7 HARD DRIVES

Starting Point

Go to www.wiley.com/college/groth to assess your knowledge of hard drives.
Determine where you need to concentrate your effort.

What You'll Learn in This Chapter

- ▲ The components and characteristics of hard drives and how they work
- ▲ PATA and SATA standards for hard drives and how to install and configure an ATA hard drive
- ▲ SCSI standards for hard drives and how to install a SCSI hard drive
- ▲ Hard drive partitioning, formatting, and management

After Studying This Chapter, You'll Be Able To

- ▲ Compare hard drives in terms of industry standard ratings
- ▲ Identify recent hard drive standards
- ▲ Distinguish unique installation considerations for different hard drive technologies
- ▲ Choose an appropriate hard drive and interface for an existing PC
Determine partitioning and formatting limits and options for a given operating system
- ▲ Install, partition, and format a hard drive
- ▲ Use system utilities to review the status of a hard drive
- ▲ Troubleshoot a faulty hard drive

INTRODUCTION

The system memory that is used by the PC to temporarily store data coming from and going to the CPU is often referred to as primary storage. In addition to system memory, PCs also need permanent, **nonvolatile storage** areas for larger amounts of data. Nonvolatile means that the data stored on a component is not lost when power to the component is turned off. These nonvolatile storage components are often referred to as **secondary storage**. Today, the most common secondary storage components are hard drives, and these typically store the bulk of the data that a PC uses. This data includes not just user documents and files, but also user and system software, such as Microsoft Word and Microsoft Office, and any files and data needed to support running these applications. Hard drives typically reside inside the computer (although there are external and removable hard drives) and can hold more information than other forms of storage.

7.1 Understanding How Hard Drives Work

One of the most common upgrades to a PC is adding or replacing a hard drive in order to gain more storage space. To choose a compatible drive for your system, it is important to understand a few of the basics of hard drives and how they work. Understanding the main characteristics of hard drives and how hard drives are rated will also help you compare equivalent hard drives from different manufacturers and select the one that is right for your needs.

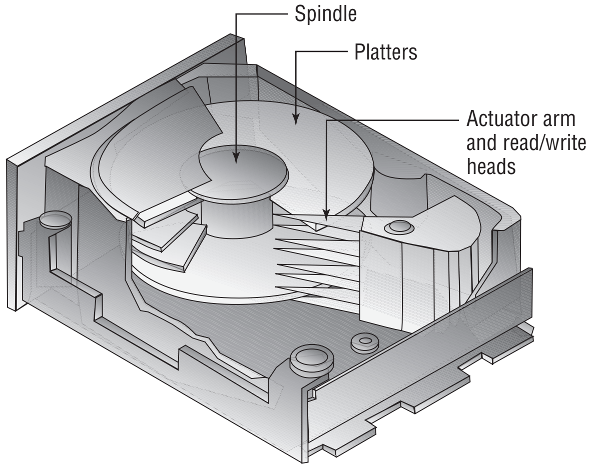
7.1.1 Hard Drive Components

Hard drives, also called hard disk drives, hard disks, or fixed disks, consist of several small, identical disks called **platters** stacked together and placed in a sealed enclosure to protect them from dust or damage. The platters are made of aluminum or glass, and are coated with a thin layer of magnetic media that stores the actual data.

The platters are mounted through their centers on a small rod called a **spindle**. The disks are rotated about the spindle at a speed typically between 4,500 and 15,000 revolutions per minute (RPM). As they rotate, **read/write heads** float approximately 10 micro inches (about one-tenth the width of a human hair) above the disk surfaces and make, modify, or sense changes in the magnetic positions of the coatings on the disks. Read/write heads have sensors and magnets used for reading and writing magnetic charges on the platters' surfaces. The read/write heads are connected to an **actuator arm**, which is used to precisely position the heads over the correct area on the platters (Figure 7-1).

Hard drives also contain a **logic board** that contains the circuits and chips that control the drive's performance. The **disk controller** is the main circuit on

Figure 7-1



Hard drive components.

the logic board that controls everything from handling requests for data to managing the mechanics of the motor, actuator arm, and read/write heads.

Also essential to the functioning of a hard drive is the **host adapter**, or host bus adapter (HBA), logical circuitry that physically connects the hard drive to the "host"—the PC. The host adapter handles basic input/output processing, converting signals from the hard drive controller to signals the PC can understand. The host adapter may be an expansion card plugged into the motherboard or its circuitry may be built directly into the motherboard.

Hard drives come in several sizes. Older hard drives were designed to fit 5.25 inch drive bays but most modern desktop computer hard drives today are designed to fit in the standard 3.5 inch drive bays. Older hard drives were much taller than modern drives and are called "full-height." Modern drives are shorter, "half-height" or even slimmer. Inside the PC, internal hard drives are connected by cables to the power supply and to the host adapter.

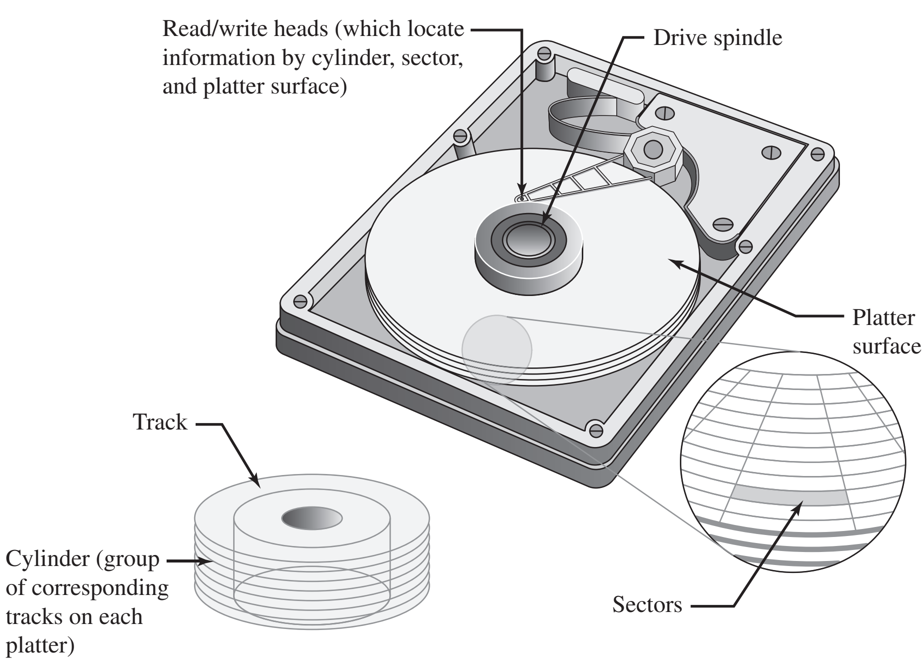
7.1.2 Drive Geometry

To read and write data to the magnetic platters of a hard drive, the drive is electronically organized into sections recognized by systems software. This organization is called **drive geometry**. The components of a hard drive's physical geometry include:

- **Heads:** A hard drive usually has one read/write head for each surface of a platter; a drive with four platters has eight read/write heads.

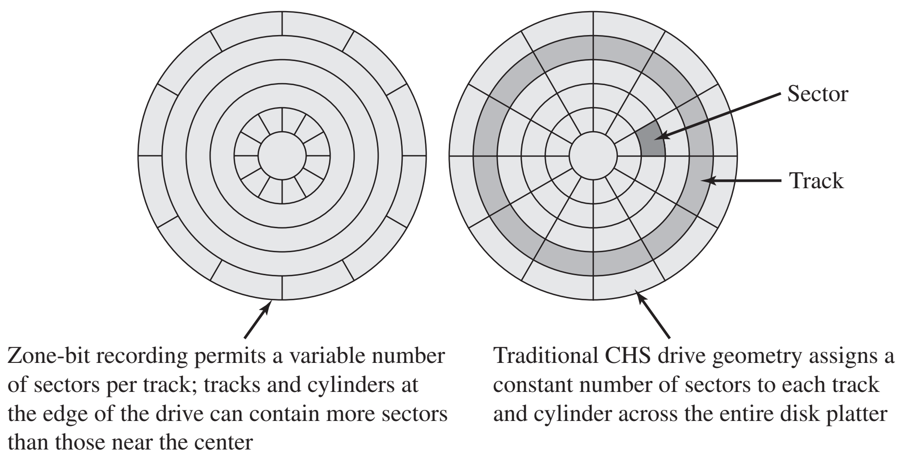
- ▲ **Tracks:** Data is written to and read from the surfaces in concentric rings called tracks. The rings, or tracks, are numbered from the outside track in, with the outside track given the initial number 0. The total number of tracks that a surface can have depends on the drive's engineering; today's hard drives may have over 16,000 tracks on each surface.
- ▲ **Cylinders:** Because all heads are on a single actuator arm, the heads read the same track number on each surface at the same time. If the actuator arm moves to Track 12, all heads will be reading from Track 12 on the separate surfaces. The collection of tracks at a single actuator-arm position is known as a **cylinder** (Figure 7-2). The total number of tracks per surface is the same as the number of cylinders. In fact, the disks' tracks aren't treated as individual tracks on single disks; they're treated as cylinders, and manufacturers more commonly note the number of cylinders that a drive has. If you need to know the number of total tracks a hard drive has over all surfaces, you can multiply the number of heads by the number of cylinders.
- ▲ **Sectors:** To organize and locate separate chunks of data on a surface, the platter is divided into 60 or more wedges that divide short sections of tracks into smaller segments called sectors. Sectors are the smallest accessible portion of data on a track, and all sectors, regardless of their

Figure 7-2



Heads, tracks, sectors, and cylinders.

Figure 7-3



Zone bit recording.

physical size, are defined as holding 512 bytes of data. When information is read from or written to a drive, the heads read or write a sector-sized division of a cylinder, from top surfaces to the bottom. In this physical geometry, with sectors defined by wedges, a certain amount of waste is built in: The sectors at the outer edges are physically quite a bit larger than inner sectors. To fit more sectors in to the outer tracks, zone bit recording (ZBR), or multiple zone recording was built in (Figure 7-3). ZBR divides the platters into different zones, nearer and further away from the spindle, and sectors within these zones are given a specified number of sectors per track. This allows outer tracks to have more sectors.

