8-bit SCSI bus, whereas the FPT-18 forces perfect all the SCSI signals on the 8-bit bus except grounds. FPT-27 also forces perfect all the 16-bit Wide SCSI signals except grounds.

HVD buses require HVD terminators, constructed using a passive network of 330ohm/150ohm/330ohm resistors. The only choice there is that the terminator matches your cable or device connection.

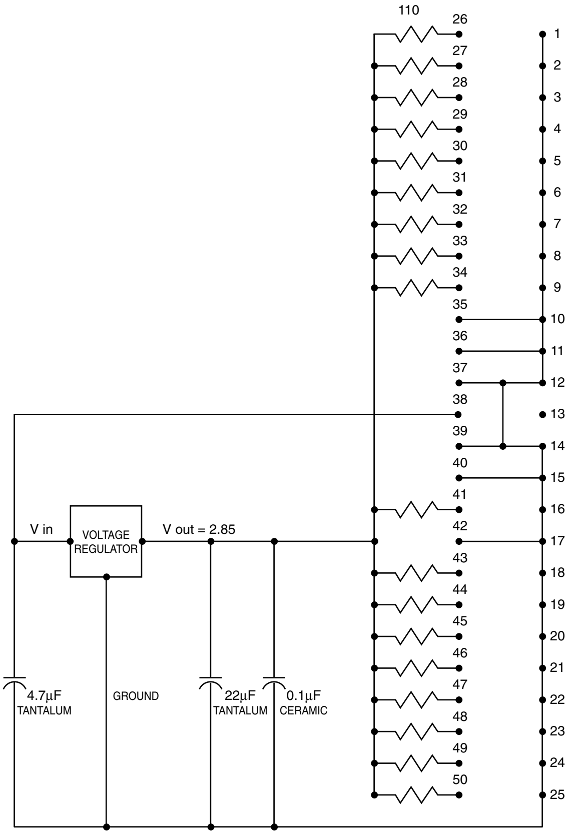


Figure 8.11 Active SCSI terminator schematic.

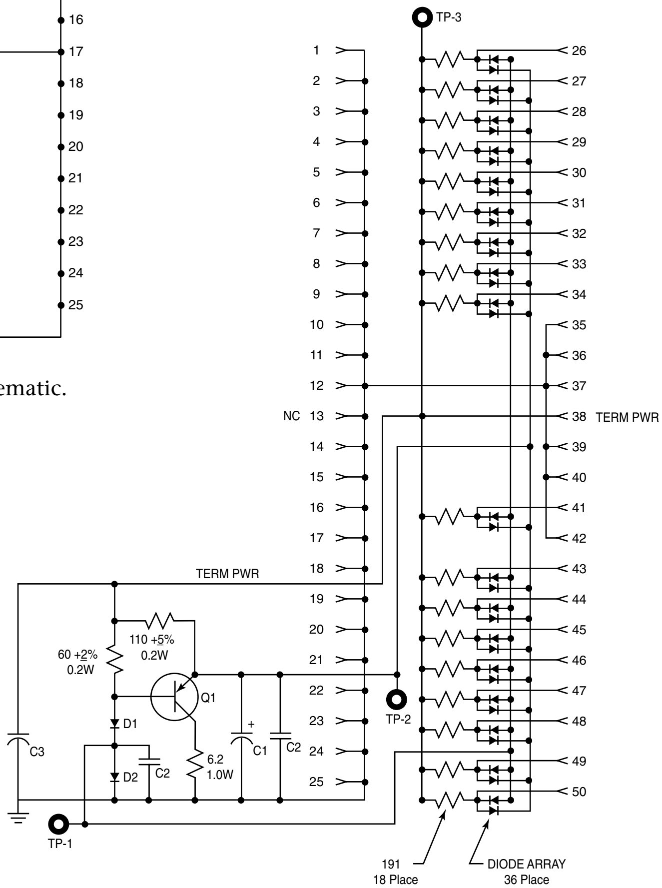


Figure 8.12 FPT SCSI terminator schematic.

The same is true for Low Voltage Differential buses. They require LVD terminators for the bus to function properly. One twist is that special LVD/SE (active) multimode terminators are available. These function as LVD types on an LVD bus and as active types on an SE bus. Note that if any SE devices are on the bus, it functions in SE mode and never uses LVD mode, severely limiting bus length and performance. If any SE-only terminators or SE devices are on the bus, the bus defaults into SE mode.

▶▶ See the next section, "SCSI Drive Configuration," p. 534.

Note

Several companies make high-quality terminators for the SCSI bus, including Aeronics and the Data Mate division of Methode. Both companies make a variety of terminators. Aeronics is well noted for some unique FPT versions that are especially suited to problem configurations that require longer cable runs or higher signal integrity. One of the best investments you can make in any SCSI installation is in high-quality cables and terminators. Contact information for both of these companies is in the Vendor List on the CD.

Special terminators also are required for LVD and HVD SCSI, so if you are using those interfaces, make sure your terminators are compatible.

With LVD or HVD buses, you don't have much choice in terminator types, but for single-ended (SE) buses, you have at least three choices.

Tip

My recommendation is to *never* use passive terminators; instead, use only active or FPT. If you want the best in reliability and integrity, choose FPT. The best rule for terminators as well as for cables is to get the best you can.

