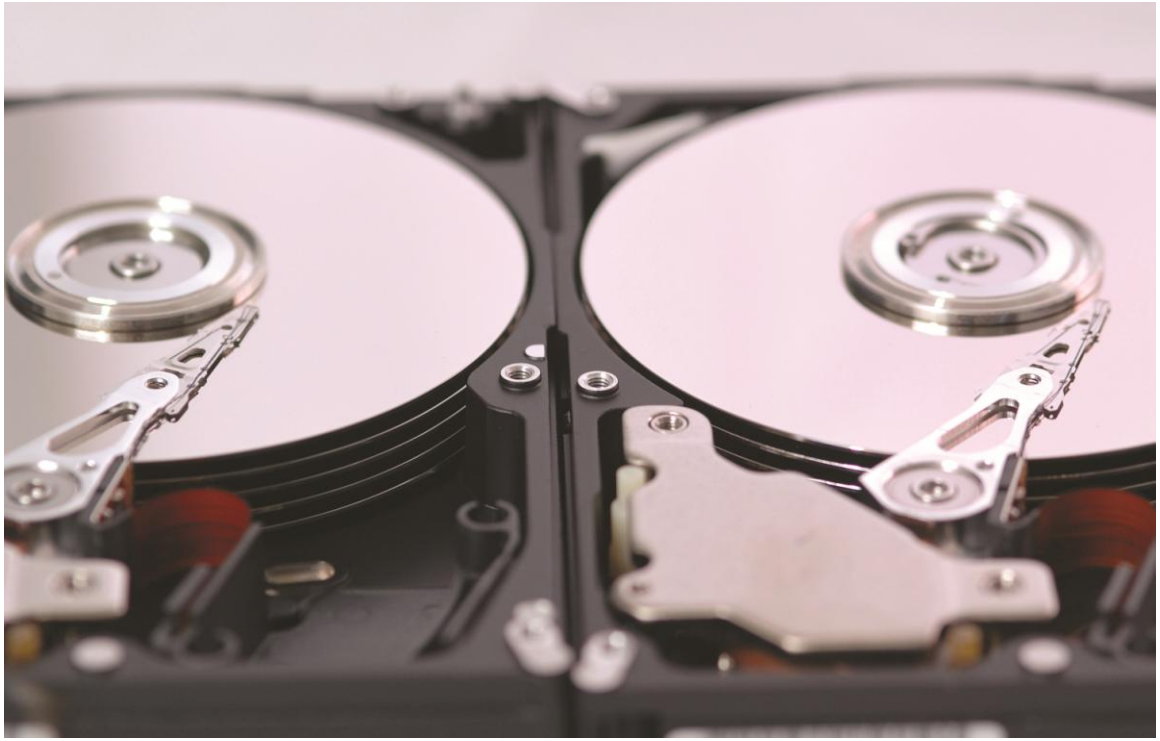
Hard Drive Technologies

Chapter 11



Overview

- **In this chapter, you will learn how to**
  - Explain how hard drives work
  - Identify and explain the PATA and SATA hard drive interfaces
  - Identify and explain the SCSI hard drive interfaces
  - Describe how to protect data with RAID
  - Install hard drives
  - Configure CMOS and install drivers
  - Troubleshoot hard drive installation

Historical/Conceptual

How Hard Drives Work

The Platter-based Hard Drive

- A traditional hard disk drive (HDD) is composed of individual disks or platters.
- The platters are made up of aluminum and coated with a magnetic medium.
- Two tiny read/write heads service each platter.

The Platter-based Hard Drive *(continued)*

Figure 1: Inside the hard drive

The Hard Drive

- The closer the read/write heads are to the platter, the more densely the data can be packed on to the drive.
- Hard drives use a tiny, heavily filtered aperture to equalize the air pressure between the exterior and interior of the hard drive.
- Platters spin between 3,500 and 15,000 revolutions per minute (RPM).

The Hard Drive *(continued)*

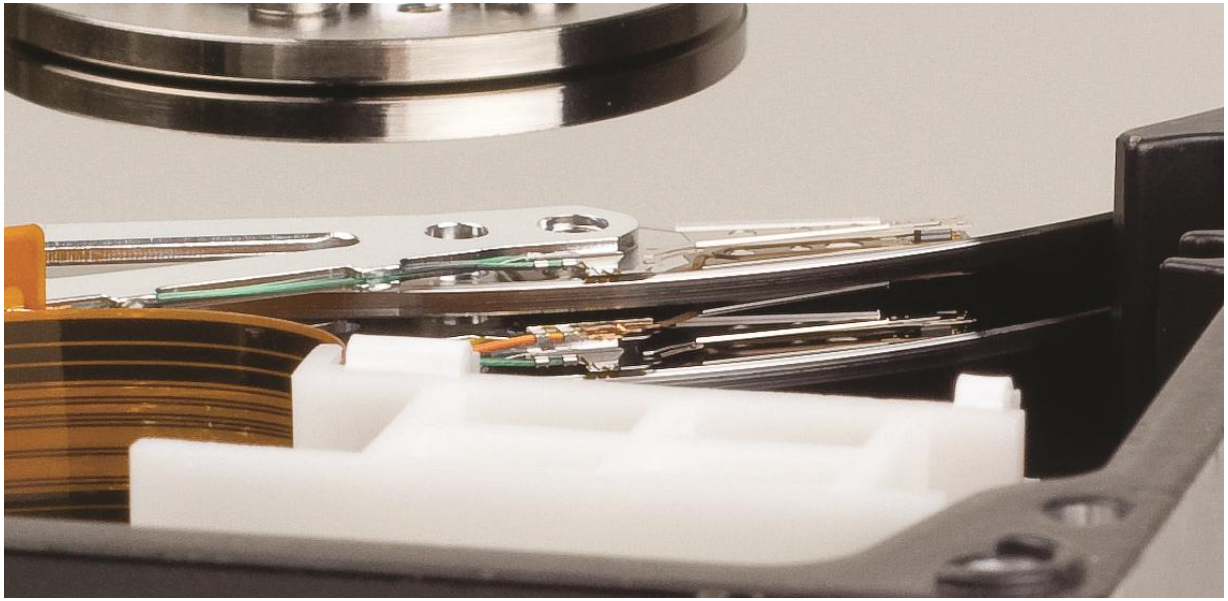
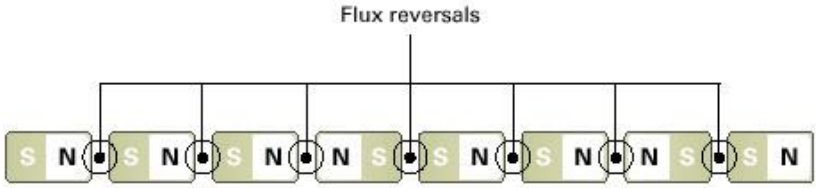


Figure 2: Read/write heads on actuator arms

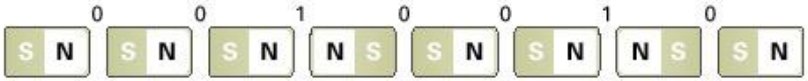
Data Encoding

- **Hard drives store data in tiny magnetic fields called fluxes**

- **The flux switches back and forth through a process called flux reversal**



- **Hard drives read these flux reversals at a very high speed when accessing or writing data**
  - Fluxes in one direction are read as 0 and the other direction as 1



Data Encoding (*continued*)

- **Encoding methods used by hard drives are**
  - Run Length Limited (RLL)
    - Data is stored using "runs" that are unique patterns of ones and zeroes
    - Can have runs of about seven fluxes
  - Partial Response Maximum Likelihood (PRML)
    - Uses a powerful, intelligent circuitry to analyze each flux reversal
    - Can have runs of about 16 to 20 fluxes
    - Significant increase in capacity (up to 1 TB)

Arm Movement in the Hard Drive

- **The stepper motor technology and the voice coil technology are used for moving the head actuator**
  - Moves the arms in fixed increments or steps
  - Only seen in floppies today
- **The voice coil technology uses a permanent magnet surrounding the coil on the head actuator to move the arm**
  - Automatically parks drive over non-data area when power removed
  - This is how modern HDDs work

Geometry

- **Geometry is used to determine the location of the data on the hard drive**
  - CHS (cylinders, heads, sectors)
- **Used to be critical to know geometry**
  - Had to enter into CMOS manually
- **Today geometry stored on hard drive**
  - BIOS can query hard drive for geometry data

Heads

- **Number of read/write heads used by the drive to store data**
- **Two heads per platter (top and bottom)**
- **Most hard drives have an extra head or two for their own usage, so the number may not be even**

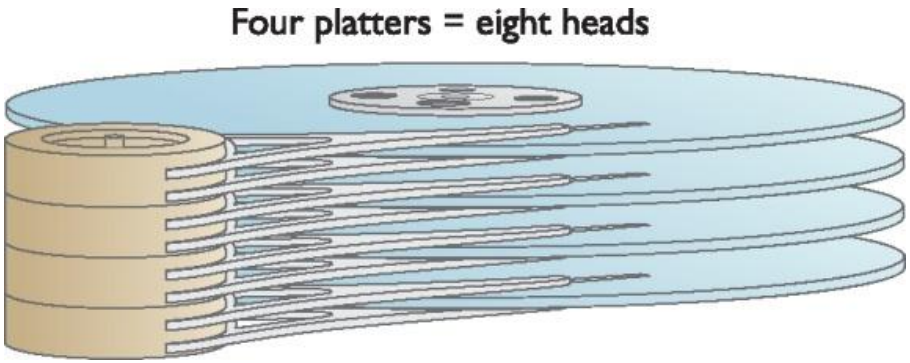


Figure 3: Two heads per platter

Cylinders

- **Data stored in concentric circles on the platters, called tracks**
- **Cylinders**
  - Group of tracks of the same diameter going completely through the drive