The PC's BIOS, however, is programmed to access each block of data through **CHS (cylinder, head, sector) addressing** and is unable to work with ZBR. To accommodate the needs of ZBR, drives were designed to have a logical geometry that was different from their physical geometry. The drive is given theoretical CHS values, which approximate the drive's total storage space. These values are its logical geometry and the hard drive controller uses these values to communicate with the BIOS. The drive itself is engineered to work with actual physical geometry (which can use ZBR) and can translate to and from the logical values needed by the BIOS using sector translation.

Sector translation uses a translation table that converts the actual physical geometry of a drive into the logical geometry used by the BIOS. An older method of sector translation, extended CHS (ECHS), uses logical values based on the traditional divisions of cylinders, sectors, and heads. Today, more drives use logical block addressing (LBA), which numbers all sectors on a drive sequentially, without reference to cylinders and heads.

7.1.3 Hard Drive Characteristics

There are a variety of characteristics and statistics that are used to rate and compare hard drives, including:

- **Capacity:** The capacity or size of a hard drive refers to how many bytes of data the drive can store. Capacity is determined by drive geometry. Each sector can contain 512 bytes, and a track can contain up to 63 sectors, so the total storage space of a hard drive can be determined by the following formula:

  $$\text{Capacity} = 512 \text{ Bytes per sector} \times 63 \text{ Sectors per track} \times \text{Cylinders} \times \text{Heads}$$

  Typical PC hard drives today have capacities ranging from 40GB to 500GB and higher.
- **Spin speed:** The **spin speed** is how fast the platters are spinning, measured in revolutions per minute (RPM). Higher RPM values mean faster speeds and faster access to data. Depending on the model, disks today typically rotate between 4,500 RPM and 15,000 RPM.
- **Seek time: Seek time** is the time it takes for the read/write head to react to a request and position itself over a track. A seek from one track to the next (called a track-to-track seek) is usually quickest; a seek from the innermost to the outermost track (called a maximum, or full stroke seek) is longer. The average seek time is usually defined as the time it takes the head to move one-third of the way across the platter, which typically takes from 5 to 10 ms.
- **Rotational latency: Rotational latency** is the time it takes for a requested sector to travel to the head after the read/write head is in position, and is measured in milliseconds. Rotational latency is determined by the spin speed (RPM). Average rotational latency is the time it takes for a disk to turn 180°, and can be determined by the following formula:

  $$\text{Average Rotational Latency} = (60)/(2 \times \text{RPM}) \times 1000.$$

  The worst-case latency is the time for the disk to make a full revolution. Of the seek time and the latency period, the seek time is usually the longer wait.
- **Access time:** The **access time** measures the full amount of time that it takes to move the read/write head to the correct position and access the correct sector. The average seek time plus the average latency equals the

drive's access time. The smaller the access time value, the faster the drive. The formula for access time is:

Access time = Average seek time + Average Rotational Latency

- **Interface:** The **interface** is the technology used to connect the hard drive to the rest of the system. The interface determines not only the type of physical connections and cables, but also the rate of data transfer to and from the hard drive. Interface technologies include the **Advanced Technology Attachment (ATA)** standards and the **Small Computer Systems Interface (SCSI)** standards, each of which is discussed in more detail later in this chapter.
- **Disk cache size:** To improve access times and data throughput, modern drives include a **disk cache** or buffer that may hold from 1 to 8 or more MB of data. The disk cache is used to store frequently used or recent data and helps to minimize the number of physical seeks to the hard drive.
- **Data transfer rate:** The **data transfer rate** measures the total amount of data that the drive can transfer over a specified time period, usually 1 second. The data transfer rate of a drive depends on its internal and external transfer rates. The external transfer rate measures the time taken to transfer data between the PC's RAM and the drive's disk cache. The internal data transfer rate measures how fast the drive can move data between its disk cache and the platter surface.
- **Data transfer mode:** The **data transfer mode** is the protocol used to transfer data to and from the hard drive. The data transfer mode is prescribed by the drive interface. SCSI hard drives use SCSI data transfer

FOR EXAMPLE

Real World Advice: Advertised Capacity

It is important to note that there is a difference between the actual capacity of a hard drive and its advertised capacity. Manufacturers use metric calculations for megabytes and gigabytes. Metric calculations assume that a kilobyte is 1000 bytes, a megabyte is a 1000 kilobytes, and so on. However, in the binary computations that PCs use, a true kilobyte is 2^{10} bytes, or 1024 bytes and a true megabyte is 1024 kilobytes. At very large drive capacities, this can mean there is a significant difference between what the manufacturer reports as the drive capacity and what your PC recognizes as the actual capacity. In addition, the final, usable capacity of a hard drive depends to a degree on the type of file system the drive is formatted with.

modes. Early parallel ATA drives used the PIO (Programmed Input/Output) mode, which relied on the CPU to control the transfer of data from the hard drive. The DMA (Direct Memory Access) mode relieves the CPU of this duty, and transfers data directly to RAM. DMA modes can also be grouped into two categories: single word DMA modes and multiword DMA modes. Single word DMA transfers data one word (two bytes of data or 16 bits) at a time. Multiword DMA transfers several words at a time in a kind of burst. UltraDMA (UDMA) is the most recent version of DMA and has transfer rates up to 150MBps.

7.1.4 Reading and Writing Data

During writing, the head's magnet is energized to polarize a small portion of the magnetic material. During reading, the head recognizes any **flux transitions** (changes from nonpolarized segments to polarized segments and vice versa) and interprets combinations of these changes as binary 1s or 0s. The process of translating from binary to flux transition patterns is called **encoding**. The simplest encoding method is to interpret the presence of a flux transition as a 1 and the absence as a 0. More complex methods were devised to allow for better performance on more densely packed drives. Early encoding methods included Frequency Modulation (FM), Modified Frequency Modulation (MFM), and Run Length Limited (RLL). On today's drives, PRML (Partial Response, Maximum Likelihood) and EPRML (Extended PRML) encoding methods analyze much smaller fluctuations to determine the sequence of bits. These encoding methods allow for far greater density of tracks and sectors on hard disks than previous encoding methods.

To make it easier for the operating system to manage the storage space, the information encoded on the drive is written to groups of sectors known as **clusters.** A cluster is made up of up to 64 sectors grouped together (the actual number of sectors included in a cluster varies with the size of the hard drive).

Traditionally, encoding utilized longitudinal recording, writing, and reading parallel to the disk surface. New technologies of perpendicular, or vertical, recording (PR) allows writing to layers below the disk's surface plane, greatly increasing storage capacities.

None of these encoding methods are 100 percent perfect—all data transmission technologies will experience some very small rates of error. Data errors can also be caused by the magnetic fields fading over long periods of time. Hard drives are designed with error correction mechanisms to recognize errors and correct them during transmission. Essentially, error correction methods use the hard drive controller to write extra bits of data, called the error correction code (ECC) wherever it writes a segment of data to the disk. When that same data is read, the ECC is analyzed to see if any errors have crept into the data.

SELF-CHECK

1. Which component of a hard drive contains the circuits and chips that control the drive's performance?
2. Define track, sector, cylinder, head, and cluster.
3. Describe the difference between physical and logical geometry.
4. Explain how average rotational latency is calculated.
5. Describe the process of reading and writing data to a hard drive.

7.2 Understanding and Installing ATA Hard Drives

Early PCs needed separate controller cards attached to the motherboard to connect the drive to the computer and manage transfers. Later PCs improved on this technology with the development of integrated device electronics (IDE) drives that had embedded controller circuitry into the drives themselves. A succession of standards, known as the ATA (Advanced Technology Attachment) standards, specified how early IDE and later hard drives interfaced with the PC. The first ATA standards used a parallel bus, transferring 8 bits at a time, and are called **parallel ATA (PATA).** Recent ATA standards specify the use of a faster, serial bus and are called **serial ATA (SATA).**

7.2.1 Parallel ATA Standards

Parallel ATA (or PATA) standards that have been developed over the years include ATA-1 through ATA/ATAPI-7 standards, summarized in Table 7-1. ATA-7 is the last standard governing the parallel ATA interface; all recent and future standards govern the serial implementation of ATA, or SATA. Note that you will often hear ATA devices referred to as IDE, or Enhanced IDE (EIDE), devices. IDE and EIDE are marketing terms, however, and do not reflect real standards. The PATA standards were designed to be backwardly compatible; you can use a motherboard ATA hard drive connector to connect to any standard of ATA drive: however, the performance will be limited to the standard of the slowest component.

Some of the most significant advancements made during the period in which the ATA standards were developed include

- ▲ **LBA addressing:** Support for LBA was added by ATA-2.
- ▲ **Faster PIO, DMA, and UDMA modes:** Successive ATA standards improved on previous data transfer modes. See Table 7-2 for a summary of data transfer modes.

Table 7-1: ATA Standards*

Standard	*Speed(s) (MBps)*	*PIO Modes*	*DMA Modes*	*UltraDMA Modes*	*ATAPI-Support?*
ATA	3.3–8.3	0, 1, 2	Single Word 0, 1, 2 Multiword 0	N/A	No
ATA-2	11.1–16.7	3, 4	Multiword 1, 2	N/A	No
ATA-3	11.–16.7	All	All	N/A	No
ATA-4	16.7–33.3	All	All	0, 1, 2	Yes
ATA-5	44.4–66.7	All	All	3, 4	Yes
ATA-6	100	All	All	5	Yes
ATA-7	133	All	All	6	Yes

*Generally speaking, each ATA standard is backward compatible with the standard before it, so each row in Table 7-1 has the features of the rows above it.

- **SMART:** ATA-3 included the Self-Monitoring and Analysis Tool (SMART). SMART comprises several circuits within the disk controller that keep track of error conditions and general drive statistics. These circuits try to predict when a hard drive failure will occur and notifies the BIOS and the operating system of possible imminent failure.
- **ATAPI:** Early ATA standards included support only for hard drives. ATA-4 and later ATA standards include an additional set of standards for connecting

Table 7-2: Data Transfer Modes

PIO Mode	*Maximum Transfer Rate (MBps)*	*DMA Mode*	*Maximum Transfer Rate (MBps)*	*UDMA Mode*	*Maximum Transfer Rate (MBps)*
0	3.3	Single Word 0	2.1	0	16.7
1	5.2	Single Word 1	4.2	1	25
2	8.3	Single Word 2	8.3	2	33.3
3	11.1	Multiword 0	4.2	3	44.4
4	16.6	Multiword 1	13.3	4	66.7
5	22.2	Multiword 2	16.7	5	100

other devices such as CD-ROMs and tape drives, called the AT Attachment Packet Interface (ATAPI) standard.

