MEMORY

COMPUTER MEMORY SYSTEM

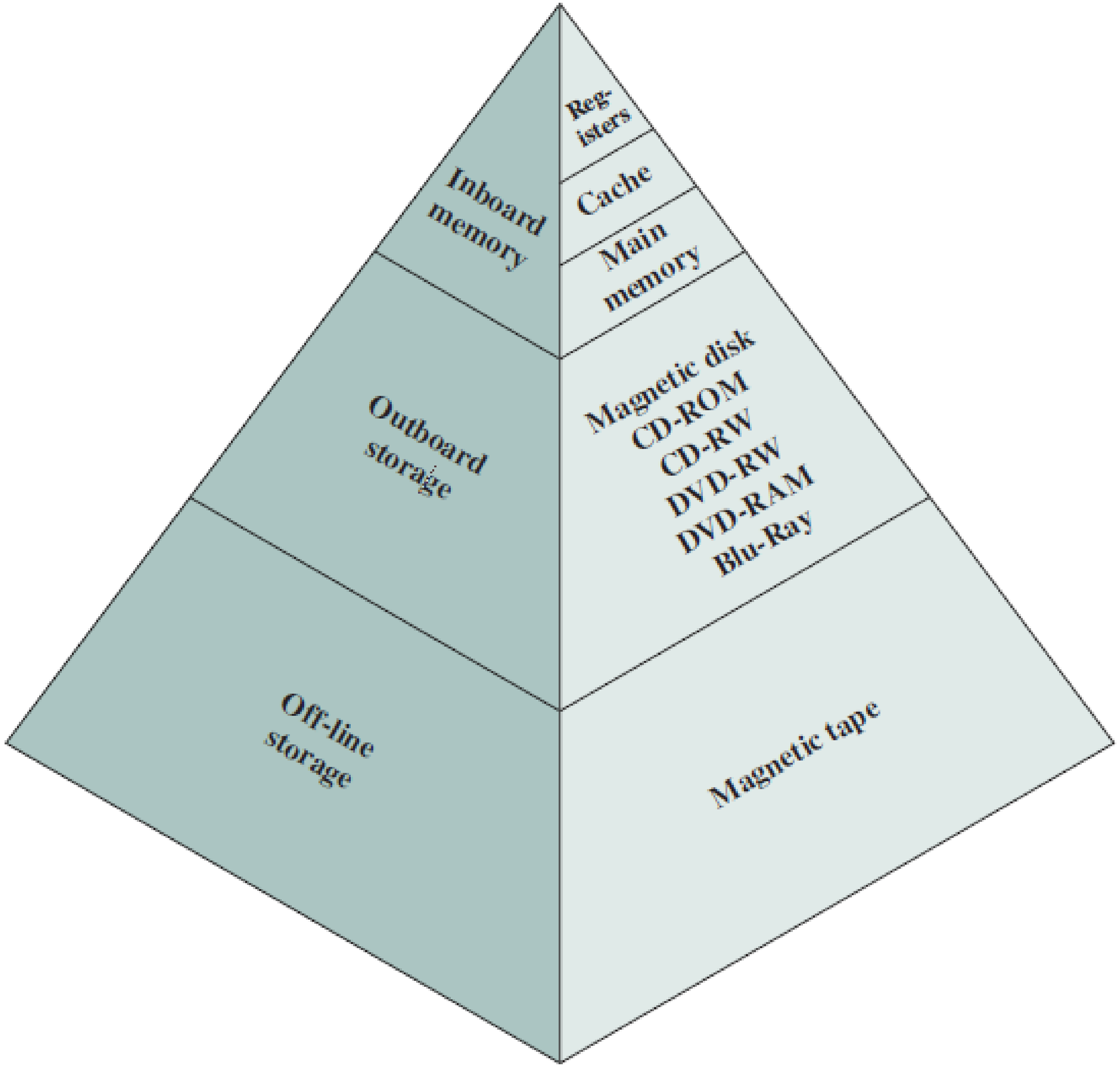
Table 4.1 Key Characteristics of Computer Memory Systems

Location	**Performance**
Internal (e.g., processor registers, cache, main memory)	Access time
External (e.g., optical disks, magnetic disks, tapes)	Cycle time
Capacity	Transfer rate
Number of words	**Physical Type**
Number of bytes	Semiconductor
Unit of Transfer	Magnetic
Word	Optical
Block	Magneto-optical
Access Method	**Physical Characteristics**
Sequential	Volatile/nonvolatile
Direct	Erasable/nonerasable
Random	**Organization**
Associative	Memory modules