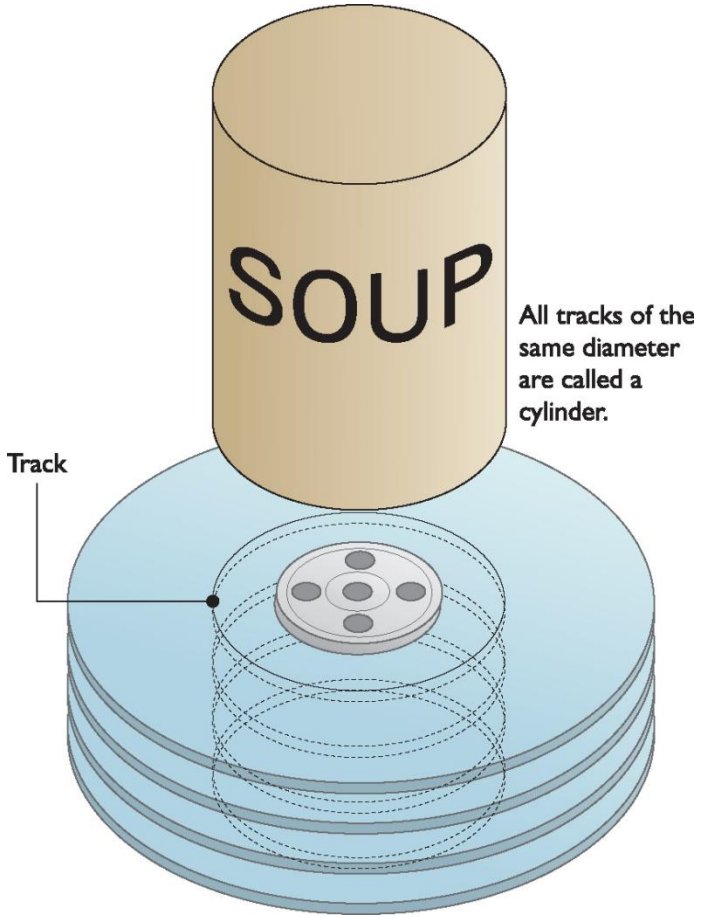


Figure 4: Cylinder

Sectors per Track

- **Number of slices in the hard drive**
- **512 bytes of storage per sector**

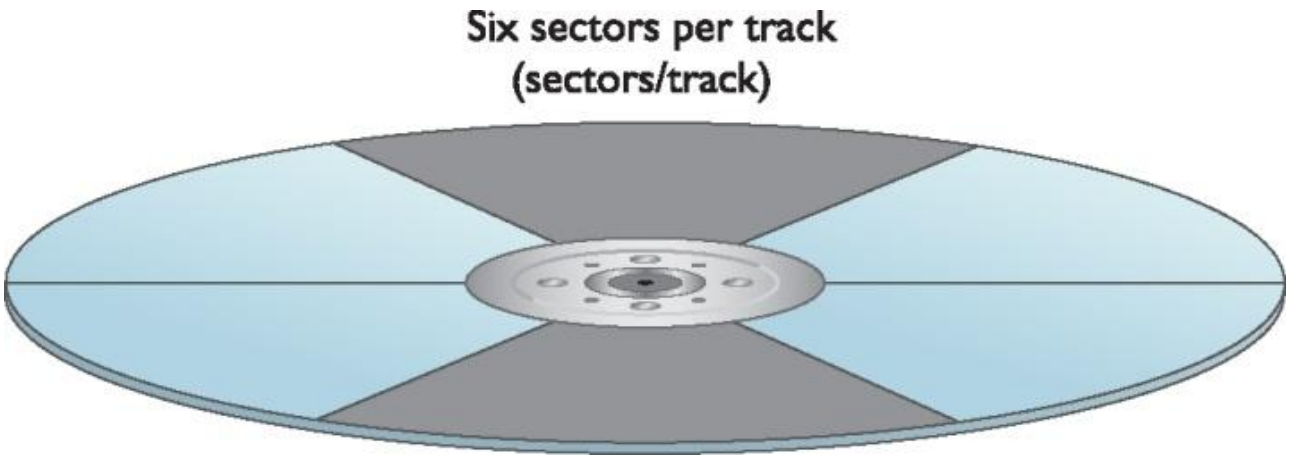
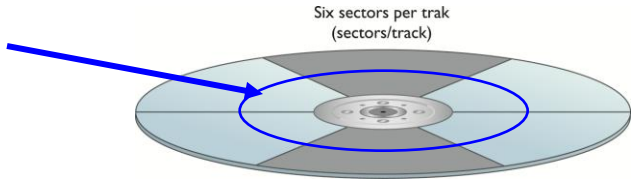


Figure 5: Sectors per track

- **Data is stored on the platters in sectors**

Obsolete Geometry

- **Might see in older systems**
- **Write precompensation cylinder**
  - The specific cylinder from where the drive would start writing data farther apart
    - Internal sectors physically smaller
    - External sectors physically larger
    - This identified cylinder where spacing changed



- **Landing zone**
  - Unused cylinder as "parking place" for heads
    - Referred to as Lzone, LZ, Park
    - Needed for older drives using stepper motors

Spindle or (rotational) speed

- **Measured in revolutions per minute (RPM)**
  - The faster the drive, the better the performance
- **Common speeds:**
  - 5400, 7200, 10,000, and 15,000 RPM
- **Faster rotational speed produces more heat**
  - Airflow is a key factor in reducing heat
  - Reduce heat with case fans or bay fans

Spindle or (rotational) speed *(continued)*

Figure 6: Bay fan

Solid-state Drives

- **A solid-state drive (SSD) uses no moving parts**
  - Fast
  - Expensive compared to HDDs
- **DRAM- and flash-based drives (latter are more common)**
- **Solid-state technology in hard drives, memory cards, and more**

Figure 7: A solid-state drive (photo courtesy of Corsair)

Flash-based SSDs

- **Pure flash drives for portables**
- **Advantages:**
  - Very low-power usage and heat generation
  - Very fast in reads because no moving parts
  - Extremely rugged—nothing to break
- **Disadvantages**
  - Price (as of early 2010)
    - HDDs: $0.10 per GB capacity
    - SSDs: $3.50 per GB capacity
  - Capacity much lower than HDDs, but climbing

Parallel and Serial ATA

- **ATA interfaces dominate today's market**
  - Many changes throughout years
  - Parallel ATA (PATA) historically prominent
  - Serial ATA (SATA) since 2003
  - Called integrated drive electronics (IDE)

ATA Overview

	Cable	Keywords	Speed	Max size
ATA-1	40-pin	PIO and DMA	3.3 MBps to 8.3 MBps	504 MB
ATA-2	40-pin	EIDE ATAPI	11.1 MBps to 16.6 MBps	8.4 GB
ATA-3	40-pin	S.M.A.R.T.	11.1 MBps to 16.6 MBps	8.4 GB
ATA-4	40-pin	Ultra	16.7 MBps to 33.3 MBps	8.4 GB
INT13		BIOS Upgrade		137 GB
ATA-5	40-pin 80-wire	ATA/33 ATA/66	44.4 MBps to 6.6 MBps	137 GB
ATA-6	40-pin 80-wire	Big Drive	100 MBps	144 PB
ATA-7	40-pin 80-wire 7-pin	ATA/133 SATA	133 MBps to 300 MBps	144 PB

ATA-1

- **40-pin ribbon cable**
- **Allowed two drives (one master, one slave)**
- **Programmable I/O (PIO)—traditional data transfer**
  - 3.3 MBps to 8.3 MBps
- **DMA—direct memory access**
  - 2.1 MBps to 8.3 MBps
- **Maximum capacity = 504 MB**

Early ATA Physical Connections

Figure 8: Back of IDE drive showing 40-pin connector (left), jumpers (center), and power connector (right)

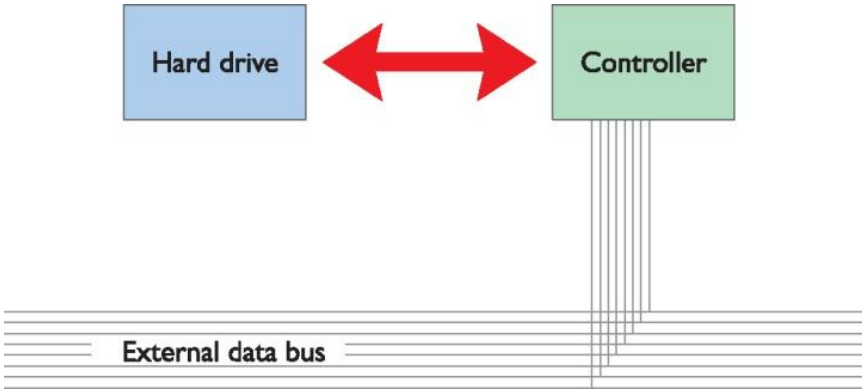


Figure 9: Relation of drive, controller, and bus

Early ATA Physical Connections *(continued)*

Figure 10: A typical hard drive with directions (top) for setting a jumper (bottom)