- **80-conductor cable:** ATA-4 defined a new 80-conductor cable to avoid transmission problems. Use of this cable is mandatory with ATA-5 onward.
- **Cyclical Redundancy Checking (CRC):** CRC is an error-checking routine that works with the new higher speeds of UltraDMA.
- **SATA:** ATA-7 included the first standards for serial ATA (SATA), an implementation of the ATA interface that operates serially.

7.2.2 Serial ATA Standards

Serial ATA (SATA) came out as a standard recently and was first adopted in desktops and then laptops. Whereas ATA had always been an interface that sends 16 bits at a time, SATA sends only one bit at a time at faster rates. Additionally, SATA does not suffer the same cross-talk interference as a parallel interface, and so SATA cables can be longer, up to 1 m. Although the industry as a whole is moving towards using SATA drives, you will still find motherboards with both PATA and SATA interface connectors.

The first SATA standard developed was **SATA-1**, (also called SATA/150), which specified transfer speeds of 150 MBps. SATA-1 is backwardly compatible with ATA devices, which means that ATA-compatible operating systems, BIOS, and disk utilities will work fine with either parallel or serial ATA drives with no special modification. The latest SATA standard is **SATA-IO**, named after its oversight committee, the SATA International Organization. You will also hear SATA-IO referred to as SATA II or SATA 3G. SATA-IO specifications provide for transfer speeds up to 3.0GB, enhanced power management, and cable lengths up to eight meters. However, note that, unlike ATA standards, the SATA-IO standards are optional: A manufacturer does not have to include all SATA-IO features to label the drive as SATA-IO.

SATA-IO features include:

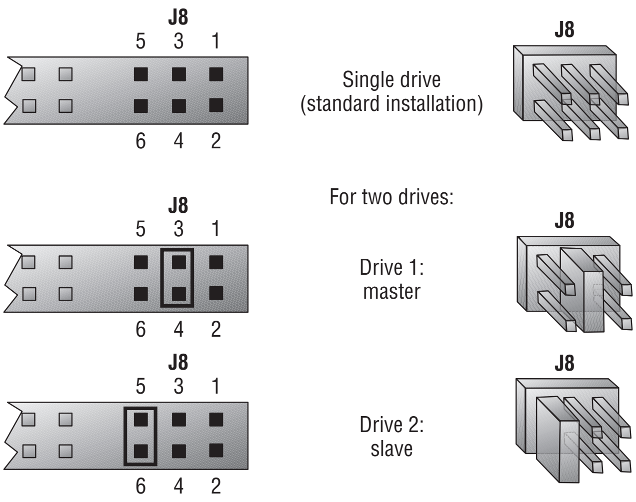
- **Port multipliers:** These devices allow up to 15 SATA devices to use the same bus.
- **Native command queuing.** Instead of having to execute hard drive requests in the order they are received, SATA drives can respond to sets of commands in the most efficient way.
- **eSATA:** External SATA (eSATA) allows external SATA drives to be connected to the host adapter.
- **Hot plug:** SATA drives are hot-pluggable, or hot-swappable. This means that the PC does not have to be powered down before attaching the hot-pluggable component.

7.2.3 Installing and Configuring ATA Hard Drives

Several concepts are essential for understanding how to install an ATA hard drive:

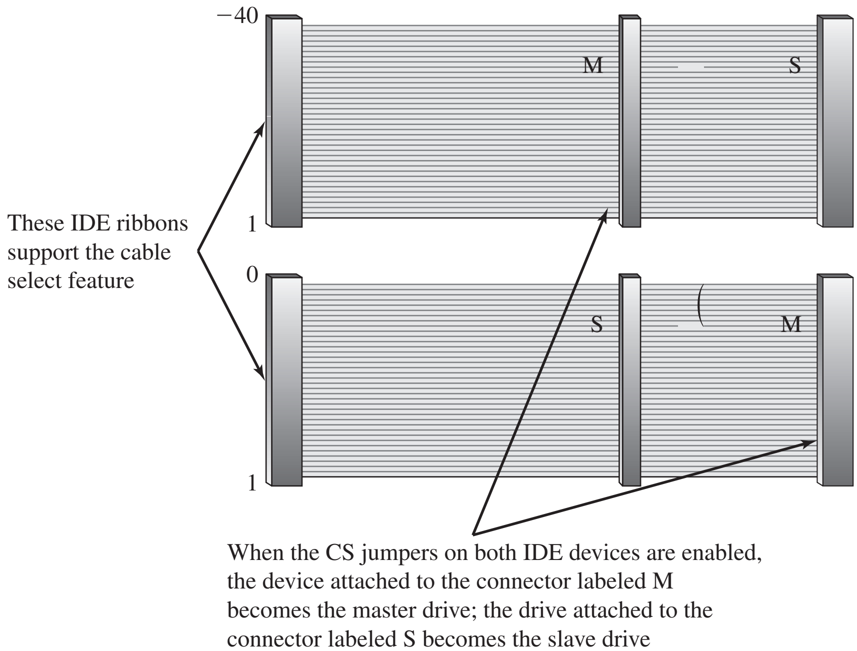
- ▲ **Master/Slave configuration:** PATA standards allow two separate PATA drives to share a single ribbon cable (and controller) using what is called a Master/Slave configuration. In this configuration, one drive is designated the Master. All signals from the host adapter are handled by the Master drive, which then forwards along any requests to the Slave drive. If you are using a Master/Slave configuration for two PATA drives using a single ribbon, you must configure one drive as Master and one as Slave. You do this typically through a jumper setting on the drive itself (Figure 7-4), but you should check the drive's documentation to see what the drive's Master/Slave settings are. You can choose the Cable Select drive setting when you are using a cable select ribbon, which designates one particular connector on the ribbon for the Master and the second for Slave (Figure 7-5). You use a Single setting when there is only one drive (a single Master) on the cable
- ▲ **IDE channel:** On most motherboards you will find two 40-pin PATA connectors, labeled **primary IDE channel** and **secondary IDE channel** (Figure 7-6). Each of these connectors can support a ribbon that

Figure 7-4



Master/Slave jumpers.

Figure 7-5

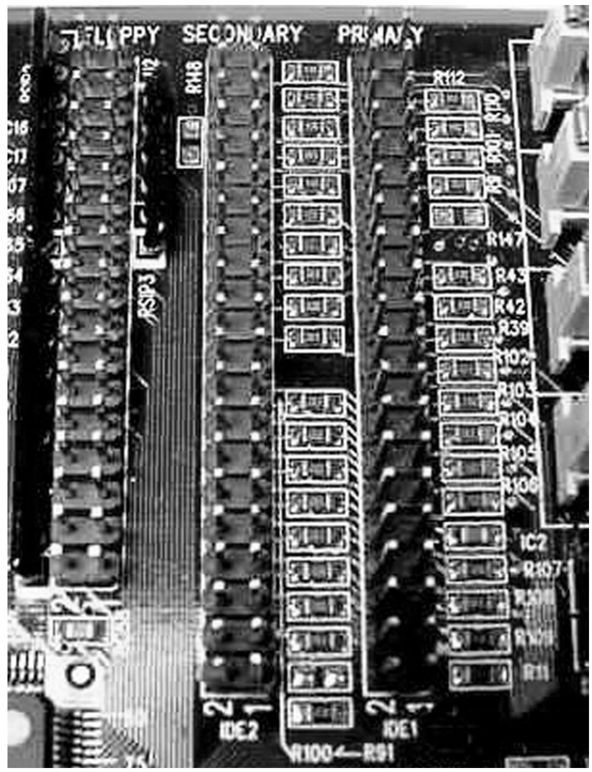


Cable select ribbons.

connects two drives. You will usually find a label or symbol pointing to one of the connector pins, Pin 1, to help in attaching a PATA ribbon.

- **Data cabling:** PATA data cables are ribbon cables (wide, flat cables) (Figure 7-7) and may have either 40 wires or 80 wires. They may have up to three connectors: for the motherboard and two PATA drives. The ribbon cable must be attached to the PATA connector on the motherboard correctly, with the Pin 1 edge on the ribbon cable connector matching up to Pin 1 on the motherboard connector. To help in making the proper connection, many ribbon cables have a colored stripe running on the edge of the cable that leads to Pin 1.
- **Power cable:** The PATA drive's power cable is attached to the power supply. It uses a Molex-type power connector that attaches directly to the drive in a matching connector port (Figure 7-8).
- **BIOS configuration:** Most new computers require little, if any, BIOS configuration to recognize a new drive. Most often, the only configuration necessary is the installation of the cable as well as changing the jumper settings. On older, pre PnP systems that don't' automatically recognize

Figure 7-6

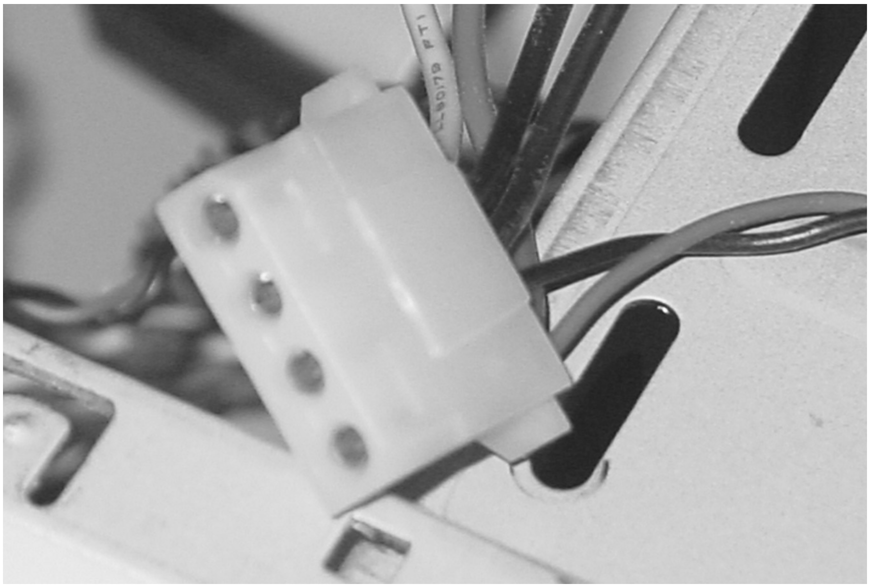


Parallel ATA interface connectors.