SCSI Drive Configuration

SCSI drives are not too difficult to configure, but they are more complicated than IDE drives. The SCSI standard controls the way the drives must be set up. You need to set up two or three items when you configure a SCSI drive:

- SCSI ID setting (0–7 or 0–15)
- Terminating resistors

The SCSI ID setting is very simple. Up to 7 SCSI devices can be used on a single narrow SCSI bus or up to 15 devices on a wide SCSI bus, and each device must have a unique SCSI ID address. There are 8 or 16 addresses respectively, and the host adapter takes 1 address, so the rest are free for up to 7 or 15 SCSI peripherals. Most SCSI host adapters are factory-set to ID 7 or 15, which is the highest priority ID. All other devices must have unique IDs that do not conflict with one another. Some host adapters boot only from a hard disk set to a specific ID. Older Adaptec host adapters required the boot hard disk to be ID 0; newer ones can boot from any ID.

Setting the ID usually involves changing jumpers on the drive. If the drive is installed in an external chassis, the chassis might have an ID selector switch that is accessible at the rear. This selector makes ID selection a simple matter of pressing a button or rotating a wheel until the desired ID number appears. If no external selector is present, you must open the external device chassis and set the ID via the jumpers on the drive.

Three jumpers are required to set the SCSI ID; the particular ID selected actually is derived from the binary representation of the jumpers themselves. One example is setting all three ID jumpers off results in a binary number of 000b, which translates to an ID of 0. A binary setting of 001b equals ID 1; 010b equals 2; 011b equals 3; and so on. (Notice that as I list these values, I append a lowercase b to indicate binary numbers.)

Unfortunately, the jumpers can appear either forward or backward on the drive, depending on how the manufacturer set them up. To keep things simple, I have recorded all the various ID jumper settings in the following tables. Table 8.7 shows the settings for drives that order the jumpers with the most significant bit (MSB) to the left; Table 8.8 shows the settings for drives that have the jumpers ordered so that the MSB is to the right.

Table 8.7 SCSI ID Jumper Settings with the Most Significant Bit to the Left

SCSI	ID	Jumper	Settings
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

1 = Jumper On; 0 = Jumper Off

Table 8.8 SCSI ID Jumper Settings with the Most Significant Bit to the Right

SCSI	ID	Jumper	Settings
0	0	0	0
1	1	0	0
2	0	1	0
3	1	1	0
4	0	0	1
5	1	0	1
6	0	1	1
7	1	1	1

1 = Jumper On; 0 = Jumper Off

SCSI termination is very simple. Termination is required at both ends of the bus; there are no exceptions. If the host adapter is at one end of the bus, it must have termination enabled. If the host adapter is in the middle of the bus, and if both internal and external bus links are present, the host adapter must have its termination disabled, and the devices at each end of the bus must have terminators installed. Unfortunately, the majority of problems I see with SCSI installations are the result of improper termination.

Figure 8.13 shows a representation of a SCSI bus with several devices attached. In this case, the host adapter is at one end of the bus and a CD-ROM drive is at the other. For the bus to work properly, those devices must be terminated, whereas the others do not.

When installing an external SCSI device, you usually will find the device in a storage enclosure with both input and output SCSI connectors, so you can use the device in a daisy-chain. If the enclosure is at the end of the SCSI bus, an external terminator module most likely will have to be plugged into the second (outgoing) SCSI port to provide proper termination at that end of the bus (see Figure 8.14).

External terminator modules are available in a variety of connector configurations, including pass-through designs, which are necessary if only one port is available. Pass-through terminators also are commonly used in internal installations in which the device does not have built-in terminating resistors. Many hard drives use pass-through terminators for internal installations to save space on the logic-board assembly (see Figure 8.15).

The pass-through models are required when a device is at the end of the bus and only one SCSI connector is available.

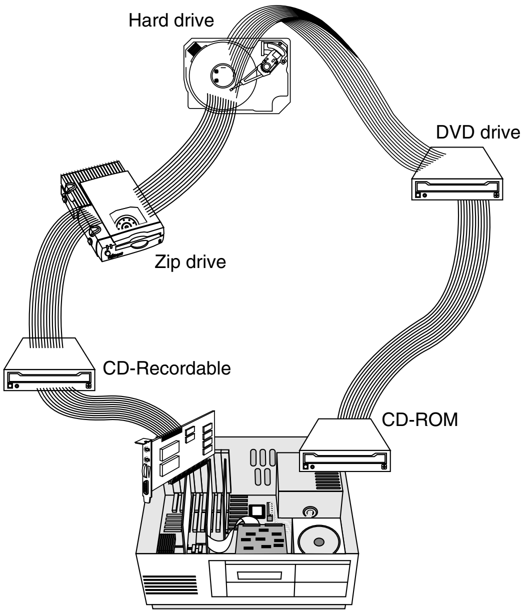


Figure 8.13 SCSI bus daisy-chain connections; the first and last devices must be terminated.

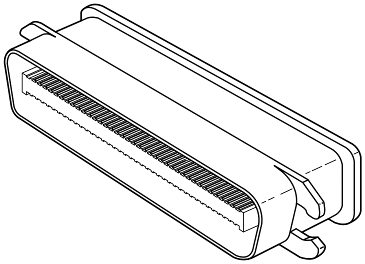


Figure 8.14 External SCSI device terminator.