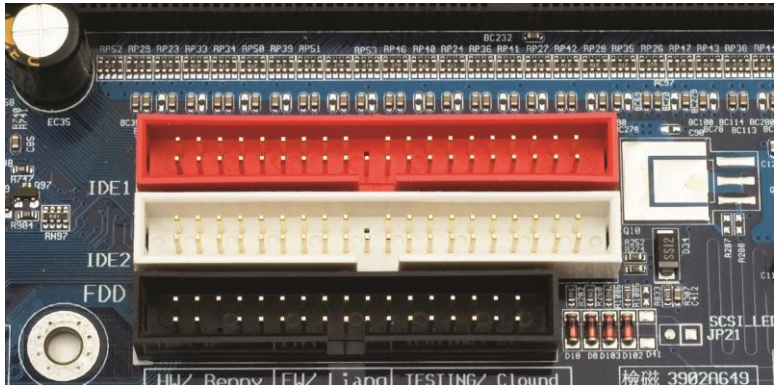


Figure 11: IDE interfaces on a motherboard

ATA-2

- **Commonly called EIDE (Western Digital marketing term)**
- **Increased maximum size to 8.2 GB through LBA and sector translation**
- **Added ATAPI**
  - Could now use CD drives
- **Added second controller**
- **Added new PIO and DMA modes to increase data transfers to 16.6 MBps**

ATA-2 (continued)

Figure 12: EIDE drive

Higher Capacity with LBA

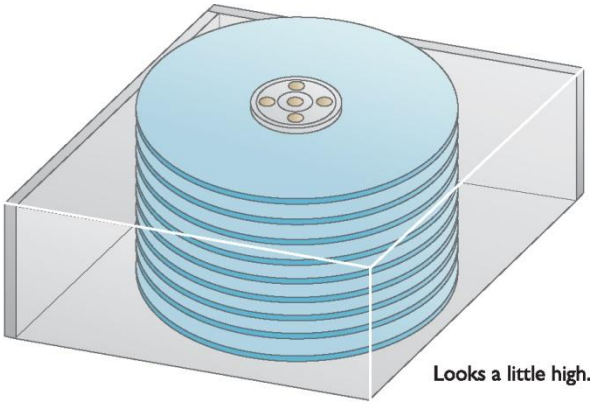


Figure 13: Too many heads

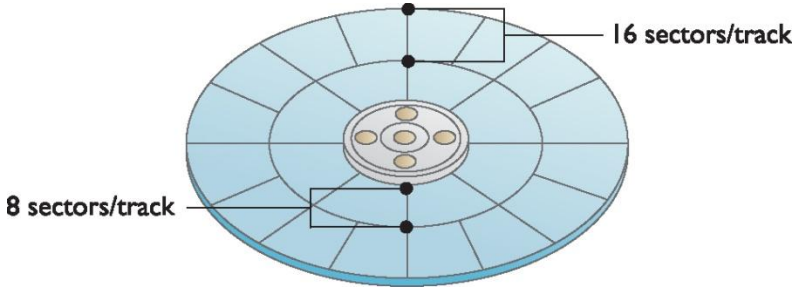


Figure 14: Multiple sectors/track

ATAPI

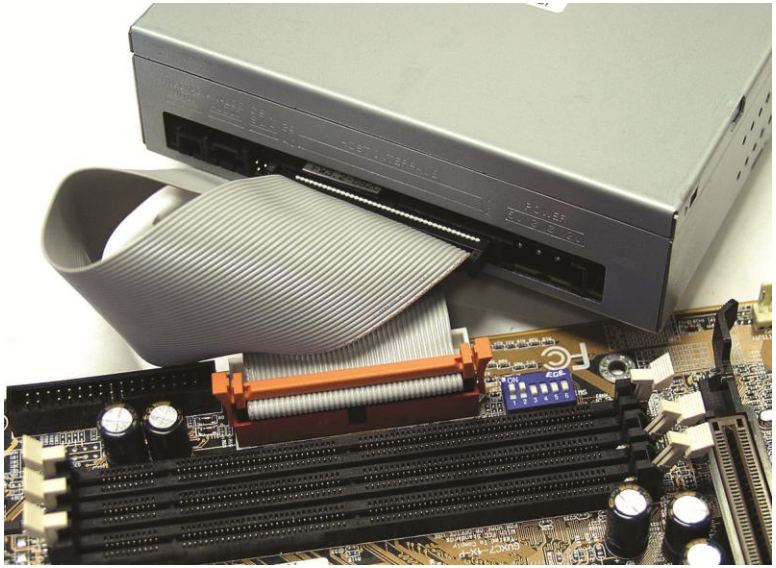


Figure 15: ATAPI CD-RW drive attached to a motherboard via a standard 40-pin ribbon cable

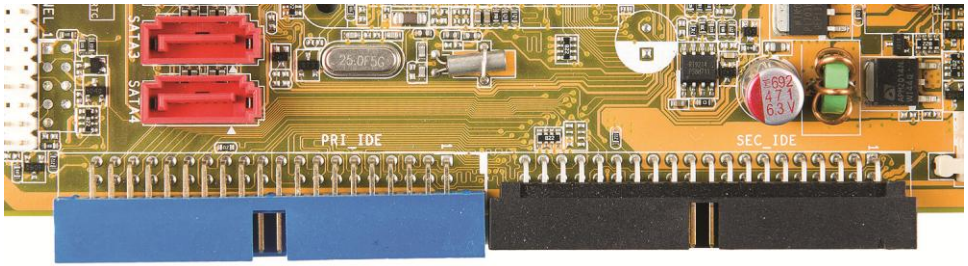


Figure 16: Primary and secondary controllers labeled on a motherboard

ATA-3

- **Self-Monitoring Analysis and Reporting Technology**
  - S.M.A.R.T.
- **No real change in other stats**

S.M.A.R.T. Information

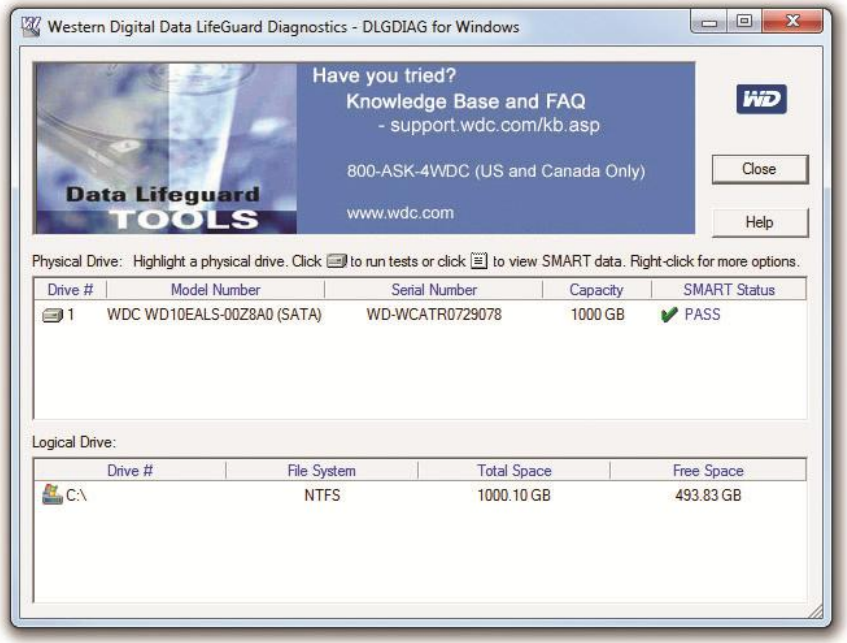


Figure 17: Data Lifeguard Tools

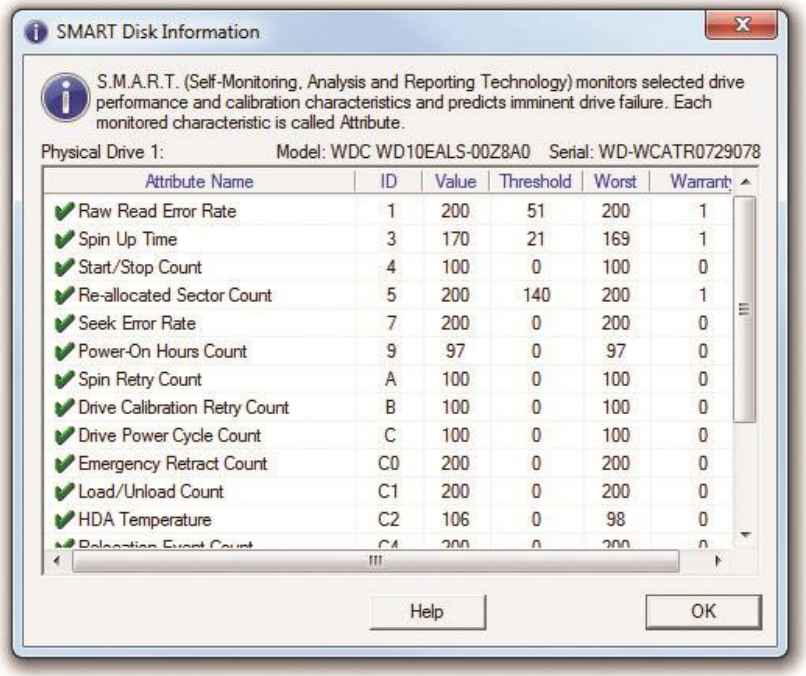


Figure 18: S.M.A.R.T. information

ATA-4

- **Introduced Ultra DMA Modes**
  - Ultra DMA Mode 0: 16.7 MBps
  - Ultra DMA Mode 1: 25 MBps
  - Ultra DMA Mode 2: 33 MBps
  - These are forms of DMA *bus mastering*
- **Ultra DMA Mode 2 also called ATA/33**