Figure 7-7

Ribbon cable.

Figure 7-8



Molex power connector.

ATA drives, you may need to run a Detect IDE utility from the BIOS Setup program.

To install a PATA hard drive:

1. **Plan the installation:** Decide which drive bay and IDE controller and ribbon you will be using, and any Master/Slave configuration.
2. **Configure drive jumpers:** Set the drive jumpers to Master, Slave, Cable Select, or Single.
3. **Mount the drive:** To mount the drive, slide it into the drive bay, lining up the front end of the drive with the front of the bay. You may need to use screws to hold the drives in place. You can install a 3.5" drive into a 5.25" drive bay, by using a 5.25" to 3.5" rail mounting kit.
4. **Connect to the drive interface:** Connect the ribbon cable to the IDE interface and to the drive (Figure 7-9).
5. **Connect to the power supply:** Connect the power cable to the power supply.
6. **Power up the PC:** Reconnect any devices you may have disconnected in order to mount the drive and power on the PC. Confirm that the BIOS recognizes the drive.

FOR EXAMPLE

PATA Drive Placement

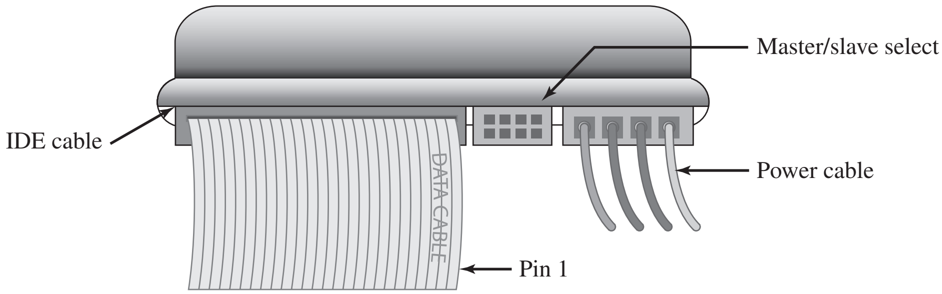
If you are installing two different PATA drives your best choice for drive placement is to use a separate IDE channel (and ribbon) for each. Using the same ribbon for the two drives will mean that, if one is built to a lower ATA standard, both drives will use the slower standard. If you need to choose a Master, choose the drive that is newer or faster. If you have three or more drives, designate drives that don't get a lot of use as the Slave drives.

7.2.4 Installing and Configuring SATA Hard Drives

Installing a SATA hard drive is virtually identical to installing an ATA Hard drive except for the following considerations:

- **Data cable:** The SATA data cable is much narrower than the PATA ribbon, and uses keyed connectors. Because SATA does not use Master/Slave configuration, a separate cable is needed for each SATA drive (Figure 7-10).
- **Power connector:** Serial ATA drives use a specific type power connector (Figure 7-11) that may not be on an older power supply. However, you can purchase adapters to convert SATA power connectors to Molex connectors.
- **SATA hard drives are hot pluggable:** They can be connected to the PC while it is running.

Figure 7-9



Installing a PATA hard drive.

Figure 7-10

SATA data cable.

Figure 7-11

SATA power connector.

SELF-CHECK

1. List four features of SATA-IO.
2. What device sends requests to an ATA Slave drive?
3. How many wires does an ATA cable have?
4. How is installing a SATA drive different from installing a parallel ATA drive?
5. How many parallel ATA connectors and SATA connectors does a motherboard typically have?

7.3 Understanding and Installing SCSI Hard Drives

SCSI (pronounced *scuzzy*) is a technology developed in the '80s that specifies an interface for connecting a specified number of devices (including the host adapter) on a single, shared cable called the **SCSI bus**. SCSI is a very fast, flexible interface. You can buy a SCSI drive and install it in any Mac, PC, or Sun workstation with a SCSI host adapter. SCSI technology is not limited to hard drives; SCSI devices include printers, scanners, and tape drives. SCSI devices can be either internal or external to the computer. The SCSI host adapter is used to manage all the devices on the bus as well as to send and retrieve data from the devices. SCSI devices are smart devices; they contain a circuit board that can control the read/write movement. SCSI drives are typically utilized in server computers, rather than individual PCs.

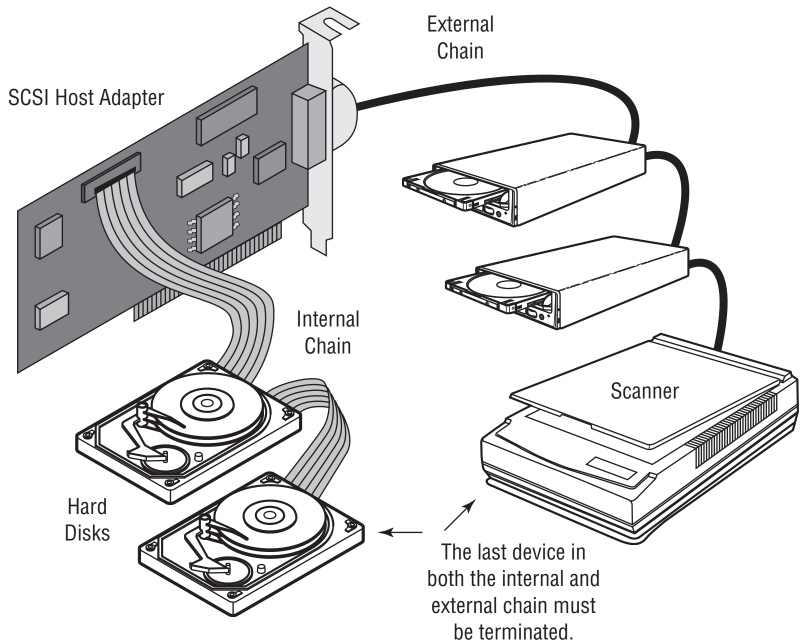
7.3.1 SCSI Features

SCSI technology is characterized by some unique features:

▲ **Daisy-chaining:** SCSI devices are connected to each other and to the host adaptor by **daisy chaining:** Each device is connected in series with the next device on the bus (Figure 7-12). Internal SCSI devices attach in sequence to a single ribbon cable. External SCSI devices use separate cables to connect to the next device in the chain and usually have two ports: one for the incoming cable, another to connect to the next device in line.

▲ **Addressing:** Each device on the SCSI bus is assigned a unique number configured through either jumpers or DIP switches on the device. When the computer needs to send data to the device, it sends a signal addressed to that number.

Figure 7-12



SCSI daisy chain.

▲ **Signaling:** Depending on the SCSI standard supported, SCSI devices use different types of signaling:

- **Single-ended signaling: Single-ended (SE) signaling**, used in the first SCSI standard, uses a positive voltage to represent binary 1, and an absence of voltage to represent binary 0. The voltages are sent over a single wire for each bit in the signal path (for example, eight wires for an 8-bit SCSI bus). SE signaling limits the length of cabling that can be used to around 6 meters.
- **High voltage differential signaling:** In **high-voltage differential (HVD) signaling**, two wires are used, each carrying the electrical opposite of the other. The receiving device takes the difference and uses the resulting value. For example, if the wires are electrically opposite (5V and –5V), the difference is zero, which represents a binary 0. If one wire is 10V and the other is +1V, the difference is a positive voltage, which represents a binary 1. Differential signaling is much more tolerant of cable distances.
- **Low-voltage differential (LVD) signaling:** Low-voltage differential (LVD) signaling works similarly to HVD signaling but uses lower voltages.

- **Bus mastering:** SCSI host adapters employ a technique called **bus mastering** that allows data to be transferred directly to system memory, bypassing the CPU. Bus mastering was designed to increase data transfer speeds and can also be used for transferring directly between peripherals.
- **Termination:** A device called a SCSI terminator (a terminating resistor pack) is configured at both ends of the bus to keep the signals from reflecting and causing interference. Termination may be external, in which a terminating block is plugged into a SCSI device's second port, or it may be internal, built into the device itself. SCSI buses use different types of termination, depending on the signaling used on the bus. LVD and HVD buses use LVD and HVD terminators respectively, although some LVD devices are equipped to switch between LVD termination and SE termination. There are three types of SE termination:
  - **Passive termination:** Passive terminators use resistors to absorb voltages; they are rarely used any more and work only with SCSI-1 devices.
  - **Active termination:** In active termination, the terminator contains (in addition to the terminating resistor) voltage regulators that actively take terminator power from the SCSI bus and use it for powering the termination of the bus.
  - **Forced Perfect Termination (FPT)** is a type of active terminator that resets voltages to the correct termination level, rather than absorbing or regulating voltages. This is the most reliable type of termination.

7.3.2 SCSI Standards

The three main SCSI standards are SCSI-1, SCSI-2, and SCSI-3. Each specifies a variety of speeds and secondary standards. Different SCSI standards have different requirements for cabling, maximum bus length, and maximum number of devices allowed on the SCSI bus. These requirements are summarized in Table 7-3:

- **SCSI-1:** The original SCSI standard supported eight devices on an 8-bit bus, using SE signaling. SCSI-1 was not universally accepted and devices from different manufacturers were not always compatible. The SCSI-1 standard is obsolete.
- **SCSI-2:** SCSI-2 defined two separate protocols:
  - **Fast SCSI:** Features data transfer speeds of up to 10MBps over the SCSI-1 8-bit cabling.
  - **Wide SCSI:** Provides for 16-bit and 32-bit SCSI bus structures.