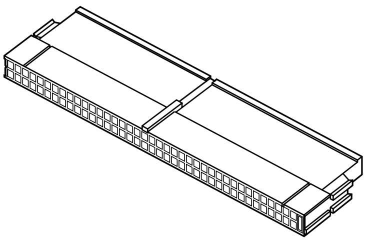


Figure 8.15 Internal pin-header connector pass-through SCSI terminator.

Other configuration items on a SCSI drive can be set via jumpers. Following are several of the most common additional settings that you will find:

- Start on Command (delayed start)
- SCSI Parity
- Terminator Power
- Synchronous Negotiation

These configuration items are described in the following sections.

Start on Command (Delayed Start)

If you have multiple drives installed in a system, it is wise to set them up so that not all the drives start to spin immediately when the system is powered on. A hard disk drive can consume three or four times more power during the first few seconds after power-on than during normal operation. The motor requires this additional power to get the platters spinning quickly. If several drives are drawing all this power at the same time, the power supply can be overloaded, which can cause the system to hang or have intermittent startup problems.

Nearly all SCSI drives provide a way to delay drive spinning so this problem does not occur. When most SCSI host adapters initialize the SCSI bus, they send out a command called Start Unit to each of the ID addresses in succession. By setting a jumper on the hard disk, you can prevent the disk from spinning until it receives the Start Unit command from the host adapter. Because the host adapter sends this command to all the ID addresses in succession, from the highest priority address (ID 7) to the lowest (ID 0), the higher priority drives can be made to start first, with each lower priority drive spinning up sequentially. Because some host adapters do not send the Start Unit command, some drives might simply delay spin-up for a fixed number of seconds rather than wait for a command that never will arrive.

If drives are installed in external chassis with separate power supplies, you need not implement the delayed-start function. This function is best applied to internal drives that must be run from the same power supply that runs the system. For internal installations, I recommend setting Start on Command (delayed start) even if you have only one SCSI drive; this setting eases the load on the power supply by spinning the drive up after the rest of the system has full power. This method is especially good for portable systems and other systems in which the power supply is limited.

SCSI Parity

SCSI Parity is a limited form of error checking that helps ensure that all data transfers are reliable. Virtually all host adapters support SCSI parity checking, so this option should be enabled on every device. The only reason it exists as an option is that some older host adapters do not work with SCSI parity, so the parity must be turned off.

Terminator Power

The terminators at each end of the SCSI bus require power from at least one device on the bus. In most cases, the host adapter supplies this terminator power; in some cases, however, it does not. For example, parallel port SCSI host adapters typically do not supply terminator power. It is not a problem if more than one device supplies terminator power because each source is diode-protected. For simplicity's sake, many people often configure all devices to supply terminator power. If no device supplies terminator power, the bus is not terminated correctly and will not function properly.

SCSI Synchronous Negotiation

The SCSI bus can run in two modes: asynchronous (the default) and synchronous. The bus actually switches modes during transfers through a protocol called *synchronous negotiation*. Before data is transferred across the SCSI bus, the sending device (called the *initiator*) and the receiving device (called the *target*) negotiate how the transfer will take place. If both devices support synchronous transfers, they will discover this fact through the negotiation, and the transfer will take place at the faster synchronous rate.

Unfortunately, some older devices do not respond to a request for synchronous transfer and can actually be disabled when such a request is made. For this reason, both host adapters and devices that support synchronous negotiation often have a jumper that can be used to disable this negotiation so it can work with older devices. By default, all devices today should support synchronous negotiation, and this function should be enabled.

Plug-and-Play SCSI

Plug-and-Play (PnP) SCSI was originally released in April 1994. This specification enables SCSI device manufacturers to build PnP peripherals that are automatically configured when used with a PnP operating system. This enables you to easily connect or reconfigure external peripherals, such as hard disk drives, backup tapes, and CD-ROMs.

To connect SCSI peripherals to the host PC, the specification requires a PnP SCSI host adapter, such as PnP ISA or PCI. PnP add-in cards enable a PnP operating system to automatically configure software device drivers and system resources for the host bus interface.

The PnP SCSI specification version 1.0 includes these technical highlights:

- A single cable connector configuration
- Automatic termination of the SCSI bus
- SCAM (SCSI Configured AutoMagically*) automatic ID assignment
- Full backward compatibility of PnP SCSI devices with the installed base of SCSI systems

Note

"AutoMagically"is not a misspelling. The word is actually used in the official name for the specification, which the X3T9.2 committee designated X3T9.2/93-109r5.

This should go a long way in making SCSI easier to use for the normal user.

Each SCSI peripheral you add to your SCSI bus (other than hard disk drives) requires an external driver to make the device work. Hard disks are the exception; driver support for them normally is provided as part of the SCSI host adapter BIOS. These external drivers are specific not only to a particular device, but also to the host adapter.

Recently, two types of standard host adapter interface drivers have become popular, greatly reducing this problem. By having a standard host adapter driver to write to, peripheral makers can more quickly create new drivers that support their devices and then talk to the universal host adapter driver. This arrangement eliminates dependence on one particular type of host adapter. These primary or universal drivers link the host adapter and operating system.