INT13 Extensions

- **ATA-1 standard actually written for hard drives up to 137 GB**
  - BIOS limited it to 504 MB due to cylinder, head, and sector maximums
  - ATA-2 implemented LBA to fool the BIOS, enabling drives up to 8.4 GB
- **INT13 Extensions extended BIOS commands**
  - Enabled drives up to 137 GB

ATA-5

- **Introduced newer Ultra DMA Modes**
  - Ultra DMA Mode 3: 44.4 MBps
  - Ultra DMA Mode 4: 66.6 MBps
- **Ultra DMA Mode 4 also called ATA/66**
- **Used 40-pin cable, but had 80 wires**
  - Blue connector—to controller
  - Gray connector—slave drive
  - Black connector—master drive

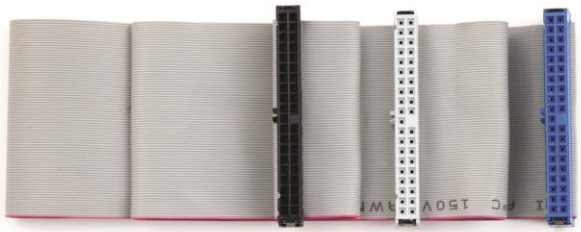


Figure 19: ATA/66 cable

ATA-6

- **"Big Drives" introduced (name soon changed to ATA/ATAPI-6)**
- **Replaced INT13 & 24-bit LBA to 48-bit LBA**
- **Increased maximum size to 144 PB**
  - 144,000,000 GB
- **Introduced Ultra DMA 5**
  - Ultra DMA Mode 5: 100 MBps (ATA/100)
  - Used same 40-pin, 80-wire cables as ATA-5

ATA-7

- **Introduced Ultra DMA 6**
  - Ultra DMA Mode 6: 133 MBps (ATA/133)
  - Used same 40-pin, 80-wire cables as ATA-5
  - Didn't really take off due to SATA's popularity
- **Introduced Serial ATA (SATA)**
  - Increased throughput to 150 MBps to 300 MBps

End of PATA

- **Ultra DMA Mode 6**
  - Up to 133 Mbps
  - ATA/133
  - 80-wire cable
- **Problems with PATA**
  - Wide, flat cables impede airflow
  - Cable limited to 18”
  - No hot-swapping
  - Reached limits of technology

Serial ATA

- **Serial ATA (SATA) creates a point-to-point connection between the device and the controller or host bus adapter (HBA)**
  - Narrower cables result in better airflow and cable control in the PC
  - Maximum cable length of 1 meter
  - Hot-swappable
  - No drive limit
  - Throughput of 150 MBps to 600 MBps

Figure 20: SATA hard disk power (left) and data (right) cables

SATA Bridge

Figure 21: SATA bridge

AHCI

- **Windows Vista/7 support Advanced Host Controller Interface (AHCI)**
  - Efficient way to work with SATA HBAs
  - Makes hot-swapping work well (otherwise have to run the Add New Hardware Wizard)
  - Native command queuing (NCQ) is a disk-optimization feature that enables faster read/write speeds
  - Implement AHCI in CMOS *before* installing the OS

SATA Naming

- **SATA drives come in two flavors**
  - SATA 1.5Gb
  - SATA 3Gb
- **Marketing hype has branded SATA 3Gb drives as SATA II**
- **SATA committee is called the SATA-IO**
- **Note the numbers don't quite add up**
  - 1.5 Gb = 192 MBps, not 150 MBps
  - Up to 20 percent lost to overhead and encoding scheme, thus the lower actual speed

External Serial ATA

- **eSATA**
  - External SATA
  - Extends SATA bus to external devices
  - Cable length up to 2 meters
  - eSATA extends the SATA bus at full speed, which tops out at a theoretical 6 Gbps, whereas the fastest USB connection (USB 3.0, also called SuperSpeed USB) maxes out at 5 Gbps.

External Serial ATA *(continued)*

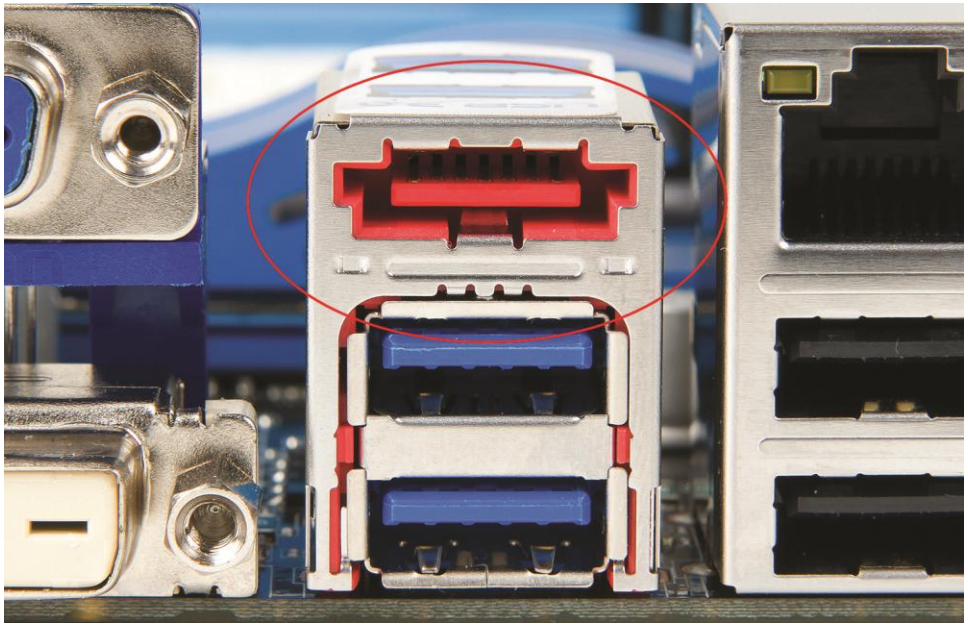


Figure 22: eSATA connectors

Figure 23: eSATA ExpressCard

SCSI
Small Computer System Interface

SCSI

- **Pronounced "Scuzzy"**
- **Been around since 1970s**
- **Devices can be internal or external**
- **Historically the choice for RAID**
  - Faster than PATA
  - Could have more than four drives
- **SATA replacing SCSI in many applications**

SCSI Chains

- A **SCSI chain** is a series of SCSI devices working together through a host adapter.
- The host adapter is a device that attaches the SCSI chain to the PC.
- All SCSI devices are divided into internal and external groups.

SCSI Chains *(continued)*

Figure 24: SCSI host adapter

SCSI Chains *(continued)*

Figure 25: Internal SCSI CD-ROM

Figure 26: Back of external SCSI device

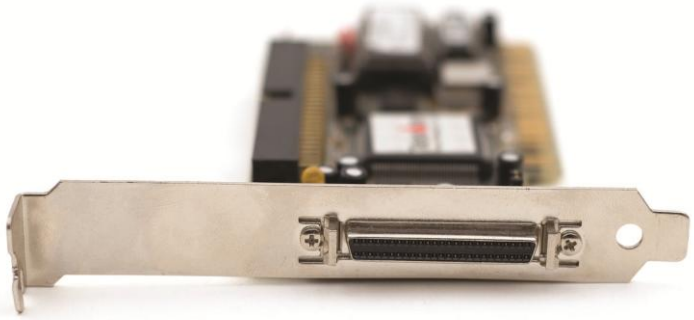
Internal Devices

- **Internal SCSI devices are installed inside the PC and connect to the host adapter through the internal connector.**
- **Internal devices use a 68-pin ribbon cable.**
- **Cables can be connected to multiple devices.**

Internal Devices *(continued)*

Figure 27: Typical 68-pin ribbon cable

Figure 28: 50-pin HD port on SCSI host adapter



External Devices

- **External SCSI devices** are connected to external connection of host adapter.
- External devices may have two connections in the back to allow for **daisy-chaining.**
- A standard SCSI chain can connect 15 devices, plus the host adapter.