  These two protocols can be used together to create a Fast-Wide SCSI bus to produce a transfer rate of 40MBps. SCSI-2 increased the number of devices that could be supported on the bus to 16 and added support

Table 7-3: SCSI Specifications

Name	*Speed (MHz)*	*Width (Bits)*	*Transfer Rate (MBps)*	*Max Devices*	*Cable Type*	*Max Length (Meters)*
SCSI-1:						
Asynchronous	5	8	4	7	A	6 (SE)/25 (HVD)
Fast-5 (Synchronous)	5	8	5	7	A	6 (SE)/25 (HVD)
SCSI-2:						
Fast-5 Wide	5	16	10	15	P	6 (SE)/25 (HVD)
Fast-10 (Fast SCSI)	10	8	10	7	A	3 (SE)/25 (HVD)
Fast-10 Wide (Fast Wide SCSI)	10	16	20	15	P	3 (SE)/25 (HVD)
SCSI-3:						
Fast-20 (Ultra SCSI)	20	8	20	7	A	1.5 or 3 (SE)/25 (HVD)
Fast-20 Wide (UltraWide SCSI)	20	16	40	7	P	1.5 or 3 (SE)/25 (HVD)
Fast-40 (Ultra2)	40	8	40	7	A	12 (LVD)
Fast-40 Wide (Ultra2 Wide)	40	16	80	15	P	12 (LVD)
Fast-80DT (Ultra160, Ultra3)	40	16	160	15	P	12 (LVD)
Fast-160DT (Utra320, Ultra4)	80	16	320	15	P	12 (LVD)
Fast-320DT (Ultra640, Ultra5)	160	16	640	15	P	2
Serial Attached SCSI (SAS)	n/a	1	300	128 (16,384 with expanders)	SAS	1

for HVD signaling. While SCSI-2 is backward compatible with SCSI-1 devices; the SCSI-1 devices can only operate at their original speeds.

- **SCSI-3:** SCSI-3 is a collection of standards, that includes the main SCSI Parallel Interface (SPI), also called **SCSI-3** or **Ultra SCSI,** and other SCSI-based interfaces such as iSCSI and Serial Attached SCSI (SAS). SCSI-3 introduced LVD signaling is the fastest implementation of SCSI.
- **Serial attached SCSI (SAS):** This is a version of SCSI that uses a serial cable and allows for more devices to be connected to the bus. It currently supports data transfer rates up to 300MBps
- **iSCSI:** Internet SCSI (iSCSI) combines Ethernet technologies with SCSI, and is used mainly for network attached storage. It can transfers data at rates up to 1GBps, over very long distances.

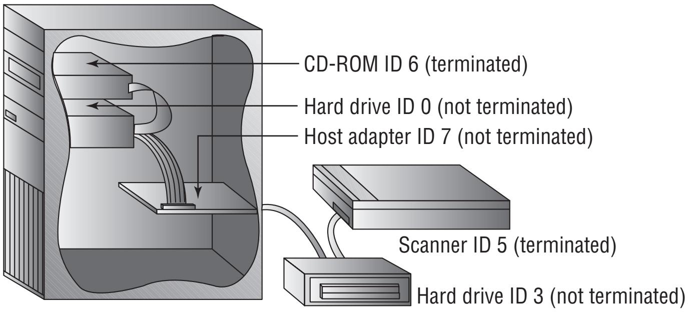
7.3.3 Installing SCSI Hard Drives

It is important to realize that the number of devices you can have on the SCSI bus is limited, as is the maximum length of the SCSI bus. Generally speaking, the faster the SCSI, the shorter the total length of the bus. Table 7-3 reviewed the device number and bus length limitations for the different types of SCSI.

Other issues central to installing SCSI devices are cabling, termination, addressing, and signaling.

- **Internal cabling:** Internal cabling is rated for the SCSI standard it supports. Terminated cables are available that come with a terminator block built into one end. There are two main types of SCSI internal cable:
  - **A cable:** A 50-pin cable used with SCSI-1 and some types of 8-bit SCSI-2 and SCSI-3.
  - **P cable:** A 68-pin cable used with most types of SCSI, including all 16-bit SCSI versions.
- **External cabling:** External cabling is also rated for the SCSI standard it supports. It uses thick, shielded cables that may have different connectors on either ends. The main connector types are:
  - **Centronics:** A standard 50-pin Centronics.
  - **Mini-Centronics:** This has the same basic shape as a Centronics connector but is smaller, with either 50 pin or 68 pin.
  - **HD:** This connector has a D-shaped ring outside of a set of 50 or 68 pins, similar to a legacy parallel port connector.
  - **VHD:** These are smaller versions of HD connectors and also have 50 or 68 pins.
- **Termination:** The first and last devices in the SCSI bus must be terminated. If you are using internal or external devices only, you terminate the

Figure 7-13



SCSI termination.

adapter and the last device in the chain only. However, if you are using a mix of internal and external devices, you must terminate the last device in the two chains, leaving the adapter unterminated (Figure 7-13). The type of terminator you use must be compatible with the type of SCSI signaling; SE (passive, active, or FTP), HVD, or LVD. If a device has built-in termination, you can, if you want, disable this (usually through a DIP switch or jumper, or through configuration software) and add a terminator.

▲ **Addressing:** All SCSI devices on a SCSI chain must be assigned a unique ID that identifies the device to other devices on the chain and to the SCSI host adapter. Depending on the SCSI version you are using, this ID is a number from 0 to 7 (Narrow SCSI) or 0 to 15 (Wide SCSI), and you assign the device its ID usually through jumpers or switches on the device itself. Some SCSI devices are assigned their IDs through their configuration software. SCSI host adapters must almost always be assigned the highest number allowed, either 7, or 15, and most host adapters expect that a bootable hard drive is located at address 0. You should check the documentation that comes with your SCSI host adapter to check the address assignments it expects. (Also, if you are configuring a SCSI chain with multiple devices, you will want to assign higher numbers to devices you use less frequently, as SCSI gives priority to the lowerSCSI IDs.). Some BIOS systems include a feature called SCSI Configured AutoMatically (SCAM) that sets SCSI device IDs through software. For this to work, the BIOS, the host adapter, and the peripheral device must support the SCAM adapter. However, SCAM was no longer continued with the SCSI-3 standard, so you will most likely find the SCAM feature on older systems.

▲ **Signaling:** Never put either SE or LVD devices on the same channel with HVD. Actual physical damage may result. Also, although SE and LVD

FOR EXAMPLE

Setting SCSI IDs

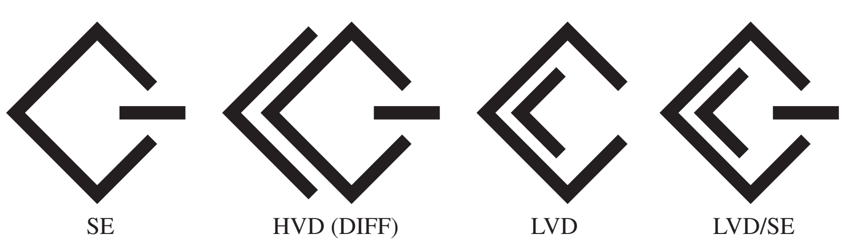
Different manufacturers of SCSI drives employ different ways of setting SCSI IDs on a device. You will usually find three or four sequential pairs of pins that represent a 3- or 4-digit binary number. The first pair represents 0001 (1), the second stands for 0010 (2), and so on. You set the ID by placing jumpers on ("shunting") the pairs, and it is the sum of the pins that have been shunted that determine the SCSI ID.

devices are electrically compatible, any SE devices on a chain with LVD devices will cause all devices to run at the SE device's slower rated speed. For best results, make sure all SCSI devices are the same type (SE, LVD, or HVD) on a single chain. Most SCSI devices are labeled with their signaling capability (Figure 7-14).

To install a SCSI drive, follow the same basic hardware installation steps mentioned for PATA drives. You don't have to modify the PC's BIOS settings. Because SCSI devices are intelligent, you tell the PC that no drive is installed, and let the adapter handle controlling the devices. However, if the drive is not recognized, you may need to do one of the following:

- If the device is bootable, you must set the host adapter to be BIOS enabled, meaning it has its own BIOS extension that allows the PC to recognize the device without a software driver.
- Load a driver for the adapter into the operating system. This method only works if you are booting from some other, non-SCSI device. If you have to boot from the SCSI drive, you must use the preceding method.

Figure 7-14



SCSI signaling labels.

SELF-CHECK

1. Explain differential signaling.
2. What is a distinguishing feature of the SAS standard?
3. How are SCSI IDs assigned?
4. Describe the difference between bus mastering and DMA.
5. Why does a SCSI bus need termination?

7.4 Partitioning, Formatting, and Managing Hard Drives

Before a drive can be used, it must be formatted and partitioned. Low-level formatting creates the physical tracks and sectors (the CHS values) on the drive. Manufacturers always perform this low-level formatting on modern drives at the factory. Partitioning is the process of assigning part or all of the drive for use by the computer. A hard drive can have one or more partitions. High-level formatting is performed by the operating system on a logical drive to install a file system that can be used by the operating system. When you purchase a new PC, it is typically ready to use, with internal drives that are formatted and partitioned. However, if you purchase a separate, new drive that you will be installing on an existing PC, you will need to partition and format it.

A partitioned and formatted hard drive must still be managed on a regular basis. Managing your hard drive means protecting your data, checking the disks for disk and file errors, ensuring that you have an emergency boot disk to use if Windows won't start normally, and knowing what to do should a drive fail.

7.4.1 Partitioning

A partition is a continuous section of sectors that are next to each other. In DOS and Windows, a partition is referred to by a drive letter, such as C: or D:. Partitioning a drive into two or more parts gives it the appearance of being two or more physical hard drives.

A hard drive can have four partitions; these are called primary partitions. These primary partitions are seen as logical drives and can be assigned only one drive letter. Each hard drive must have one primary partition that is designated as the active partition. The active partition is used to start up the PC.

One primary partition on the hard drive can be converted to an **extended partition.** An extended partition can be logically subdivided into many logical drives.

The partition that contains the specific hardware files needed to start the drive and select an operating system is referred to as the **system partition.** On most systems, the active partition is the system partition. The partition that contains the operating system's executable and support files is called the **boot partition**. The boot partition can be (and often is) the same as the system partition but may also be on an extended partition. Some PCs are configured as multiboot computers, which have more than one operating system. On startup of a multiboot computer, you can choose which operating system to load. Therefore, on a multiboot system there will be just one system partition, but several boot partitions, one for each operating system installed.