The Advanced SCSI Programming Interface (ASPI) currently is the most popular universal driver, with most peripheral makers writing their drivers to talk to ASPI. The *A* in ASPI used to stand for Adaptec, the company that introduced it, but other SCSI device vendors have licensed the right to use ASPI with their products. DOS does not support ASPI directly, but it does when the ASPI driver is loaded. Windows 9x/Me, Windows NT/2000, and OS/2 2.1 and later versions provide automatic ASPI support for several SCSI host adapters.

Future Domain and NCR have created another interface driver called the Common Access Method (CAM). CAM is an ANSI-approved protocol that enables a single driver to control several host adapters. In addition to ASPI, OS/2 2.1 and later versions currently offer support for CAM. Future Domain also provides a CAM-to-ASPI converter in the utilities that go with its host adapters.

SCSI Configuration Troubleshooting

When you are installing a chain of devices on a single SCSI bus, the installation can get complicated very quickly. If you have a problem during installation, check these items first:

- Make sure you are using the latest BIOS from your motherboard manufacturer. Some have had problems with their PCI bus slots not working properly.
- Make sure that all SCSI devices attached to the bus are powered on.
- Make sure all SCSI cables and power cables are properly connected. Try removing and reseating all the connectors to be sure.
- Check that the host adapter and each device on each SCSI bus channel have a unique SCSI ID setting.
- Make sure the SCSI bus is terminated properly. Remember there should be only two terminators on the bus, one at each end. All other termination should be removed or disabled.
- If your system BIOS setup has settings for controlling PCI bus configuration, make sure the PCI slot containing the SCSI adapter is configured for an available interrupt. If your system is Plug and Play, use the Windows Device Manager to check and possibly change the resource configuration.
- Make sure the host adapter is installed in a PCI slot that supports bus mastering. Some older motherboards did not allow bus mastering to work in all PCI slots. Check your motherboard documentation and try moving the SCSI host adapter to a different PCI slot.
- If you have a SCSI hard disk installed and your system will not boot from the SCSI drive, there can be several causes for this problem. Note that if both SCSI and non-SCSI disk drives are installed in your computer, in almost all cases the non-SCSI drive will be the boot device. If you want to boot from a SCSI drive, check the boot sequence configuration in your BIOS. If your system allows it, change the boot sequence to allow SCSI devices to boot first. If not, try removing the non-SCSI drives from your system.

If the system has only SCSI disk drives and it still won't boot, check the following items:

- Make sure your computer's BIOS Setup drive configuration is set to "No Drives Installed." The PC BIOS supports only ATA (IDE) drives; by setting this to no drives, the system will then try to boot from another device, such as SCSI.
- Make sure the drive is partitioned and that a primary partition exists. Use FDISK from DOS or Windows to check.
- Make sure the boot partition of the boot hard disk is set to active. This can be checked or changed with the FDISK program.
- Finally as a last resort, you can try backing up all data on the SCSI hard disk, and then perform a low-level format with the Format utility built into or included with the host adapter.

Here are some tips for getting your setup to function quickly and efficiently:

- *Start by adding one device at a time.* Rather than plugging numerous peripherals into a single SCSI card and then trying to configure them at the same time, start by installing the host adapter and a single hard disk. Then, you can continue installing devices one at a time, checking to make sure that everything works before moving on.
- *Keep good documentation.* When you add a SCSI peripheral, write down the SCSI ID address and any other switch and jumper settings, such as SCSI Parity, Terminator Power, and Delayed or Remote Start. For the host adapter, record the BIOS addresses, Interrupt, DMA channel, and I/O Port addresses used by the adapter, and any other jumper or configuration settings (such as termination) that might be important to know later.
- *Use proper termination.* Each end of the bus must be terminated, preferably with active or Forced Perfect terminators. If you are using any Fast SCSI-2 device, you must use active terminators rather than the cheaper passive types. Even with standard (slow) SCSI devices, active termination is highly recommended. If you have only internal or external devices on the bus, the host adapter and last device on the chain should be terminated. If you have external and internal devices on the chain, you generally will terminate the first and last of these devices but not the SCSI host adapter (which is in the middle of the bus).
- *Use high-quality shielded SCSI cables.* Make sure your cable connectors match your devices. Use high-quality shielded cables, and observe the SCSI bus-length limitations. Use cables designed for SCSI use, and, if possible, stick to the same brand of cable throughout a single SCSI bus. Different brands of cables have different impedance values; this situation sometimes causes problems, especially in long or high-speed SCSI implementations.

Following these simple tips will help minimize problems and leave you with a trouble-free SCSI installation.

SCSI Versus IDE

When you compare the performance and capabilities of IDE and SCSI interfaced drives, you need to consider several factors. These two types of drives are the most popular drives used in PC systems today, and a single manufacturer might make identical drives in both interfaces. Deciding which drive type is best for your system is a difficult decision that depends on many factors.

In most cases, you will find that an IDE drive using the same head-disk assembly as a SCSI drive from the same manufacturer will perform about the same or outperform the equivalent SCSI drive at a given task or benchmark. This is mainly true when using a single disk drive with a single-user operating system, such as Windows 9x/Me. More powerful operating systems, such as Windows NT or Windows 2000, can more effectively use the command queuing and other features of SCSI, thus improving performance over IDE—especially when supporting multiple drives.

