Semiconductor Memory Types

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Semiconductor Memory

- **RAM**
  - Misnamed as all semiconductor memory is random access
  - Read/Write
  - Volatile
  - Temporary storage
  - Static or dynamic

Memory Cell Operation

- **Dynamic RAM**
  - Bits stored as charge in capacitors
  - Charges leak
  - Need refreshing even when powered
  - Simpler construction
  - Smaller per bit
  - Less expensive
  - Need refresh circuits
  - Slower
  - Main memory
  - Essentially analogue
    - Level of charge determines value

Dynamic RAM Structure
**DRAM Operation**
- Address line active when bit read or written
  - Transistor switch closed (current flows)
- Write
  - Voltage to bit line
    - High for 1 low for 0
  - Then signal address line
    - Transfers charge to capacitor
- Read
  - Address line selected
    - Transistor turns on
  - Charge from capacitor fed via bit line to sense amplifier
    - Compare with reference value to determine 0 or 1
    - Capacitor charge must be restored

**Static RAM**
- Bits stored as on/off switches
- No charges to leak
- No refreshing needed when powered
- More complex construction
- Larger per bit
- More expensive
- Does not need refresh circuits
- Faster
- Cache
- Digital
  - Uses flip-flops

**Static RAM Structure**

**Static RAM Operation**
- Transistor arrangement gives stable logic state
- State 1
  - C1 high, C2 low
  - T1 T4 off, T2 T3 on
- State 0
  - C2 high, C1 low
  - T3 T2 off, T1 T4 on
- Address line transistors T5 T6 is switch
  - Write - apply value to B & compliment to B
  - Read - value is on line B

**SRAM v DRAM**
- Both volatile
  - Power needed to preserve data
- Dynamic cell
  - Simpler to build, smaller
  - More dense
  - Less expensive
  - Needs refresh
  - Larger memory units
- Static
  - Faster
  - Cache

**Read Only Memory (ROM)**
- Permanent storage
  - Nonvolatile
- Microprogramming (see later)
- Library subroutines
- Systems programs (BIOS)
- Function tables
Types of ROM
- Written during manufacture
  - Very expensive for small runs
- Programmable (once)
  - PROM
  - Needs special equipment to program
- Read “mostly”
  - Erasable Programmable (EPROM)
  - Erased by UV
  - Electrically Erasable (EEPROM)
  - Takes much longer to write than read
  - Flash memory
  - Erase whole memory electrically

Organisation in detail
- A 16Mbit chip can be organised as 1M of 16 bit words
- A bit per chip system has 16 lots of 1Mbit chip with bit 1 of each word in chip 1 and so on
- A 16Mbit chip can be organised as a 2048 x 2048 x 4bit array
  - Reduces number of address pins
  - Multiplex row address and column address
  - 11 pins to address ($2^{11} = 2048$)
  - Adding one more pin doubles range of values so x4 capacity

Refreshing
- Refresh circuit included on chip
- Disable chip
- Count through rows
- Read & Write back
- Takes time
- Slows down apparent performance

Typical 16 Mb DRAM (4M x 4)

Error Correction
- Hard Failure
  - Permanent defect
- Soft Error
  - Random, non-destructive
  - No permanent damage to memory
- Detected using Hamming error correcting code
**Error Correcting Code Function**

**Advanced DRAM Organization**

- Basic DRAM same since first RAM chips
- Enhanced DRAM
  - Contains small SRAM as well
  - SRAM holds last line read (c.f. Cache!)
- Cache DRAM
  - Larger SRAM component
  - Use as cache or serial buffer

**Synchronous DRAM (SDRAM)**

- Access is synchronized with an external clock
- Address is presented to RAM
- RAM finds data (CPU waits in conventional DRAM)
- Since SDRAM moves data in time with system clock, CPU knows when data will be ready
- CPU does not have to wait, it can do something else
- Burst mode allows SDRAM to set up stream of data and fire it out in block
- DDR-SDRAM sends data twice per clock cycle (leading & trailing edge)

**IBM 64Mb SDRAM**

**SDRAM Operation**

**RAMBUS**

- Adopted by Intel for Pentium & Itanium
- Main competitor to SDRAM
- Vertical package – all pins on one side
- Data exchange over 28 wires < cm long
- Bus addresses up to 320 RDRAM chips at 1.6Gbps
- Asynchronous block protocol
  - 480ns access time
  - Then 1.6 Gbps
**RAMBUS Diagram**

**Types of External Memory**
- Magnetic Disk
  - RAID
  - Removable
- Optical
  - CD-ROM
  - CD-Recordable (CD-R)
  - CD-R/W
  - DVD
- Magnetic Tape