Partitioning disks can improve drive efficiency. Under DOS and Windows, cluster sizes are automatically assigned in proportion to the drive size. The bigger the drive, the bigger the clusters, and large clusters can result in wasted disk space. Reducing the size of the drive through partitioning also reduces the cluster size.

At the beginning of each hard drive (in the very first sector) is a special file called the Master Boot Record (MBR). The MBR contains the partition information about the beginning and end of each partition, and there is only one MBR for each hard drive, even if the drive has many partitions and logical drives. However, if you have an extended partition, an additional Extended Master Boot Record (EMBR) is created to store information about the logical drives on that partition.

7.4.2 High-Level Formatting and File Systems

High-level formatting prepares a drive for writing and managing files. During formatting, the surface of the hard drive platter is briefly scanned to find any possible bad spots, and the areas surrounding a bad spot are marked as bad sectors that will not be used for storage. An operating system boot record is created along with the root directory, and a File Allocation Table (FAT) or Master File Table (MFT) is created. This table contains information about the location of files as they are placed onto the hard drive. Formatting also assigns a file system to the drive, and you must use a file system that your operating system supports: different operating systems support a number of file system formats (see Table 7-4).

The most common file systems for Windows operating systems are:

- **FAT16:** Used with DOS, Windows 3.x, and early versions of Windows 95. FAT16 (generally just called FAT) has a number of advantages. First, it's extremely fast on small (under 500MB) drives. Second, it's a file system that nearly all operating systems can agree on, making it excellent for dual-boot systems. However, FAT has a limit of 4GB per partition, making it unsuitable for today's large drives of 60GB and higher. The size of clusters that FAT uses to write files is also larger than later file systems, and on large drives, this wastes hard drive space.

  FAT32: Introduced with Windows 95. FAT32 is similar to FAT but has a number of advantages. It supports larger drives and smaller allocation units. A disadvantage of FAT32 is that it isn't compatible with older DOS, Windows 3.x, and Windows 95 operating systems.

Table 7-4: Operating System Support for Different File Systems

Operating System	*FAT16*	*FAT32*	*NTFS 4*	*NTFS 5*
MS-DOS	Yes	No	No	No
Windows 95 (Original, A, B)	Yes	No	No	No
Windows 95C (OSR2)	Yes	Yes	No	No
Windows 98	Yes	Yes	No	No
Windows 98 Second Edition (SE)	Yes	Yes	No	No
Windows Me	Yes	Yes	No	No
Windows NT 4 Workstation	Yes	No	Yes	No
Windows 2000 Professional	Yes	Yes	No*	Yes
Windows XP Professional/Home Edition	Yes	Yes	No*	Yes
Windows Vista	Yes	Yes	No	Yes

*You convert NTFS 4 file systems to NTFS 5 as part of the Setup when upgrading from Windows NT 4 to Windows 2000, XP or Vista.

- **NTFS:** The NTFS file system was designed for the Windows NT operating system. NTFS includes enhanced attributes for compressing files, support for larger hard drives, improved security permissions, system logging, and disk spanning (using two or more hard disks as a single logical volume). NTFS4 is used only with Windows NT 4.0, and NTFS5 is used with Windows 2000, Windows XP and Windows Vista.

FOR EXAMPLE

FAT16 Cluster Sizes

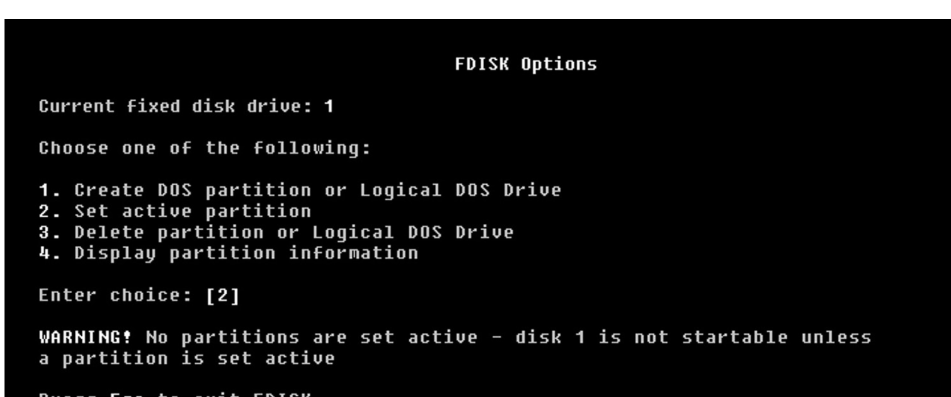
A cluster is the basic unit used to store a file or a portion of a file. On hard disks, each cluster can contain 4, 8, 16, or more sectors, depending on the file system and the size of the partition. Under FAT16, a 2GB (2048MB) partition will have 64 sectors in a cluster. Because one sector always uses 512 bytes, each cluster on this 2GB partition will be able to hold 64 x 512 bytes or 32,768 bytes. When you write a file, the hard disk will use one or more entire clusters, even if the file doesn't fill a full cluster. On a 2GB FAT16 partition, a 4KB text file and a 30KB text file will both take up a full cluster; and a 34KB text file will occupy two full clusters. When you have hundreds or thousands of such files, a lot of disk space is wasted. The FAT32 file system allows smaller numbers of sectors per cluster, so is usually a better choice when you are using large hard drive volumes.

7.4.3 Partitioning and Formatting Utilities

Although you can use third-party software to partition and format a drive, Windows operating systems include partitioning and formatting utilities:

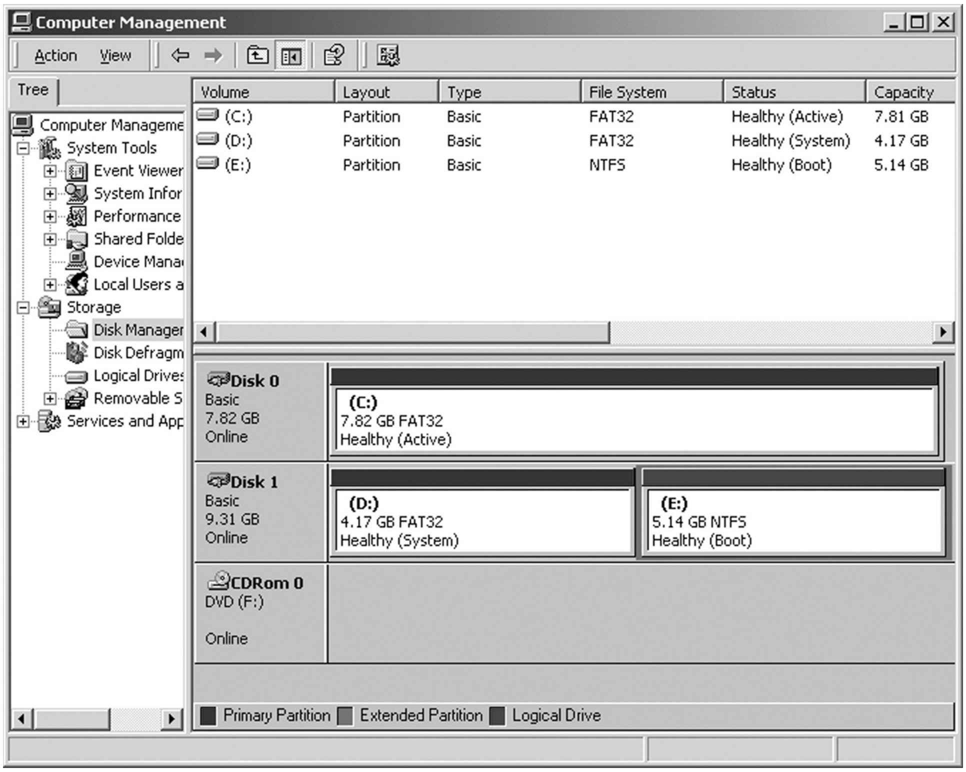
- **FDISK:** The FDISK utility is available with DOS or Windows 9x/ME. You can use FDISK to create, modify, or delete FAT16 or FAT32 partitions. To partition a boot drive, FDISK must be run from a command prompt on a startup floppy. To partition a secondary drive, you can run FDISK from the Window command prompt. FDISK can create only one primary partition and one extended partition (Figure 7-15).
- **FORMAT:** FORMAT is a command-line utility that allows you to prepare a disk to hold data. The FORMAT command can be used to format a disk. This utility is located in the C:\Windows\System32 folder but can be accessed from any command prompt. To use the FORMAT command, you type FORMAT X: (replacing X with the letter of the drive you are formatting). You can also further configure the formatting (such as specifying a files system) by adding a series of extra commands, called switches, to the command line. For a list of the switches available, use the command FORMAT /?.
- **My Computer:** You can access a Windows-based Format utility by right-clicking a drive icon in the My Computer window and selecting Format. This opens the Format Local Disk dialog box, which will guide you through the procedure.
- **Windows Setup:** When you are installing Windows NT, 2000, XP, or Vista Windows Setup will guide you through partitioning and formatting a drive, allowing you to choose sizes and file systems.

Figure 7-15



The FDISK Options menu.

Figure 7-16



Disk Management utility.

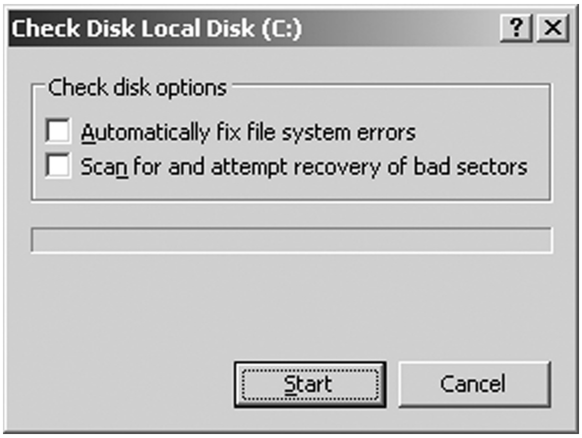
- **Disk Management:** The Disk Management utility is available with Windows NT4, 2000, XP and Vista (Figure 7-16). (In Windows NT, this component is called Disk Administrator and looks somewhat different than in Windows 2000/XP/Vista.) You use Disk Management to partition and format drives. In Windows 2000/XP/Vista you can use Disk Management to create dynamic disks. Dynamic disks are a Microsoft technology that allows you to create logical "volumes" instead of partitions, and permits an unlimited number of these volumes.
- **Recovery Console:** The Recovery Console is a command-line utility available on Windows 2000 and XP Setup CDs that is designed for troubleshooting (In Windows Vista, the Recovery Console has been replaced by the Command Prompt). From the Recovery Console, you can format drives, stop and start services, and interact with files stored on FAT, FAT32, or NTFS. The Recovery Console isn't installed on a system by default, but you can add it as a menu choice at the bottom of the startup menu.