External Devices *(continued)*

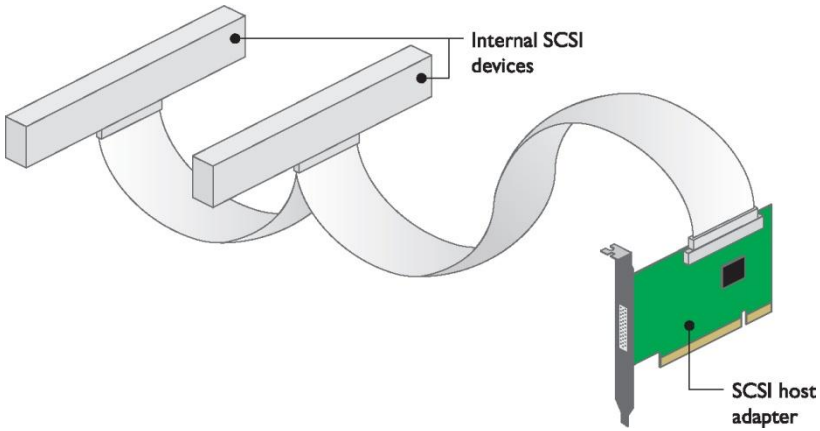
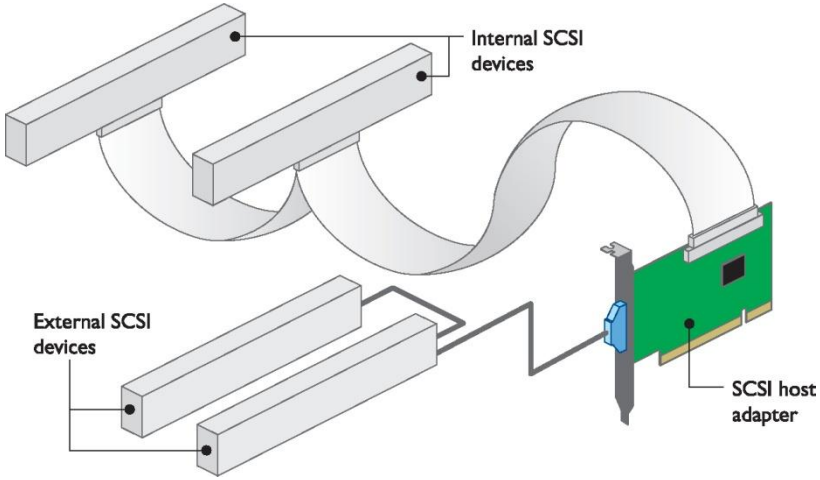


Figure 29: Internal SCSI chain with two devices

Figure 30: Internal and external devices on one SCSI chain



SCSI IDs

- **Each SCSI device must have a unique SCSI ID.**
- **The values of ID numbers range from 0 to 15.**

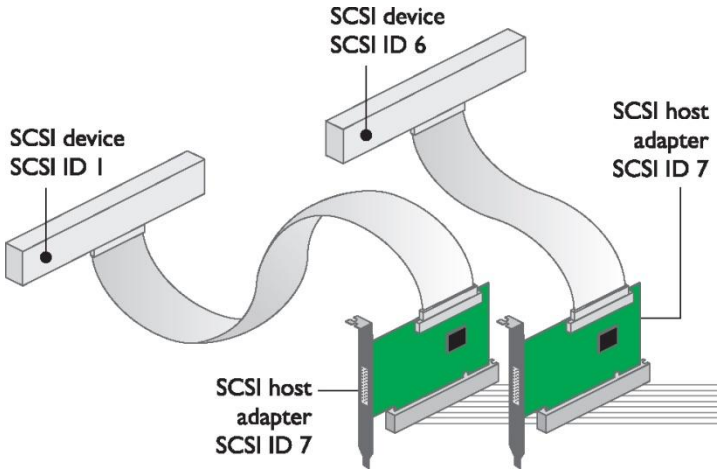


Figure 31: IDs don't conflict between separate SCSI chains.

- **No two devices connected to a single host adapter can share the same ID number.**
- **No order for the use of SCSI IDs, and any SCSI device can have any SCSI ID.**

SCSI IDs (*continued*)

- **The SCSI ID for a particular device can be set by configuring jumpers, switches, or even dials.**

- **Use your binary knowledge to set the device ID:**
  - Device 1 = 0 0 0 1 Off, Off, Off, On
  - Device 7 = 0 1 1 1 Off, On, On, On
  - Device 15 = 1 1 1 1 On, On, On, On

- **Host adapters often set to 7 or 15 but can be changed.**

Termination

- **Terminators are used to prevent a signal reflection that can corrupt the signal.**
- **Pull-down resistors are usually used as terminators.**
- **Only the ends of the SCSI chains should be terminated.**
- **Most manufacturers build SCSI devices that self-terminate.**

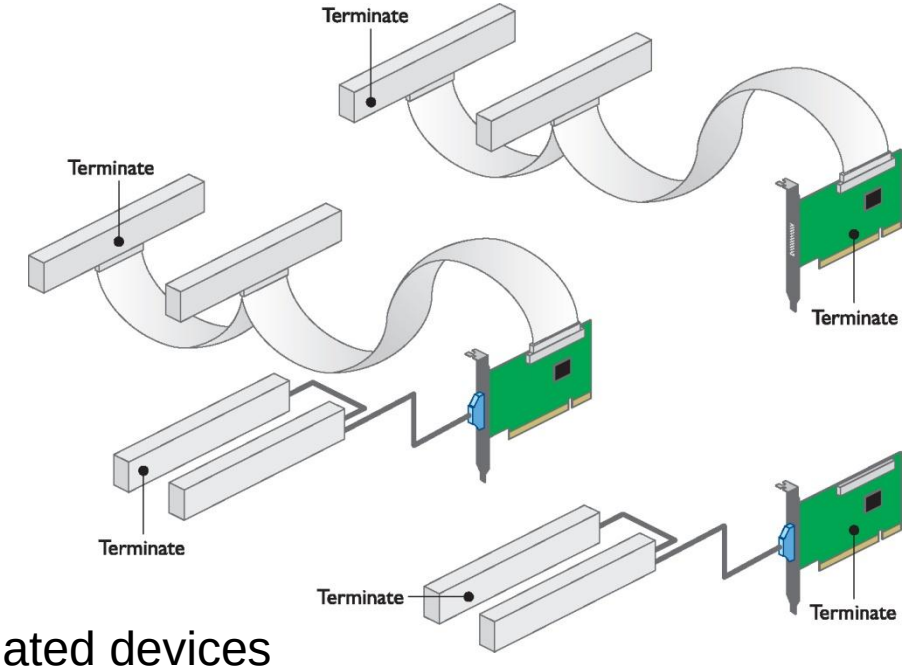


Figure 32: Location of the terminated devices

Termination *(continued)*

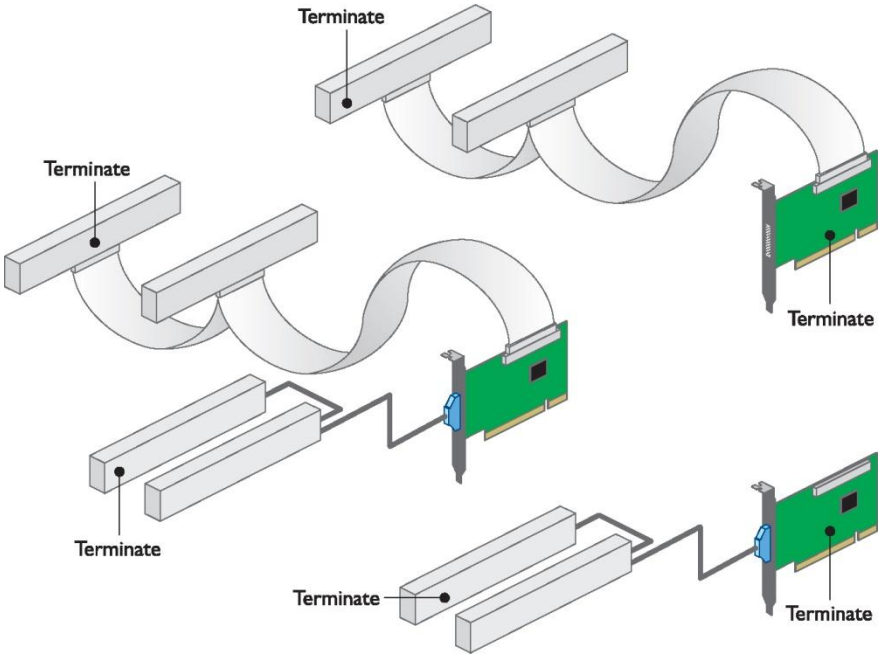


Figure 32: Location of the terminated devices

Figure 33: Setting termination

Protecting Data with RAID

Protecting Data

- **The most important part of a PC is the data it holds.**
  - Companies have gone out of business because of losing data on hard drives.
- **Hard drives will eventually develop faults.**
- **Fault tolerance enables systems to operate even when a component fails.**
  - Redundant array of inexpensive disks (RAID) is one such technology.