**Magnetic Disk**
- Disk substrate coated with magnetizable material (iron oxide... rust)
- Substrate used to be aluminium
- Now glass
  - Improved surface uniformity
  - Reduction in surface defects
  - Lower flight heights (See later)
  - Better stiffness
  - Better shock/damage resistance

**Read and Write Mechanisms**
- Recording and retrieval via conductive coil called a head
- May be single read/write head or separate ones
- During read/write, head is stationary, platter rotates
- Write
  - Current through coil produces magnetic field
  - Pulses sent to head
  - Magnetic pattern recorded on surface below
- Read (traditional)
  - Magnetic field moving relative to coil produces current
  - Coil is the same for read and write
- Read (contemporary)
  - Separate read head, close to write head
  - Partially shielded magneto resistive (MR) sensor
  - Electrical resistance depends on direction of magnetic field
  - High frequency operation
    - Higher storage density and speed

**Data Organization and Formatting**
- Concentric rings or tracks
  - Gaps between tracks
  - Reduce gap to increase capacity
  - Same number of bits per track (variable packing density)
  - Constant angular velocity
- Tracks divided into sectors
- Minimum block size is one sector
- May have more than one sector per block
**Disk Data Layout**

- Bit near centre of rotating disk passes fixed point slower than bit on outside of disk
- Increase spacing between bits in different tracks
- Rotate disk at constant angular velocity (CAV)
  - Gives pie shaped sectors and concentric tracks
  - Individual tracks and sectors addressable
  - Move head to given track and wait for given sector
  - Waste of space on outer tracks
  - Lower data density
- Can use zones to increase capacity
  - Each zone has fixed bits per track
  - More complex circuitry

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**Disk Velocity**

- Increases the distance between bits in different tracks.
- To address this, the disk rotates at a constant angular velocity (CAV) to ensure that each bit passes a fixed point at the same speed.
- This results in pie-shaped sectors and concentric tracks, allowing individual tracks and sectors to be addressable.
- To access a specific sector, the head is moved to the given track and then waits for the given sector to pass under it.
- However, this can result in waste of space on outer tracks due to lower data density.
- To increase capacity, zones can be used, where each zone has a fixed number of bits per track, requiring more complex circuitry.

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**Disk Layout Methods Diagram**

- Shows two methods of finding sectors:
  1. Constant angular velocity: Tracks and sectors are addressed in a pie-shaped manner.
  2. Multiple speed recording: Tracks and sectors are addressed at different speeds.

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**Finding Sectors**

- Must be able to identify start of track and sector.
- Format disk:
  - Additional information not available to user
  - Marks tracks and sectors

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**ST506 format (outdated)**

- Shows the format of ST506 data:
  - Sync, Gap1, Id, Gap2, Data, Gap3
  - Track, Head, Sector, CRC
- Foreground reading:
  - Find others

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**Characteristics**

- Fixed (rare) or movable head
- Removable or fixed
- Single or double (usually) sided
- Single or multiple platter
- Head mechanism:
  - Contact (Floppy)
  - Fixed gap
  - Flying (Winchester)
**Fixed/Movable Head Disk**
- **Fixed head**
  - One read write head per track
  - Heads mounted on fixed ridged arm
- **Movable head**
  - One read write head per side
  - Mounted on a movable arm

**Removable or Not**
- **Removable disk**
  - Can be removed from drive and replaced with another disk
  - Provides unlimited storage capacity
  - Easy data transfer between systems
- **Nonremovable disk**
  - Permanently mounted in the drive

**Multiple Platter**
- One head per side
- Heads are joined and aligned
- Aligned tracks on each platter form cylinders
- Data is striped by cylinder
  - Reduces head movement
  - Increases speed (transfer rate)

**Multiple Platters**

**Cylinders**

**Floppy Disk**
- 8", 5.25", 3.5"
- Small capacity
  - Up to 1.44Mbyte (2.88M never popular)
- Slow
- Universal
- Cheap
- Obsolete?
Winchester Hard Disk (1)
- Developed by IBM in Winchester (USA)
- Sealed unit
- One or more platters (disks)
- Heads fly on boundary layer of air as disk spins
- Very small head to disk gap
- Getting more robust

Winchester Hard Disk (2)
- Universal
- Cheap
- Fastest external storage
- Getting larger all the time
  - Multiple Gigabyte now usual

Removable Hard Disk
- ZIP
  - Cheap
  - Very common
  - Only 100M
- JAZZ
  - Not cheap
  - 1GB
- L-120 (floppy drive)
  - Also reads 3.5" floppy
  - Becoming more popular?
- All obsoleted by CD-R and CD-R/W?