7.4.4 Managing a Hard Drive

To protect your hard drive from data loss and maximize its efficiency, there are several tasks you should perform regularly.

- **Backing up:** Data backups ensure that should a problem develop with your PC that jeopardizes your data, you have a copy of the data to restore when the problem is solved. It is important to not only backup user data, but also essential system files. Windows 2000, XP Professional and Vista include a Microsoft Backup utility that you can find on the Tools tab of a drive's Properties dialog box.
- **Protecting against viruses:** A computer virus is a malicious third-party program that can do considerable damage to your data and cause a hard drive to malfunction. Viruses are typically infected files or programs that are downloaded from the Internet or copied from infected disks. It is important to have a virus-protection program installed and to run the program regularly to scan your system.
- **Error-checking:** There are two types of errors a drive can develop in a hard drive. Physical errors are imperfections in the surface coat of the platters that prevent accurate data encoding. Logical errors are errors that occur in a drive's table of contents. For example, the location of a file may point to the wrong file. Logical errors are typically caused when an application, or the operating system freezes and crashes, losing data stored in system memory. You can use disk-checking utilities to detect and repair physical and logical errors. In Windows 9x (95, 98, and Me), you use ScanDisk. In Windows NT, 2000, XP, and Vista, you use Check Disk (Figure 7-17).

Figure 7-17



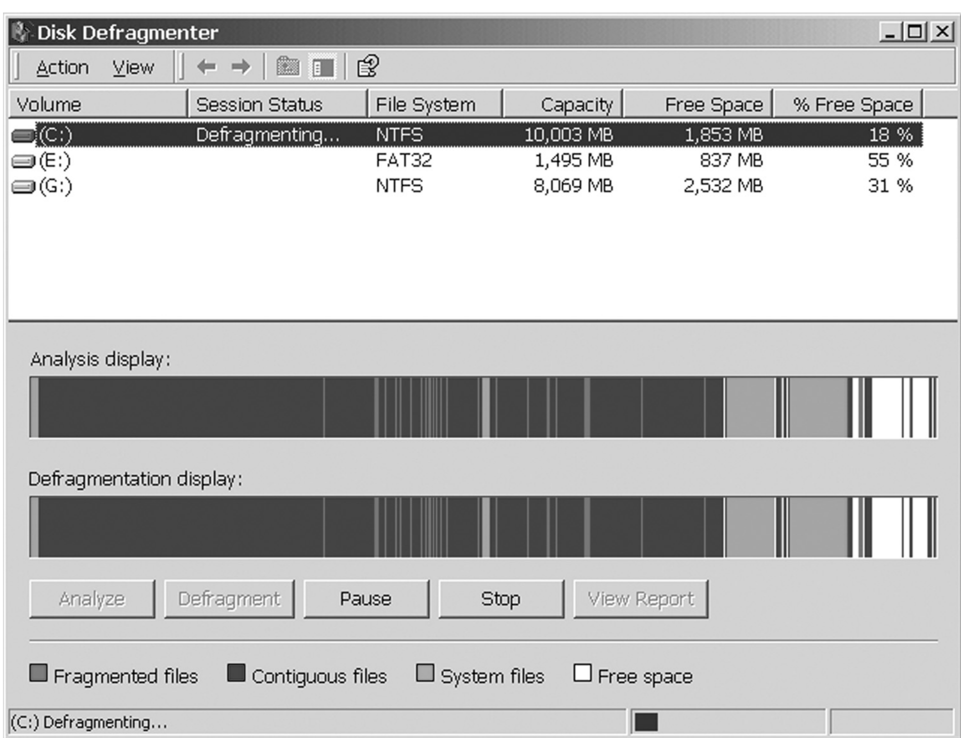
CheckDisk utility.

- **Defragmenting:** The operating system uses the first available cluster to write new files. If there is not enough contiguous (unbroken) space, the operating system will split a new file and write it to several locations. These split files are called fragmented, and they take longer to access by the read/write heads than nonfragmented files. To defragment your drive, you use the Windows Disk Defragmenter utility (Start > (All) Programs > Accessories > System Tools). Disk Defragmenter can tell you how much a drive is defragmented, whether defragmentation is recommended, and if you choose, defragment the drive (Figure 7-18).

For instances when a system's bootable hard drive crashes, you should make sure that you have an alternate way to start your computer. You do this through using a separate boot disk, either a floppy disk (for older systems) or a bootable CD. The disks you use depend on the operating system you are running.

- **Windows 9x:** In Windows 9x, you can create an emergency bootable floppy, from Add/Remove Programs in the Control Panel. When you boot

Figure 7-18



Disk Defragmenter utility.

from this floppy, you will be able to use troubleshooting utilities such as FDISK, FORMAT, and ScanDisk.

- **Windows NT/2000/XP/Vista:** These operating systems allow you to boot from their startup CDs. However, you should also create an Emergency Repair Disk (ERD). The ERD can check registry files, system files, the startup environment, and the boot sector. If it finds problems, it will tell you what files to use to fix the problems. In Window NT, you create an ERD by running RDISK.EXE located in \winnt\system32. In Windows 2000, you create an ERD by running the Emergency Repair Disk utility from the first screen of the Backup utility. In Windows XP, this emergency disk is called Automated System Recovery. You create the ASR disk using the Automated System Recovery Wizard button in the Backup utility. In Windows Vista, this functionality is called Windows Complete PC Restore.

7.4.5 Ensuring Drive Fault Tolerance

If the loss of data from a hard drive failure would be catastrophic to your organization, you need to use some method of **drive fault tolerance**. Drive fault tolerance means a hard drive is able to recover from an error condition and is implemented primarily with networked servers and data storage. Fault tolerance methods include:

- **Mirroring:** Mirroring uses two drives attached to a single host adaptor. When the OS writes data to the first drive, the same data is written to its duplicate, or mirror. If the first drive fails, the mirror drive is already online.
- **Duplexing:** Duplexing is the same as mirroring except it uses two separate host adaptors (one for each drive). Duplexing provides fault tolerance even if one of the controllers fails.
- **Disk striping with parity:** In striping, data files are subdivided and different portions written to separate disks. Striping data by itself improves only performance. To add fault tolerance, you need to use parity, or fault tolerance information computed for each block of data written to a drive. This parity information can be used to reconstruct missing data, should a drive fail.
- **Redundant Array of Independent Disks (RAID):** RAID is a storage technology that uses at least two hard drives in combination for high availability, fault tolerance, and performance. RAID drives are primarily used on servers. RAIDs can be created by using either hardware or software. A software RAID uses dynamic disks and is set up in the OS. Windows Server operating systems support RAID drives, as do Windows

2000, XP, and Vista. A hardware RAID is set up through drives that are physically connected to a RAID host adapter. Many RAID levels exist, each at a higher complexity than the next, including:

- **RAID 0:** Stripes data to multiple disks without parity or duplicating data. This RAID level only improves performance; it does not provide fault tolerance.
- **RAID 1:** Uses mirroring or duplexing with two drives
- **RAID 2:** Uses disk striping with parity with at least three drives; one of the drives is used only for parity information.
- **RAID 5:** The data and parity are striped across several drives in which the parity information for data on one drive is stored with the data on another drive.

7.4.6 Troubleshooting Inaccessible Hard Drives

Hard drive problems usually stem from one of three causes:

1. **The adapter is bad.** In this case, the BIOS will not recognize the drive. However, the drive will work properly when attached to a different host adapter. To fix this problem, replace the host adaptor.
2. **The adapter and disk are connected incorrectly.** To make sure that the hardware connection is working:
    - Check that the front panel drive LED lights up and stays on constantly. If not, the hard drive data cable is probably not properly connected.
    - Check both ends of the connecting cables to make sure they are plugged in: at the device and on the motherboard or adapter card, and check the power supply connectors. Make sure the drive's jumpers are properly configured. If another drive works with the same cable, the cable is working.
    - Install the drive on a different IDE channel. If this works, the original IDE channel may be at fault.
3. **The disk is bad.** If the BIOS recognizes the drive, but you are still having problems accessing the drive, the disk itself may be faulty. However, there are a number of different ways in which a drive may be faulty. To troubleshoot a disk, check for the following:
    - **Incorrect CMOS configuration:** Check the CMOS configuration for each hard drive. The information that you need should be in the documentation for each drive.
    - **Resource conflict:** Newly added hardware is conflicting with hard drive. Check the system resource settings to verify that a resource conflict has not been created by installing a new piece of hardware.

FOR EXAMPLE

Hard Drive Noise

During startup and while running, most hard drives produce certain characteristic noises. Pay attention to the normal sounds your hard drive makes—if you hear any unusual sounds (a high-pitched tone, a new clicking, rumbling, or grinding, or even any louder than normal noises continuing for over a month), this may be a signal that your hard drive is about to fail.

- **Corrupt or missing boot partition:** The boot partition on the hard drive may be corrupted. If the system files on the boot partition are corrupt, the system cannot boot properly. Copy your backed-up system files to the drive or use an ERD to repair the system files. You may have to format the partition and reinstall the operating system, should this fail to solve the problem. Also, verify that the boot partition has not been accidentally removed.
- **Virus infection:** The hard drive may be infected with a virus. Many viruses can corrupt the Master Boot Record on the hard drive and cause errors that show up as hard drive errors. If an antivirus program is not installed on the PC, install one and scan the hard drive.
- **Defective hard drive:** The hard drive may be defective. A louder-than-usual noise that the drive has been making for over a month may have been a sign that the bearings were seizing. Drives can experience mechanical problems; read/write problems; and circuitry problems.