Protecting Data *(continued)*

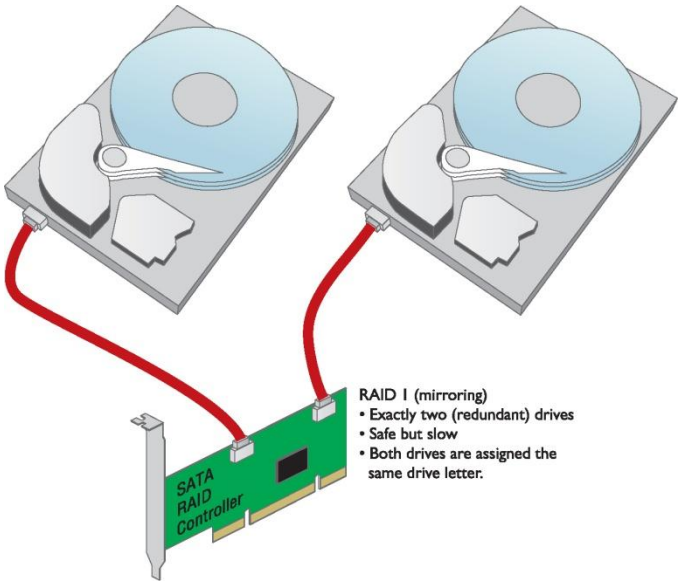


Figure 34:Mirrored drives

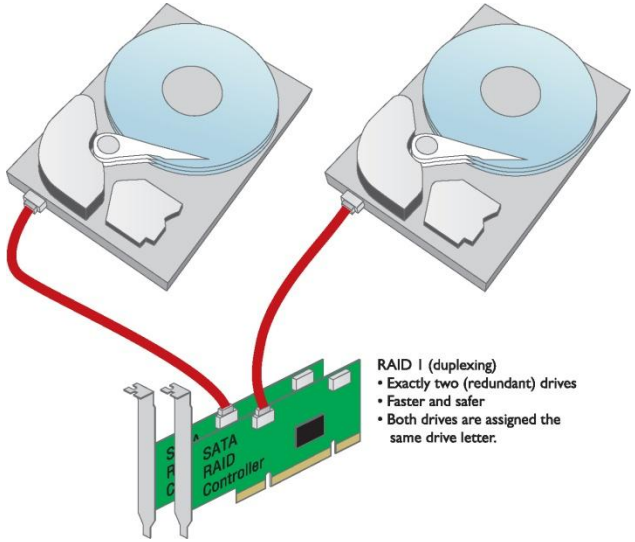


Figure 35: Duplexing drives

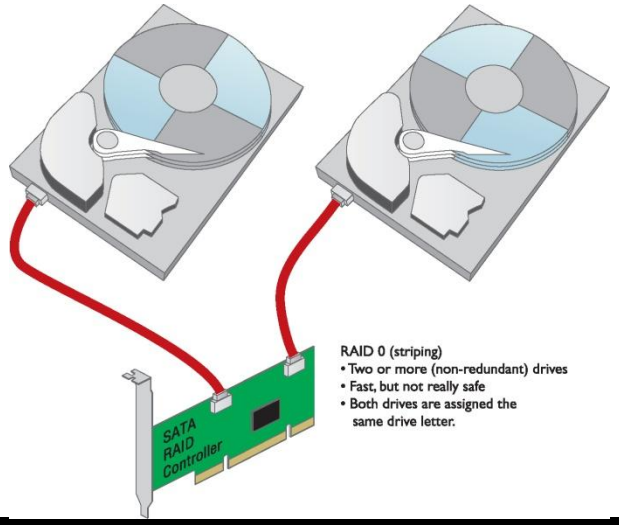


Figure 36: Disk striping

RAID Level 0

- **Disk striping**
  - Writes data across multiple drives at once
  - Requires at least two hard drives
  - Provides increased read and writes
- **Not fault tolerant**
  - If any drive fails, the data is lost

RAID Level 1

- **Disk mirroring/duplexing is the process of writing the same data to two drives at the same time**
  - Requires two drives
  - Produces an exact mirror of the primary drive
  - Mirroring uses the same controller
  - Duplexing uses separate controllers

RAID Levels 2 to 4

- **RAID 2**
  - Disk striping with multiple parity drives
  - Not used
- **RAID 3 and 4**
  - Disk striping with dedicated parity
  - Dedicated data drives and dedicated parity drives
  - Quickly replaced by RAID 5

RAID Level 5

- **Disk striping with distributed parity**
  - Distributes data and parity evenly across the drives
  - Requires at least three drives
  - Most common RAID implementation

RAID Level 6

- **Super disk striping with distributed parity**
  - RAID 5 with asynchronous and cached data capability
  - Requires at least five drives, but can lose up to two drives and still recover

RAID Oddities and JBOD

- **Consumer-oriented boards offer "special" features**
- **RAID 0+1**
  - Two striped sets mirrored
- **RAID 1+0 (RAID "10")**
  - Two mirrored sets striped
  - Both require four drives
- **Just a Bunch of Disks (JBOD)**

Implementing RAID

- **SCSI has been the primary choice in the past**
  - Faster than PATA
  - Hot-swappable
  - PATA supported only four drives
- **SATA today viewed as comparable choice**
  - Speeds comparable to SCSI
  - Less expensive than SCSI
  - Hot-swappable
  - Dedicated SATA controllers can support up to 15 drives

Hardware vs. Software

- **Hardware RAID**
  - Dedicated controller
  - Operating system views it as single volume
- **Software RAID**
  - Operating system recognizes all individual disks
  - Combines them together as single volume

Hardware vs. Software *(continued)*

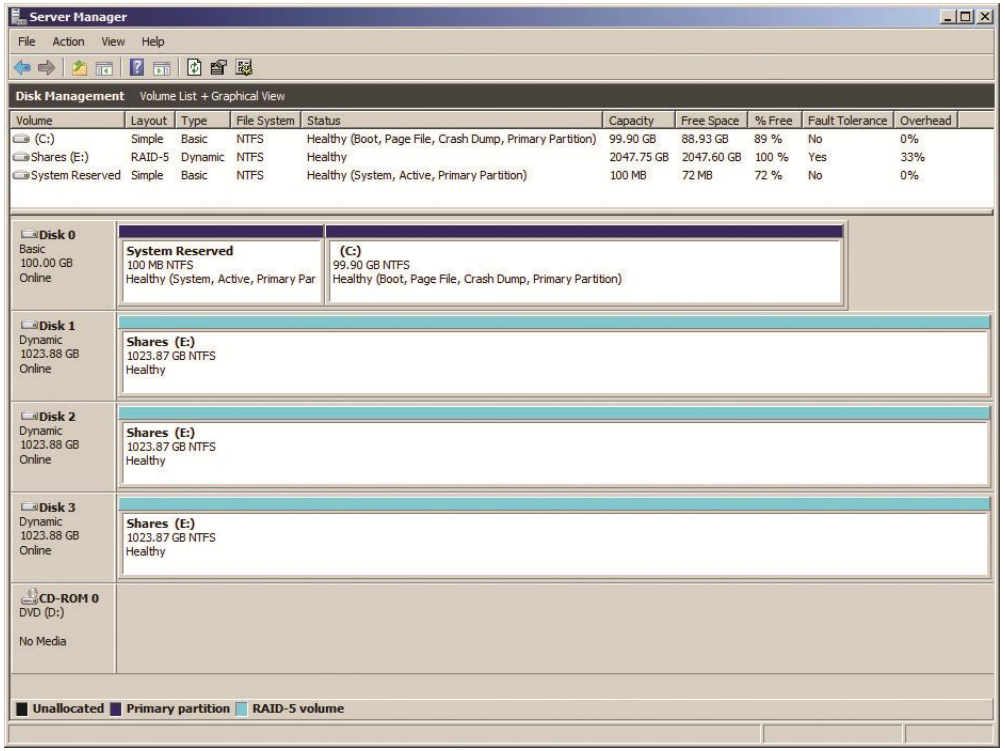


Figure 37: Disk Management tool of Computer Management in Windows 2003 Server 2008 R2