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Speed
- Seek time
  - Moving head to correct track
- (Rotational) latency
  - Waiting for data to rotate under head
- Access time = Seek + Latency
- Transfer rate

Timing of Disk I/O Transfer

RAID
- Redundant Array of Independent Disks
- Redundant Array of Inexpensive Disks
- 10 levels in common use
- Not a hierarchy
- Set of physical disks viewed as single logical drive by O/S
- Data distributed across physical drives
- Can use redundant capacity to store parity information.
**RAID 0 – Disk Striping**
- No redundancy – Min. 2 disks
- Data striped across all disks
- Round Robin striping
- Increase I/O speed
  - Multiple data requests probably not on same disk
  - Disks seek in parallel
  - Can read/write blocks on one drive while seeking on another
  - A set of data is likely to be striped across multiple disks

**RAID 1 – Disk Mirroring**
- Provides Redundancy – Min. 2 equal size disks
- Same data is written to each disk in array.
- Read from either
- Write to all
- High Data Reliability:
  - Recovery is simple
    - Swap faulty disk & re-mirror
    - No down time
- Expensive

**RAID 5 – Disk Striping with parity**
- Provides redundancy – Min 3 disks required
- Parity striped across all disks
- Round robin allocation for parity stripe
- High read but medium write performance
- Commonly used in network servers
- Most popular: balance redundancy & cost.
**RAID 0+1 - Disk Stripping with Mirroring**
- Provides redundancy – Min. 2 similar disks pairs (in effect min. 4 disks)
- High Data transfer Performance
- Limited data reliability
- Failure of any disk will cause whole array to become a RAID 0 array.
- Very expensive

**RAID 0+1 at work**

**RAID 10 - Disk Mirroring with Striping**
- Provides redundancy – Min. 2 similar disks pairs (in effect min. 4 disks)
- High Data transfer Performance
- High Data reliability
- Can sustain multiple simultaneous disk failures under certain conditions.
  - More expensive than RAID 0+1

**RAID 10 at work**

**Data Mapping For RAID 0**

**Optical Storage CD-ROM**
- Originally for audio
- 650 Megabytes giving over 70 minutes audio
- Polycarbonate coated with highly reflective coat, usually aluminium
- Data stored as pits
- Read by reflecting laser
- Constant packing density
- Constant linear velocity
**CD Operation**

![Diagram of CD Operation]

**CD-ROM Drive Speeds**

- Audio is single speed
  - Constant linear velocity
  - \(1.2 \text{ m/s}^{-1}\)
  - Track (spiral) is 5.27 km long!
  - Gives 4391 seconds = 73.2 minutes
- Other speeds are quoted as multiples
  - e.g. 24x
  - Quoted figure is maximum speed the drive can achieve.

**CD-ROM Format**

![Diagram of CD-ROM Format]

- Mode 0 = blank data field
- Mode 1 = 2048 byte data + error correction
- Mode 2 = 2336 byte data

**Random Access on CD-ROM**

- Difficult
  - Move head to rough position
  - Set correct speed
  - Read address
  - Adjust to required location

**CD-ROM pros & cons**

- Large capacity
- Easy to mass produce
- Removable
- Robust
- Expensive for small runs
- Slow
- Read only

**Other Optical Storage**

- CD-Recordable (CD-R)
  - WORM
  - Now affordable
  - Compatible with CD-ROM drives
- CD-RW
  - Erasable
  - Getting cheaper
  - Mostly CD-ROM drive compatible
  - Phase change
    - Material has two different reflectivities in different phase states
**DVD** - *What’s in a name?*

- Digital Video Disk
  - Used to indicate a player for movies
  - Only plays video disks
- Digital Versatile Disk
  - Used to indicate a computer drive
  - Will read computer disks and play video disks
- Dogs Veritable Dinner
- Officially - nothing!!!

**DVD** - *Technology*

- Multi-layer
- Very high capacity (4.7 GB per layer)
- Full length movie on single disk
  - Using MPEG-2 compression
- Finally standardized
- Movies carry regional coding
- Players only play correct region films
- Can be “fixed”

**DVD** - *Writable*

- Loads of trouble with standards
- First generation DVD drives may not read first generation DVD-RW disks
- First generation DVD drives may not read CD-RW disks
- Wait for it to settle down before buying!

**CD and DVD**

**Magnetic Tape**

- Serial access
- Slow
- Very cheap
- Backup and archive

**Digital Audio Tape (DAT)**

- Uses rotating head (like video)
- High capacity on small tape
  - 4 Gigabyte uncompressed
  - 8 Gigabyte compressed
- Backup of PC/network servers