Some of the common PC system error messages for hard drive problems are as follows:

- ▲ **Hard disk configuration error:** An incorrect CMOS configuration or a loose data cable causes this message.
- ▲ **Hard disk 0 failure:** Disk 0 is the Master drive on the primary IDE channel. This message is caused by an incorrect CMOS configuration or a bad connection to the power supply.
- ▲ **Hard disk controller failure:** Check the connection of the data cable on the drive and the power connectors.

When you are troubleshooting a SCSI hard drive, keep in mind the following:

- ▲ **CMOS setup:** The hard drive settings in the CMOS should be set to None or Auto-detect.

- **SCSI device drivers:** SCSI devices require device drivers. Make sure that the latest drivers are installed.
- **Host adapter and hard drive IDs:** The SCSI host adapter is almost always device 7 on the SCSI chain, and the first SCSI hard drive on the channel should be assigned as SCSI ID 0. If you have two or more SCSI hard drives, or any other SCSI devices, on the same SCSI cable, each device must have a unique SCSI ID number.
- **Termination:** If the SCSI hard drive is the only internal device or the last device on the internal SCSI channel, the hard drive must be terminated.

If nothing you do helps to resurrect a hard drive, you do have some options for trying to recover data on the drive. You can purchase a specialized data recovery utility program (one example is Ontrack's Easy-Recovery). These are designed to recover and reconstruct whatever file fragments are readable on the drive. A more expensive option is to send the drive to a data recovery service that specializes in retrieving data from failed drives.

SELF-CHECK

1. Describe low-level formatting, partitioning, and high-level formatting.
2. What is the difference between a primary partition and an extended partition?
3. What is a file allocation table?
4. List three partitioning utilities.
5. Describe the difference between a physical drive error and a logical drive error.
6. How does a file become fragmented?

SUMMARY

Key components of a hard drive system include platters coated with magnetic media, read/write heads, controller circuitry, and the host adaptor. Hard drive organization, called geometry, consists of heads, tracks, cylinders, and sectors. Characteristics used to rate and compare hard drives include capacity, spin speed, seek time, rotational latency, access time, interface, disk cache, data transfer rate, and data transfer mode. Hard drives connect to a host adaptor on the motherboard or a separate expansion card. They use a specific interface technology in order to communicate.

Popular interfaces include parallel Advanced Technology Attachment (ATA), Serial ATA (SATA), and Small Computer Systems Interface (SCSI). Each interface type has a succession of improved standards defining characteristics such as transfer rate and cabling.

Internal hard drives are mounted in a drive bay and use a data cable to connect to the motherboard and power cable to connect to the power supply. All drives need the appropriate cabling, connectors, and host adapters for connecting to the PC. Two ATA drives can be connected on a single cable to either a primary or a secondary IDE channel, but must be configured as either Master or Slave and the drives' positions will affect their performances. SATA drives do not share cables and do not require special configuration.

SCSI devices on a chain must be configured with a unique ID and devices at either end of the chain must carry a terminator resistor pack to prevent signals from reflecting. Depending on the SCSI standard, one of three signaling methods may be used: single-ended (SE), high-voltage differential (HVD), and low-voltage differential (LVD). SCSI chains are limited in total cable lengths and number of devices supported on a chain.

Hard drives must be partitioned and formatted before use. A drive manufacturer performs low-level formatting to define the drive's geometry. Partitioning divides a drive into separate areas defined by drive letters. A hard drive can have up to four primary partitions, or three partitions and one extended partition. The extended partition can contain numerous logical drives. High-level formatting prepares the logical drives by establishing a file system. Different operating systems support different files systems. Operating systems provide various utilities for partitioning and formatting. Windows 2000, XP and Vista support dynamic disks, which allow for unlimited numbers of volumes and combining disks as single volumes.

Managing a hard drive includes protecting data by making backups, guarding against viruses, checking drives for errors, defragmenting the file system, and ensuring that you have a means to boot the computer and troubleshoot a drive should it fail.

KEY TERMS

Access time

Active partition

Active termination

Actuator arm

Advanced Technology Attachment (ATA)

Boot partition

Bus mastering

Cylinder

Cylinder, Head, Sector (CHS) addressing

Daisy-chaining

Data transfer mode

Data transfer rate

Differential signaling
Disk cache
Disk controller
DMA (Direct Memory Access)
Drive fault tolerance
Drive geometry
Duplexing
Dynamic disks
Encoding
Error correction code (ECC)
Extended CHS (ECHS)
Extended partition
FAT16
FAT32
FDISK
File allocation table (FAT)
Flux transition
Forced perfect termination
Hard drive
High-level formatting
High-voltage differential (HVD) signaling
Host adaptor
Interface
Logic board
Logical Block Addressing (LBA)
Logical drive
Logical geometry
Low-level formatting
Low-voltage differential (LVD) signaling
Master Boot Record (MBR)
Mirroring
Multiword DMA
Nonvolatile storage
NTFS
Partitioning
Passive termination
PIO (Programmed Input/Output) mode
Platters
Primary partition
Read/write head
Redundant Array of Independent-Disks (RAID)
Rotational latency
SCSI terminator
Secondary storage
Sector
Sector translation
Seek time
Serial Advanced Technology Attachment (Serial ATA)
Single-ended (SE) signaling
Single word DMA
Small Computer System Interface (SCSI)
Spanning
Spin speed
Spindle
Striping
System partition
Tracks
Virus
Volume
Zone bit recording (ZBR)

ASSESS YOUR UNDERSTANDING

Go to www.wiley.com/college/groth to evaluate your knowledge of hard drives. *Measure your learning by comparing pre-test and post-test results.*

Summary Questions

1. Which device converts signals from an ATA drive into signals the CPU can understand?
   (a) disk controller
   (b) host adapter
   (c) bus
   (d) connector
2. What is the name for the wedge-shaped areas into which a typical hard drive is divided?
   (a) tracks
   (b) sectors
   (c) clusters
   (d) spindles
3. Which of the following is not a drive performance characteristic?
   (a) data transfer rate
   (b) data transfer mode
   (c) signaling method
   (d) rotational latency
4. Which of the following does a hard drive controller use to detect and correct minor data loss?
   (a) EPRML
   (b) drive fault tolerance
   (c) duplexing
   (d) ECC
5. How many devices can be used by a single ATA channel?
   (a) 1
   (b) 2
   (c) 4
   (d) 7
6. How many devices can SCSI-1 support (including the controller)?
   (a) 8
   (b) 7

(c) 1
(d) 15

7. An ATA Slave drive only listens for data being sent to it from the Master drive. True or false?
8. Unlike SATA drives, parallel ATA drives can be removed or added while the computer is running. True or false?
9. Which of the following is *not* a form of SCSI signaling?
   (a) single-ended
   (b) differential
   (c) VHD
   (d) HVD
10. The SCSI-3 standard defined which of the following specifications?
   (a) Fast-Wide SCSI, HVD, and bus mastering
   (b) Wide SCSI, HVD, and SAS
   (c) Ultra SCSI, LVD, and bus mastering
   (d) Ultra SCSI, LVD, and SAS
11. A primary partition can hold up to four logical drives. True or false?
12. How do you low-level format an ATA drive?
   (a) run FDISK
   (b) execute FORMAT.COM
   (c) you don't; it's done at the factory
   (d) low-level formatting is done automatically during Windows Setup
13. Which of the following utilities will *not* allow you to partition a hard drive?
   (a) FDISK utility
   (b) FORMAT command
   (c) Disk Management
   (d) Recovery console
14. If you convert a basic disk to a dynamic one, it won't let you span or stripe volumes. True or false?
15. Which of the following is *not* a way to protect data?
   (a) disk striping
   (b) duplexing
   (c) fault tolerance
   (d) virus protection
16. Duplexing is the same as mirroring, except that it:
   (a) uses parity to add fault tolerance
   (b) uses disk striping to improve performance

(c) uses a separate host adapter for each drive
(d) uses dynamic disks

17. Which of the following is *not* a type of hard drive error?
(a) soft error
(b) high-level error
(c) surface error
(d) logical error

18. A fragmented file has data stored in non-contiguous ____________.
(a) clusters
(b) cylinders
(c) tracks
(d) surfaces

19. Which of the following would you use to start your computer without the help of your hard drive?
(a) system disk
(b) ASR disk
(c) boot disk
(d) ERD disk

20. If a hard drive is not responding, what is one of the first troubleshooting steps you should take?
(a) Run an ERD.
(b) Check the BIOS.
(c) Reinstall the FAT.
(d) Repair the MBR.

Applying This Chapter

1. If a hard drive has 903 cylinders, 12 heads, 63 sectors per track, and 512 bytes per sector, what is its capacity?
2. If a drive is listed with a spin speed of 1200 RPM, what is its average rotational latency?
3. Explain to a novice technician how to properly connect an ATA data ribbon cable.
4. Compare and contrast the advantages of SATA and SCSI interfaces.
5. List the main steps used in installing any hard drive.

YOU TRY IT

Configuring and Positioning ATA Hard Drives

You are installing two ATA-7 hard drives using a parallel ATA interface to a computer. One of the new hard drives is significantly faster than the other. The computer system supports ATA-7 and already has an older ATA-6 internal hard drive and a CD-ROM drive. Describe how you will configure and position the drives.

Troubleshooting an ATA Installation

You need to explain to a technician over the phone how to take some simple troubleshooting steps with respect to a newly installed hard drive that isn't being recognized by the system. What steps will you ask the technician to perform?

Terminating SCSI Buses

You have installed an internal SCSI hard drive and two external SCSI devices: a scanner and a CD-ROM drive. The scanner is the last device on the chain. Which device(s) should be terminated?

Purchasing the Right Drives

Your organization's multimedia developer needs 500GB of additional drive space with a fast response time, but your budget is limited to $300 or less. You have inspected the developer's system: it supports ATA-7 and has two internal ATA-drives with one drive bay open. The motherboard does have four SATA connectors and a free PCI slot for an additional expansion card. What interface will you recommend? Go online to research hard drives from Maxtor (Maxtor.com), Seagate (Seagate.com), and Western Digital (Westerndigital.com), and then determine the hard drive or drives you would recommend for the system. List the reasons why you think your proposed hard drive is a good choice over its competitors.