Hardware vs. Software *(continued)*

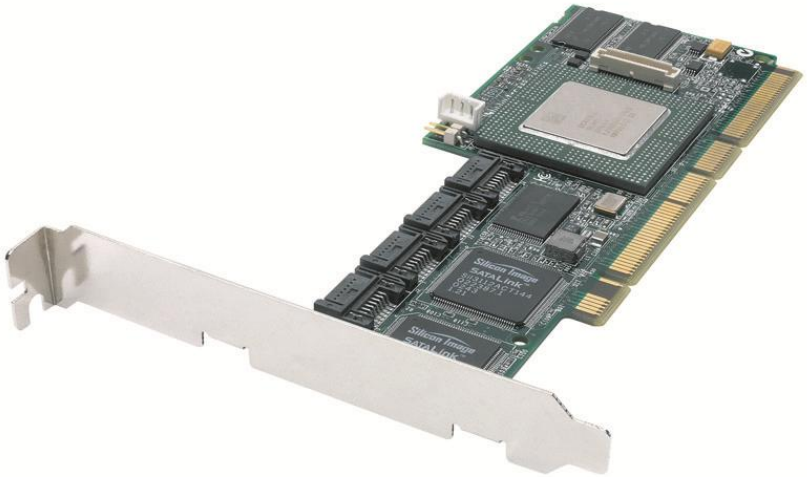
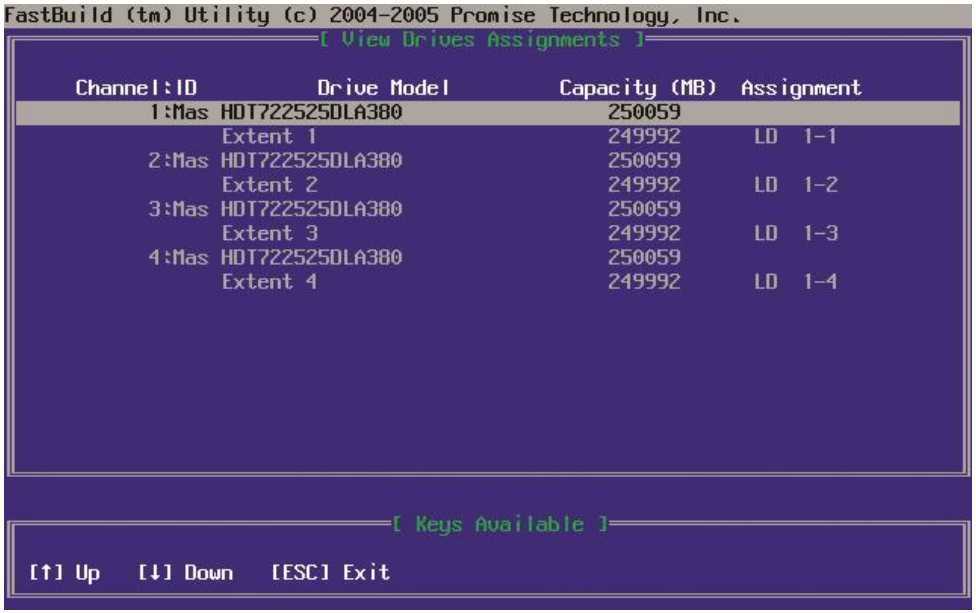


Figure 38: Serial ATA RAID controller

Figure 39: RAID configuration utility



Personal RAID

- **ATA RAID controller chips have gone down in price.**
- **Many motherboards are now shipping with RAID built-in.**
- **The future is RAID.**
  - RAID has been around for 20 years, but is now less expensive and moving into desktop systems.

Installing Drives

Connecting Your Drive

- **Choosing your drive**
  - PATA, SATA, or SCSI
  - Check BIOS and motherboard for support
- **Jumpers and cabling on PATA**
  - Master
  - Slave
  - Cable select

Connecting Your Drive *(continued)*

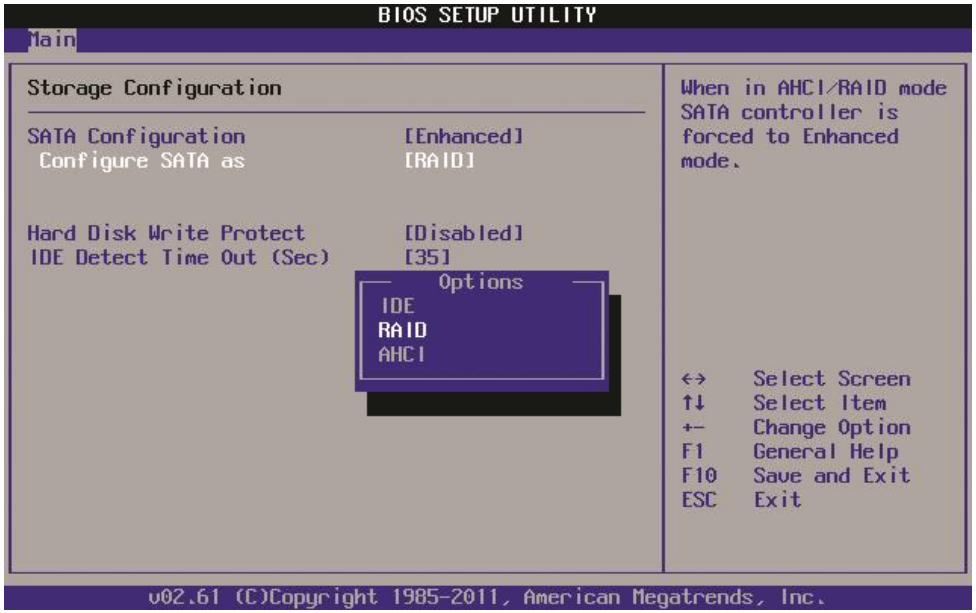


Figure 40: Settings for RAID in CMOS

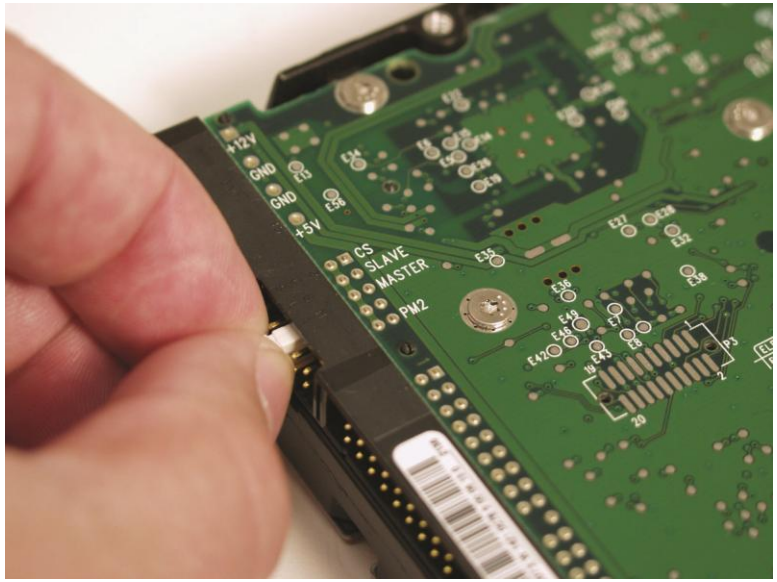


Figure 41: Master/slave jumpers on a hard drive

Connecting Your Drive *(continued)*

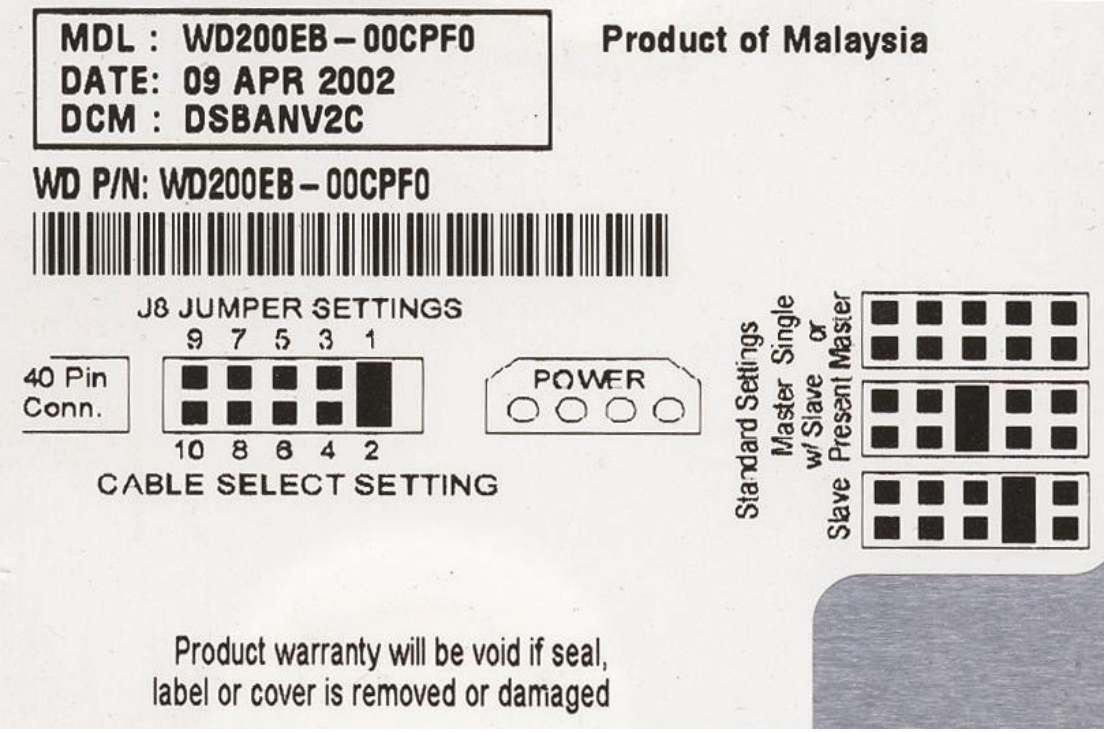


Figure 42: Drive label showing master/slave settings

Connecting ATA Drives

- **PATA**
  - Ribbon cable pin 1 to pin 1
  - Molex for power
- **SATA**
  - Cable keyed, so goes in one way
  - SATA for power, though some can use Molex
- **SATA best practice**
  - Install drive you want as primary/bootable into first SATA controller, usually SATA 0