It is interesting to see that SCSI really evolved from IDE, or you could say that both evolved from the ST-506/412 and ESDI interfaces that were once used.

SCSI Hard Disk Evolution and Construction

SCSI is not a disk interface, but a bus that supports SCSI bus interface adapters connected to disk and other device controllers. The first SCSI drives for PCs were standard ST-506/412 or ESDI drives with a separate SCSI bus interface adapter (sometimes called a bridge controller) that converted the ST-506/412 or ESDI interfaces to SCSI. This interface originally was in the form of a secondary logic board, and the entire assembly often was mounted in an external case.

The next step was to build the SCSI bus interface "converter" board directly into the drive's own logic board. Today, we call these drives embedded SCSI drives because the SCSI interface is built in.

At that point, there was no need to conform to the absolute specifications of ST-506/412 or ESDI on the internal disk interface because the only other device the interface ever would have to talk to was built in as well. Thus, the disk-interface and controller-chipset manufacturers began to develop more customized chipsets that were based on the ST-506/412 or ESDI chipsets already available but offered more features and higher performance.

Today, if you look at a typical SCSI drive, you often can identify the chip or chipset that serves as the disk controller on the drive as being exactly the same kind that would be used on an ST-506/412 or ESDI controller, or as some evolutionary customized variation thereof.

Consider some examples. An ATA IDE drive must fully emulate the system-level disk-controller interface introduced with the Western Digital WD1003 controller series IBM used in the AT. These drives must act as though they have a built-in ST-506/412 or ESDI controller; in fact, they actually do. Most of these built-in controllers have more capabilities than the original WD1003 series (usually in the form of additional commands), but they must at least respond to all the original commands that were used with the WD1003.

If you follow the hard-drive market, you usually will see that drive manufacturers offer most of their newer drives in both ATA-IDE and SCSI versions. In other words, if a manufacturer makes a particular 20GB IDE drive, you invariably see that the company also makes a SCSI model with the same capacity and specifications, which uses the same head disk assembly (HDA) and even looks the same as the IDE version. If you study these virtually identical drives, the only major difference you will find is the additional chip on the logic board of the SCSI version, called a SCSI Bus Adapter Chip (SBIC).

Figures 8.16 and 8.17 show the logic-block diagrams of an ATA/IDE and a SCSI drive from the same manufacturer. These drives use the same HDA; they differ only in their logic boards, and even the logic boards are the same except for the addition of an SBIC on the SCSI drive's logic board.

Notice that even the circuit designs of these two drives are almost identical. Both drives use an LSI (large scale integrated circuit) chip called the WD42C22 Disk Controller and Buffer Manager chip. In the ATA drive, this chip is connected through a DMA control chip directly to the AT bus. In the SCSI version, a WD33C93 SCSI bus interface controller chip is added to interface the disk-controller logic to the SCSI bus. In fact, the logic diagrams of these two drives differ only in the fact that the SCSI version has a complete subset of the ATA drive, with the SCSI bus interface controller logic added. This essentially is a very condensed version of the separate drive and bridge controller setups that were used in the early days of PC SCSI.

◄◄ See "DMA Transfer Modes," p. 504.

To top off this example, study the logic diagram in Figure 8.18 for the WD 1006V-MM1, which is an ST-506/412 controller.

You can clearly see that the main LSI chip onboard is the same WD42C22 disk controller chip used in the IDE and SCSI drives. Here is what the technical reference literature says about that chip:

> *The WD42C22 integrates a high performance, low cost Winchester controller's architecture. The WD42C22 integrates the central elements of a Winchester controller subsystem such as the host interface, buffer manager, disk formatter/controller, encoder/decoder, CRC/ECC (Cyclic Redundancy Check/Error Correction Code) generator/checker, and drive interface into a single 84-pin PQFP (Plastic Quad Flat Pack) device.*

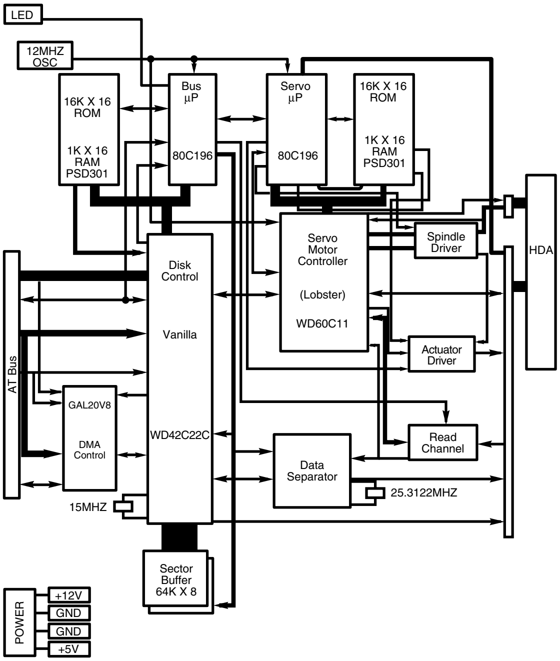


Figure 8.16 Typical ATA-IDE drive logic-board block diagram.

