IS 335: Information Technology in Business
Lecture Outline
Computer/Data Storage Technology

Objectives
- Describe the distinguishing characteristics of primary and secondary storage
- Describe the devices used to implement primary storage
- Compare secondary storage alternatives
- Describe factors that affect magnetic storage devices
- Explain how to choose appropriate secondary storage technologies and devices

Storage Device Characteristics
- Consist of a read/write mechanism and a storage medium
- Storage medium: device or substance that actually holds data
  - Device controller provides interface between storage device and system bus

Storage Device Characteristics (continued)
- Speed
- Volatility
- Access method
- Portability
- Cost and capacity

Speed
- Most important characteristic differentiating primary and secondary storage
- Primary storage extends the limited capacity of CPU registers
- Secondary storage speed influences execution speed
- Access time
- Blocks and sectors
- Data transfer rate = 1 second/access time (in seconds) x unit of data transfer (in bytes)

Volatility
- Primary storage devices are generally volatile
  - Cannot reliably hold data for long periods
- Secondary storage devices are generally nonvolatile
  - Holds data without loss over long periods of time

Access Method
- Serial access (linear)
- Random access (direct access)
- Parallel access (simultaneous)

Portability
- Typically implemented in two ways
  - Entire storage device (USB flash drive)
  - Storage medium can be removed (DVDs)
- Typically results in slower access speeds

Cost and Capacity
- Cost increases:
  - With improved speed, volatility, or portability
  - As access method moves from serial to random to parallel access method
- Primary storage: expensive (high speed and combination of parallel/random access methods)
- Capacity of secondary storage devices is greater than primary storage devices

Storage device characteristics and their relationship to cost

Characteristic	Description	Cost
Speed	Time required to read or write a bit, byte, or larger unit of data	Cost increases as speed increases
Volatility	Capacity to hold data indefinitely, particularly in the absence of external power	For devices of similar type, cost decreases as volatility increases
Access Method	Can be serial, random, or parallel; parallel devices are also serial or random access	Serial is the least expensive; random is more expensive than serial; parallel is more expensive than non-parallel
Portability	Capability to easily remove and reinstall storage media from the device or the device from the computer	For devices of similar type, portability increases cost, if all other characteristics are held constant
Capacity	Maximum data quantity the device or storage medium holds	Cost usually increases in direct proportion to capacity

Primary Storage Devices

- Critical performance characteristics
  - Access speed
  - Data transfer unit size
- Must closely match CPU speed and word size to avoid wait states

Storing Electrical Signals

- Directly
  - By devices such as batteries and capacitors
  - Trade off between access speed and volatility
- Indirectly
  - Uses energy to alter the state of a device
  - Inverse process regenerates equivalent electrical signal
- Modern computers use memory implemented with semiconductors (RAM and NVM)

Random Access Memory

- Characteristics
  - Microchip implementation with semiconductors
  - Capability to read and write with equal speed
  - Random access to stored bytes, words, or larger data units
- Basic types
  - Static RAM (SRAM): implemented entirely with transistors
  - Dynamic RAM (DRAM): uses a single transistor and capacitor

Random Access Memory

- To bridge performance gap between memory and microprocessors
  - Read-ahead memory access
  - Synchronous read operations

Nonvolatile Memory

- Random access memory with long-term or permanent data retention
- Usually relegated to specialized roles and secondary storage
  - Slower write speeds and limited number of rewrites
- Generations of devices (ROM, EPROM, and EEPROM)

Nonvolatile Memory (continued)

- Flash RAM (most common NVM)
  - Competitive with DRAM in capacity and read performance
  - Relatively slow write speed
  - Limited number of write cycles
- NVM technologies under development
  - Magnetoresistive RAM (MRAM)
  - Phase-change memory (PCM)

Memory Packaging

- Dual in-line packages (DIPs)
  - Early RAM and ROM circuits
- Single in-line memory module (SIMM)
  - Standard RAM package in late 1980s
- Double in-line memory module (DIMM)
  - Newer packaging standard
  - A SIMM with independent electrical contacts on both sides of the module