Connecting ATA Drives *(continued)*

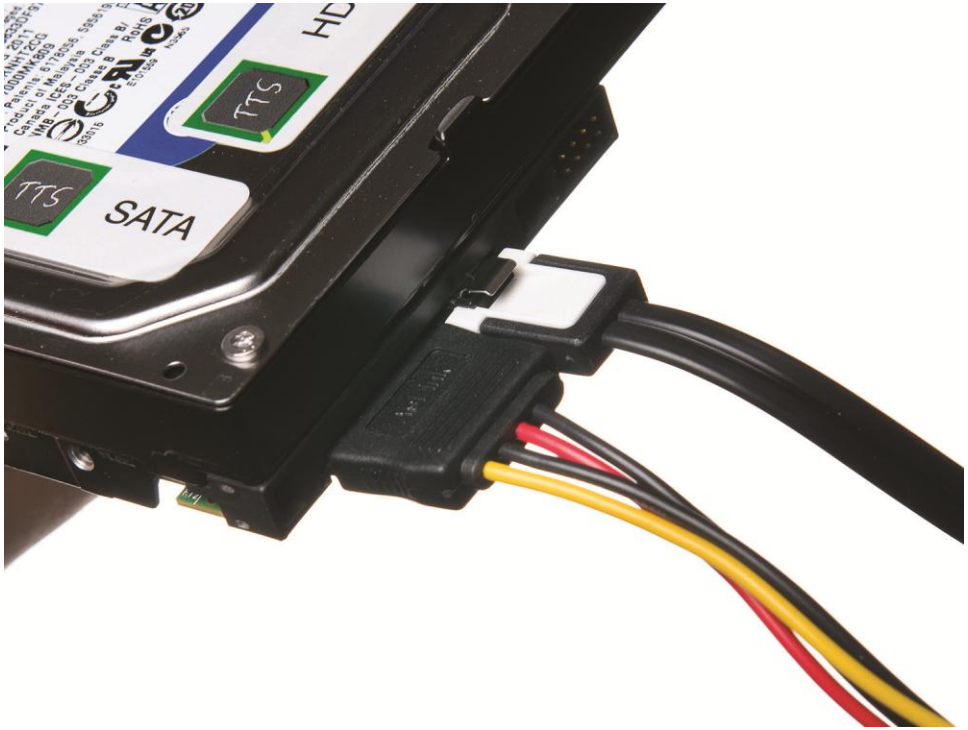


Figure 43: Properly connected SATA cable

Connecting SSDs

- **Most likely to find in portable PCs**
- **Connect the same way HDDs connect**
  - PATA
  - SATA
- **Drivers needed for pre-Vista Windows**

Connecting SCSI Drives

- **First need compatible controller**
  - Different types of SCSI
- **Connect data cable**
  - Reversing this cable can damage drive, data, or both
  - Pin 1 to pin 1, just like PATA
- **Connect power—Molex connector**
- **Configure SCSI IDs on drives and controller**

BIOS Support: Configuring CMOS and Installing Drivers

Configuring Controllers and Autodetection

- **Enable controller**
- **Auto detection runs**
- **Enable AHCI**

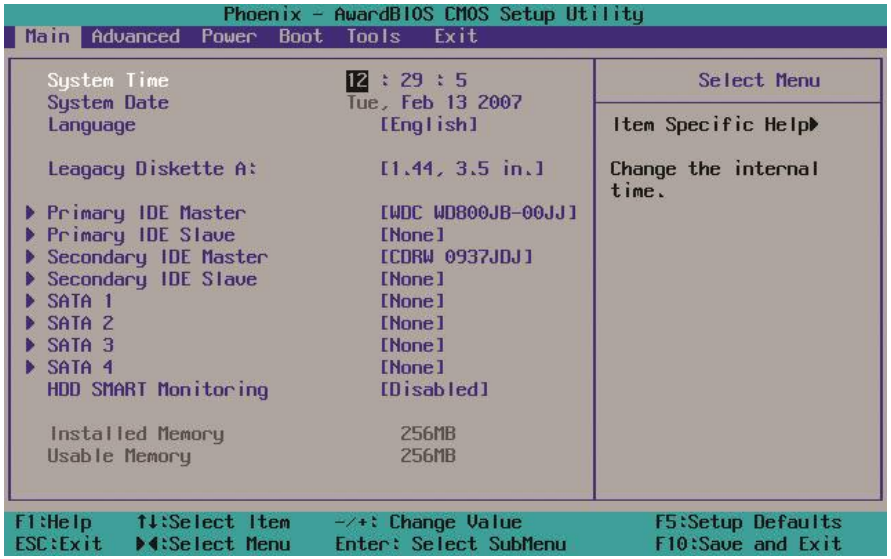


Figure 45: Old standard CMOS settings

Figure 44: Typical controller settings in CMOS

Configuring Controllers and Autodetection *(continued)*

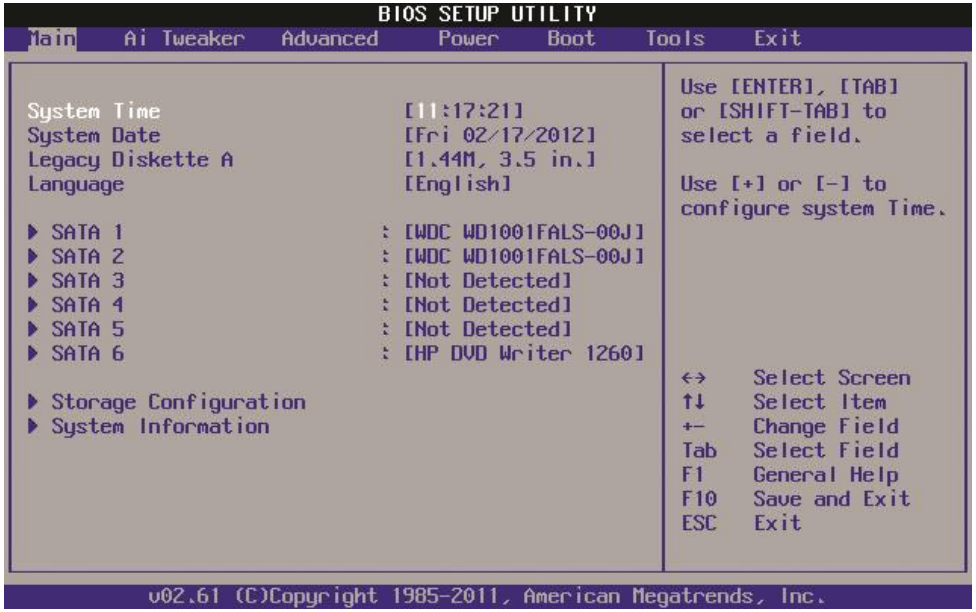


Figure 46: New standard CMOS features

Boot Order

- **Identifies where computer will try to load an operating system**
  - Multiple devices configured
  - First one with an OS will boot

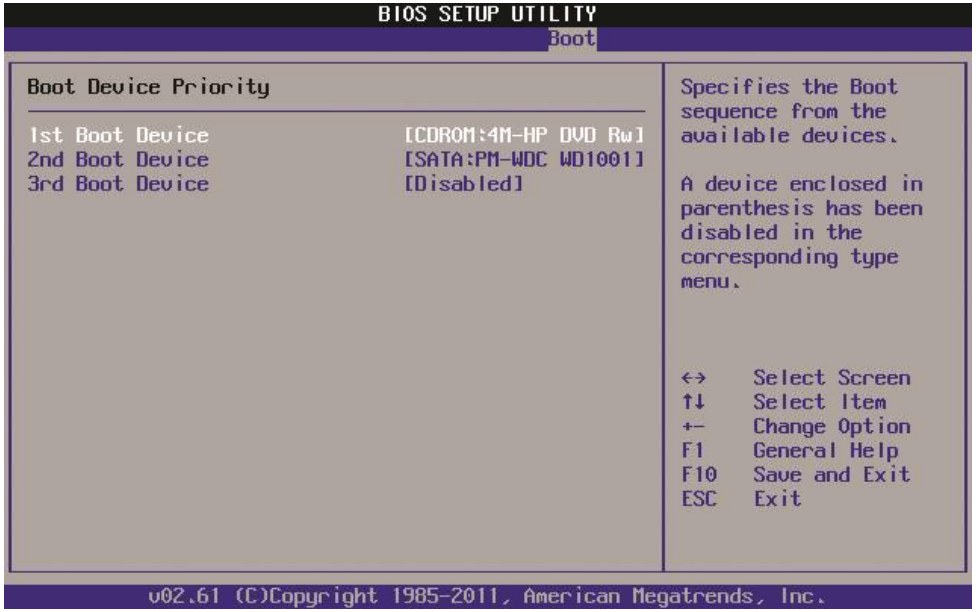


Figure 47: Boot order

Troubleshooting Hard Drive Installation

- **Autodetect fails**
  - Power
  - Ribbon cable installed improperly
  - Jumpers set incorrectly
- **Simplify and try again, one drive at a time**
- **Physical settings correct? Try CMOS errors**
  - Controller disabled
  - ATA level supported? (i.e., is the drive too large for your BIOS to see properly?)
  - Check the manufacturer's Web site for known issues

Beyond A+

- **Hybrid Hard Drives (HHD)**
  - Combine flash memory and traditional platters
  - Up to 256-MB flash for fast cache for data and boot
    - Essential OS boot files on flash
  - Platters do not spin by default
    - Lower power usage
  - Read/write to flash unless need data from HDD or buffer exceeded
  - Could shave boot times in half and add battery life
  - Only Windows Vista and Windows 7