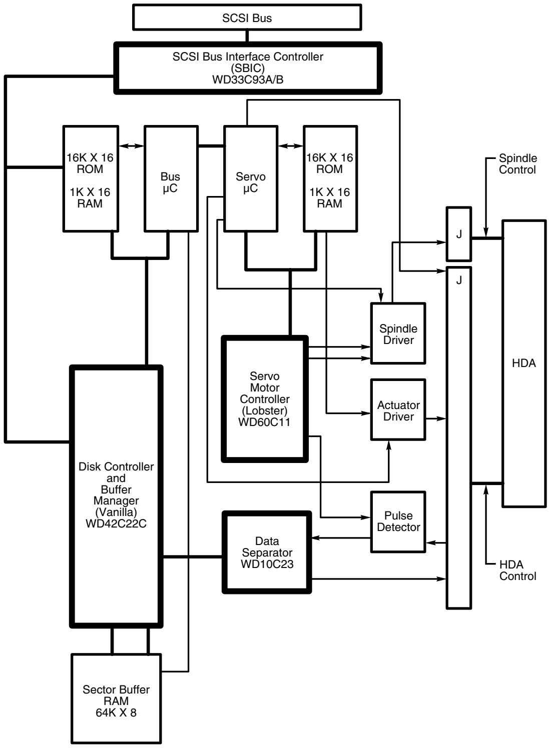


Figure 8.17 Typical SCSI drive logic board block diagram.

The virtually identical design of ATA-IDE and SCSI drives is not unique to Western Digital. Most drive manufacturers design their ATA-IDE and SCSI drives the same way, often using these very same WD chips, and disk controller and SCSI bus interface chips from other manufacturers. You now should be able to understand that most SCSI drives are "regular" ATA-IDE drives with SCSI bus logic added. This fact will come up again later in this chapter in the section "SCSI Versus IDE: Advantages and Limitations," which discusses performance and other issues differentiating these interfaces.

For another example, I have several old IBM 320MB and 400MB embedded SCSI-2 hard disks; each of these drives has onboard a WD-10C00 Programmable Disk Controller in the form of a 68-pin Plastic Leaded Chip Carrier (PLCC) chip. The technical literature states:

> *This chip supports ST412, ESDI, SMD and Optical interfaces. It has 27Mbit/sec maximum transfer rate and an internal, fully programmable 48- or 32-bit ECC, 16-bit CRC-CCITT or external user defined ECC polynomial, fully programmable sector sizes, and 1.25 micron low power CMOS design.*

In addition, these particular embedded SCSI drives include the 33C93 SCSI Bus Interface Controller chip, which also is used in the other SCSI drive I mentioned. Again, there is a distinctly separate disk controller, and the SCSI interface is added on.

So again, most embedded SCSI drives have a built-in disk controller (usually based on previous ST-506/412 or ESDI designs) and additional logic to interface that controller to the SCSI bus (a built-in bridge controller, if you like). Now think about this from a performance standpoint. If virtually all SCSI drives really are ATA-IDE drives with a SCSI Bus Interface Controller chip added, what conclusions can you draw?

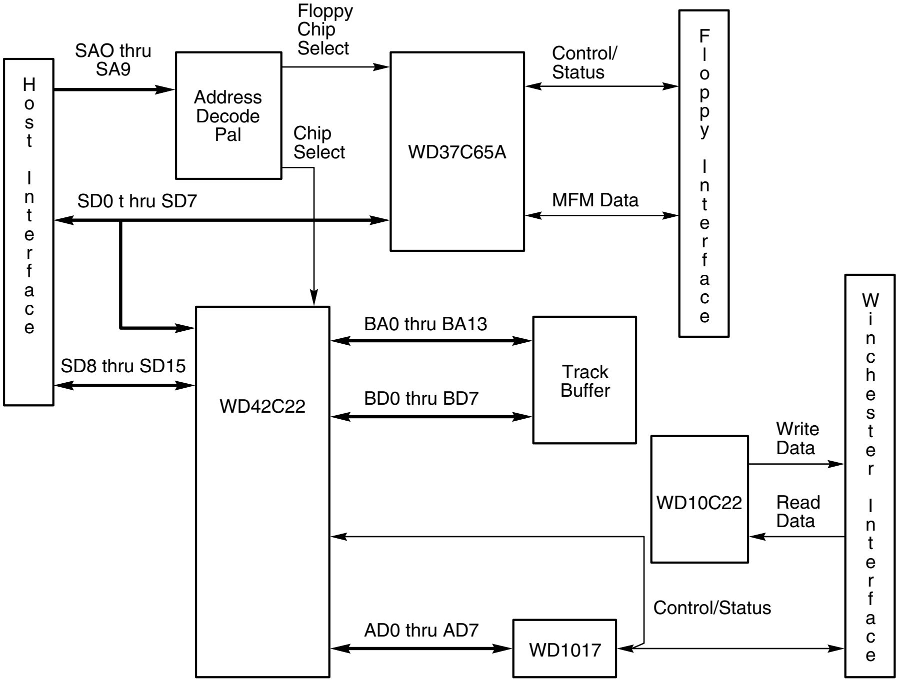


Figure 8.18 Western Digital WD1006V-MM1 ST-506/412 Disk Controller block diagram.