Magnetic Storage

- Exploits duality of magnetism and electricity
  - Electrical current can generate a magnetic field
  - Magnetic field can generate electricity
- Polarity of magnetic charge represents bit values zero and one

Magnetic Storage (continued)

- Devices must control or compensate for some undesirable characteristics of magnetism and magnetic storage media
  - Magnetic decay
  - Magnetic leakage
  - Minimum threshold current for read operations
  - Storage medium coercivity
  - Long-term storage medium integrity

Magnetic Decay and Leakage

- Magnetic decay
  - Tendency of magnetically charged particles to lose their charge over time
  - Constant over time and proportional to the power of the charge
- Magnetic leakage
  - If the polarity of adjacent bits is opposite
- •Their magnetic fields tend to cancel out the charge of both areas
- Strength of both charges falls below read threshold

Areal Density

- Surface area allocated to a bit
- Coercivity: capability of a substance or magnetic storage medium to accept and hold a magnetic charge

Media Integrity

- Depends on its construction and the environmental factors it's subjected to
- Hard disk drives and MRAM have high media integrity
- Magnetic tape and others have thin coatings of coercible material layered over a plastic or other substrate

Magnetic Tape

- Ribbon of plastic with a coercible (usually metallic oxide) surface coating
- Mounts in a tape drive for reading and writing
- Compounds magnetic leakage; wraps upon itself
- Susceptible to stretching, friction, and temperature variations
- Two geometric approaches to recording data
  - Linear recording
  - Helical scanning

Magnetic Disk

- Flat, circular platters with metallic coating that is rotated beneath read/write heads
- Data normally recorded on both sides
- Tracks, cylinders, and sectors
- Hard disks and drive arrays

Magnetic Disk (continued)

- Access time
  - Head-to-head switching time
  - Track-to-track seek time
  - Rotational delay
  - Most important performance numbers
- Average access time
- Sequential access time
- Sustained data transfer rate
- To increase capacity per platter, disk manufacturers divide tracks into zones and vary the sectors per track in each zone

Solid-State Drives

- Expected to supplant magnetic disk as the dominant secondary storage technology
- Mimics the behavior of a magnetic disk drive but uses flash RAM or other NVM devices as
- the storage medium and read/write mechanism
- Currently implemented with the same physical size and interfaces as magnetic drives
- Have an advantage in power consumption

Optical Mass Storage Devices

- Store bit values as variations in light reflection
- Higher areal density and longer data life than magnetic storage
- Standardized and relatively inexpensive
- Uses: read-only storage with low performance requirements, applications with high capacity requirements, and where portability in a standardized format is needed
- Optical storage devices read data by shining laser beam on the disc.

CD-ROM, DVD-ROM, and BD

- CD
  - Bit values represented as flat areas (lands) and concave dents (pits) in the reflective layer
  - Data recorded in single continuous track that spirals outward from center of disc
- DVD: standard format for movies and audiovisual content
- Blu-ray disc (BD): update to DVD-ROM
- DVD and BD technologies improve on CD technology
  - Increased areal density achieved with smaller wavelength lasers and more precise
- mechanical control
  - Higher rotational speeds
  - Improved error correction
  - Multiple recording sides and layers

Recordable Discs

- Use a laser that can be switched between high and low power and a laser-sensitive dye
- embedded in the disc
- Dye is stable when scanned at low power during a read operation
- Write operation is destructive: recordable formats only written once
- Should be stored in dark location at room temperature

Phase-Change Optical Discs

- Enables nondestructive writing to optical storage media
- Materials change state easily from non-crystalline (amorphous), to crystalline, and then back again
- Reflective layer loses its capability to change state with repeated heating and cooling
- Current rewritable media wear out after about 1000 write operations

Summary

- Storage devices and their underlying technologies
- Characteristics common to all storage devices
- Technology, strengths, and weaknesses of primary and secondary storage