First, no drive can perform sustained data transfers faster than the data can actually be read from the disk platters. In other words, the HDA limits performance to whatever it is capable of achieving. Drives can transmit data in short bursts at very high speeds because they often have built-in cache or read-ahead buffers that store data. Many of the newer high-performance SCSI and ATA-IDE drives have 1MB or more of cache memory onboard. No matter how big or intelligent the cache is, however, sustained data transfer is still limited by the HDA.

◀◀ See "ATA IDE," p. 480.

Data from the HDA must pass through the disk controller circuits, which, as you have seen, are virtually identical between similar SCSI and ATA-IDE drives. In the ATA-IDE drive, this data then is presented directly to the system bus. In the SCSI drive, however, the data must pass through a SCSI bus interface adapter on the drive, travel through the SCSI bus, and then pass through another SCSI bus interface controller in the SCSI host adapter card in your system. The longer route a SCSI transfer must take makes this type of transfer slower than the much more direct ATA-IDE transfer.

The conventional wisdom has been that SCSI always is much faster than IDE; unfortunately, this wisdom is usually wrong. This incorrect conclusion was derived by looking at the raw SCSI and ISA bus performance capabilities. A 16-bit Ultra3 SCSI drive can transfer data at a claimed 160MB/sec, whereas an Ultra-ATA/66 IDE drive can transfer data at 66MB/sec. Based on these raw transfer rates, SCSI seems to be faster, but the raw transfer rate of the bus is not the limiting factor. As discussed previously, the actual HDA and disk-controller circuitry place limits on this performance. The key figure to check is what is reported as the internal transfer rate for the drive. For example, here are the specs on two similar drives (one IDE and one SCSI):

IDE Drive

Drive	IBM Deskstar 18GXP ATA
Interface	Ultra-ATA/66
Platters	5
Data heads	10
Capacity	18.0GB
Recording density	218.6KB/inch
Rotational speed	7,200rpm
Internal cache buffer	2MB
Interface transfer rate	up to 66.7MB/sec
Media transfer rate	27.9MB/sec max.
Sustained data transfer rate	10.7–17.9MB/sec max.
Average sustained transfer rate	14.3MB/sec

SCSI Drive

Drive	IBM Ultrastar 18ES SCSI
Interface	Ultra2/Wide SCSI
Platters	5
Data heads	10
Capacity	18.2GB
Recording density	220KB/inch
Rotational speed	7,200rpm
Internal cache buffer	2MB
Interface transfer rate	up to 80MB/sec
Media transfer rate	30.5MB/sec maximum
Sustained data transfer rate	12.7–20.2MB/sec
Average sustained transfer rate	16.45MB/sec

Note that although the SCSI drive can claim a much higher external transfer rate of 80MB/sec as compared to the ATA drive's 66.7MB/sec, in actuality these drives are almost identical performers. The real specs to look at are in the last two lines of the tables, which detail how fast data can actually be read from the drive. In particular, the sustained transfer rates are the true transfer rates for reading data from these drives; as you can see, they are very close indeed. The true transfer rate of a drive is mainly influenced by the rotational speed, track density, and things such as internal buffers or caches.

Then you have to factor in that the SCSI drive listed earlier would cost 50%–100% more than the IDE counterpart. Not to mention the cost of springing for an Ultra2/Wide host adapter to plug the drive into. Decent SCSI adapters, especially Wide SCSI versions, can easily run $300 or more. When you consider that the UltraATA interface is built into most modern motherboards for free, you can see that, depending on your needs, spending a ton of extra cash for SCSI can be a significant waste of money.

Now to present the counterpoint: Although these two drives are basically equivalent, the ATA version was one of the top ATA drives offered by IBM at the time, whereas the SCSI drive listed earlier was only a middle-of-the-pack performer. IBM and others make SCSI drives that have rotational speeds of 10,000rpm, increased track density, and larger buffers. Of course, these drives cost even more. So the bottom line is that if you must have the absolute best performing drives, by all means get the top-of-the-line SCSI drives and Ultra SCSI Wide adapters. However, if you want something that is literally 1/3 to 1/4 the cost and 3/4 or more the performance, stick with IDE.

Performance

ATA IDE drives currently are used in most PC configurations on the market because the cost of an IDE-drive implementation is low and the performance capabilities are high. In comparing any given IDE and SCSI drive for performance, you have to look at the capabilities of the HDAs that are involved.

To minimize the variables in this type of comparison, it is easiest to compare IDE and SCSI drives from the same manufacturer that also use the identical HDA. You will find that in most cases, a drive manufacturer makes a given drive available in both IDE and SCSI forms. For example, most hard drive companies make similar SCSI and IDE drives that use identical HDAs and that differ only in the logic board. The IDE version has a logic board with a built-in disk controller and a direct AT bus interface. The SCSI version has the same built-in disk controller and bus interface circuits and also a SBIC chip. The SBIC chip is a SCSI adapter that places the drive on the SCSI bus. What you will find, in essence, is that virtually all SCSI drives actually are IDE drives with the SBIC chip added.

The HDAs in these sample drives are capable of transferring data at a sustained rate of up to 8MB/sec or more. Because the SCSI version always has the additional overhead of the SCSI bus to go through, in almost all cases the directly attached IDE version performs slightly faster.

SCSI Versus IDE: Advantages and Limitations

Modern operating systems are multitasking, and SCSI devices (with all their additional controller circuitry) function independently of one another, unlike IDE. Therefore, data can be read and written to any of the SCSI devices simultaneously. This enables smoother multitasking and increased overall data throughput. The most advanced operating systems, such as Windows NT/2000, even allow drive striping. A *striped drive set* is two or more drives that appear to the user as one drive. Data is split between the drives equally, again increasing overall throughput. Increased fault tolerance and performance are readily implemented and supported in SCSI drive arrays.

The new Ultra3 (Ultra160) SCSI drives offer even more advantages when compared with IDE. Ultra160 SCSI is 240% faster than UDMA/66 (Ultra DMA) IDE, which has a maximum data rate of 66MB/sec. Ultra160 SCSI also fully supports multitasking and can significantly improve system performance in workstations and servers running Windows NT or 2000. IDE limits cable lengths to 18 inches, effectively eliminating the ability to connect remote or external devices, whereas Ultra3 (Ultra160) SCSI allows external connections of up to 12 meters or more in length. Also note that IDE allows only 2 devices per cable, whereas Ultra160 SCSI can connect up to 15 devices. Finally, the domain validation feature of Ultra160 SCSI enables noise and other problems on the bus to be handled properly, whereas with IDE, if a problem occurs with the connection (and that is more common at the UDMA/66 speeds), the IDE drives simply fail.

IDE drives have much less command overhead for a given sector transfer than do SCSI drives. In addition to the drive-to-controller command overhead that both IDE and SCSI must perform, a SCSI transfer involves negotiating for the SCSI bus; selecting the target drive; requesting data; terminating the transfer over the bus; and finally converting the logical data addresses to the required cylinder, head, and sector addresses. This arrangement gives IDE an advantage in sequential transfers handled by a single-tasking operating system. In a multitasking system that can take advantage of the extra intelligence of the SCSI bus, SCSI can have the performance advantage.

SCSI drives offer significant architectural advantages over IDE and other drives. Because each SCSI drive has its own embedded disk controller that can function independently from the system CPU, the computer can issue simultaneous commands to every drive in the system. Each drive can store these commands in a queue and then perform the commands simultaneously with other drives in the system. The data could be fully buffered on the drive and transferred at high speed over the shared SCSI bus when a time slot was available.

Although IDE drives also have their own controllers, they do not operate simultaneously, and command queuing is not supported. In effect, the dual controllers in a dual-drive IDE installation work one at a time so as not to step on each other.

IDE does not support overlapped, multitasked I/O, which enables a device to take on multiple commands and work on them independently and in an order different from which they were received, releasing the bus for other devices to use. The ATA bus instead waits for each command to be completed before the next one can be sent.

As you can see, SCSI has some advantages over IDE, especially where expansion is concerned, and also with regard to support for multitasking operating systems. Unfortunately, it also costs more to implement.

One final advantage of SCSI is in the portability of external devices. It is easy to take an external SCSI CD-ROM, tape drive, scanner, or even a hard disk and quickly move it to another system. This allows moving peripherals more freely between systems and can be a bonus if you have several systems with which you might want to share a number of peripherals. Installing a new external SCSI device on a system is easier because you normally will not need to open it up.

Recommended SCSI Host Adapters

For SCSI host adapters, I normally recommend Adaptec. Its adapters work well and come with the necessary formatting and operating software. Windows 9x, Windows 2000, and even OS/2 have built-in support for Adaptec SCSI adapters. This support is a consideration in many cases because it frees you from having to deal with additional drivers.

Standard or Fast SCSI is adequately supported by the ISA bus, but if you are going to install a Wide SCSI bus—or especially an Ultra, Ultra2, or Ultra160 bus—you should consider some form of local bus SCSI adapter, normally PCI. This is because ISA supports a maximum transfer speed of only about 8MB/sec, whereas a Fast-Wide SCSI bus runs up to 20MB/sec, and an Ultra3 (Ultra160) SCSI bus runs up to a blazing 160MB/sec! In most cases, a local bus SCSI adapter would be a PCI bus version, which is supported in most current PC systems.

◀◀ See "The ISA Bus," p. 300.

◀◀ See "The PCI Bus," p. 310.

Like all modern PCI adapters, plug-and-play is supported, meaning virtually all functions on the card can be configured and set through software. No more digging through manuals or looking for interrupt, DMA, I/O port, and other jumper settings—everything is controlled by software and saved in a flash memory module on the card. Following are some features found on the latest SCSI cards:

- Complete configuration utility built into the adapter's ROM
- Software-configurable IRQ, ROM addresses, DMA, I/O port addresses, SCSI parity, SCSI ID, and other settings
- Software-selectable automatic termination (no resistors to pull out!)
- Enhanced BIOS support for up to 15 drives
- No drivers required for more than two hard disks
- Drive spin-up on a per-drive basis available
- Boots from any SCSI ID

Adaptec has full PnP support on all its SCSI adapters. These adapters either are automatically configured in any PC that supports the PnP specification or can be configured manually through supplied software in non-PnP systems. The PnP SCSI adapters are highly recommended because they can be configured without opening up the PC! All functions are set by software, and there are no jumpers or switches to attend to. Most peripheral manufacturers write drivers for Adaptec's cards first, so you will not have many compatibility or driver-support problems with any Adaptec card.