The Memory Hierarchy

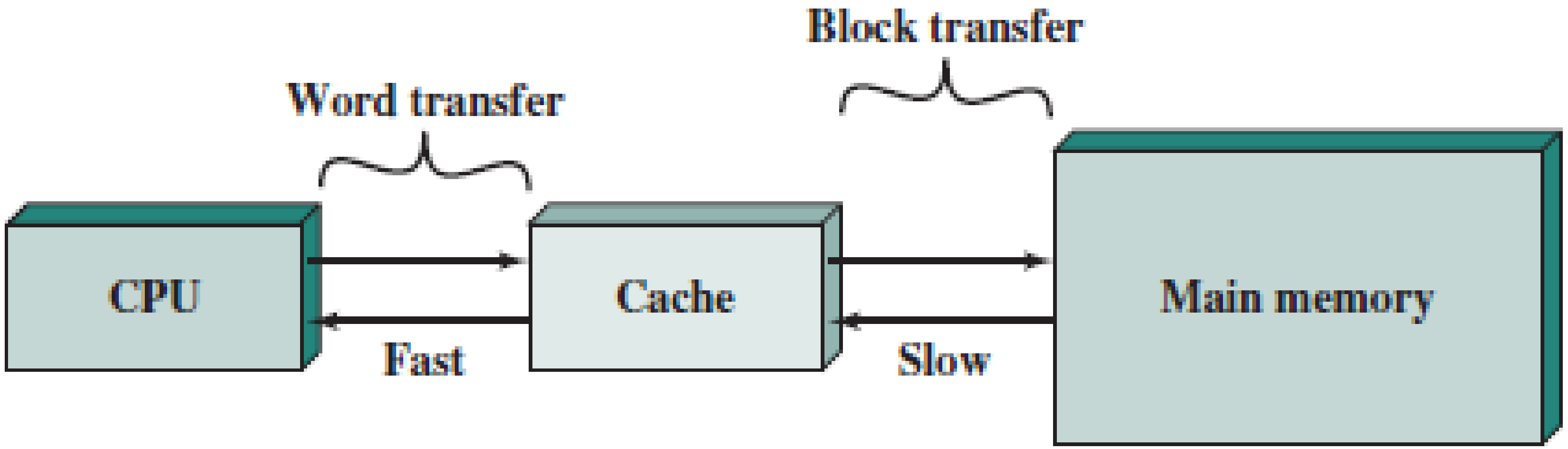
- Three key characteristics of memory:
  - capacity
  - access time and
  - cost

FROM TOP TO BOTTOM:
CAPACITY (SIZE): INCREASES
ACCESS TIME (SPEED): DECREASES
COST (PER BIT): DECREASES

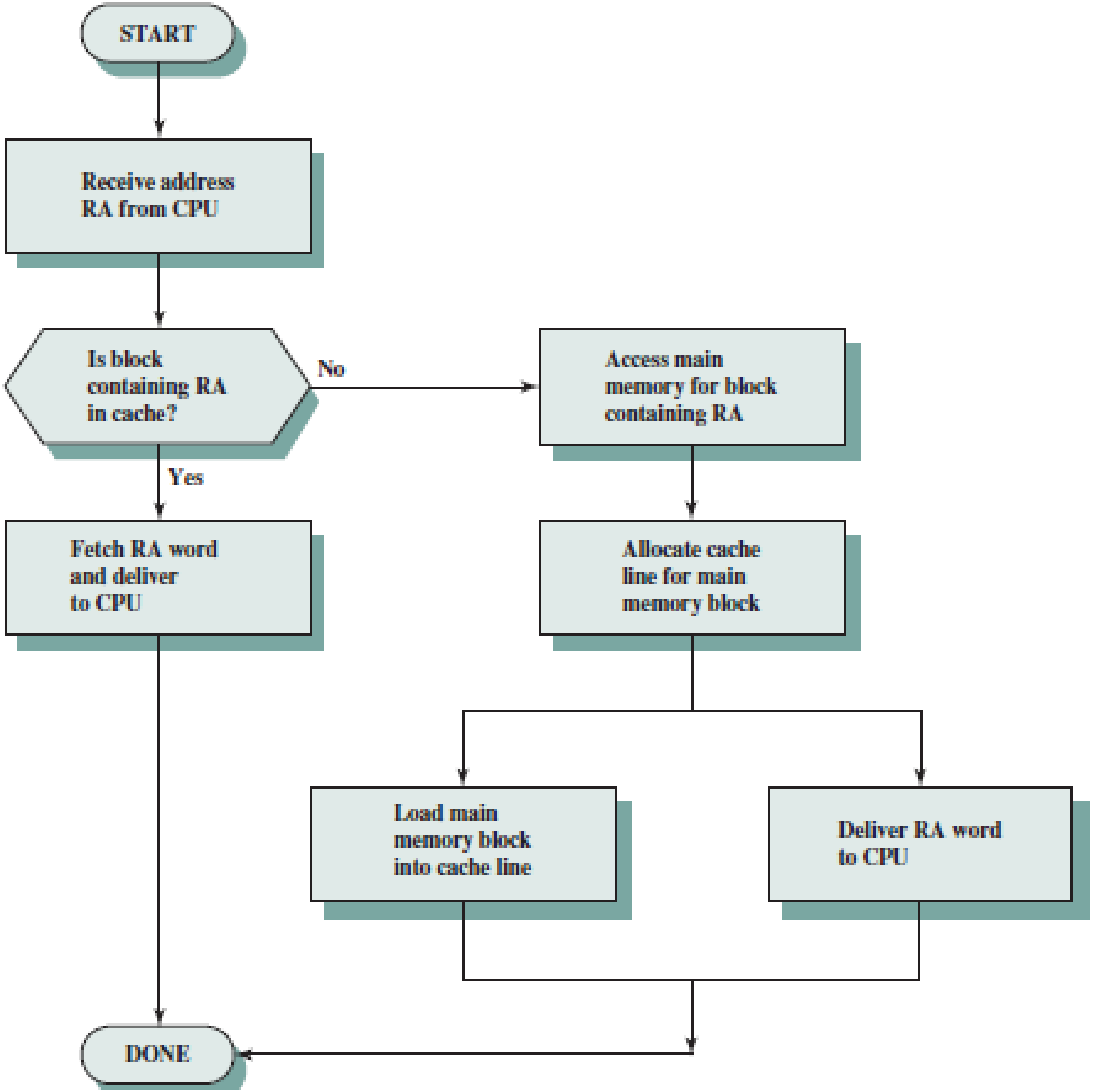


CACHE MEMORY PRINCIPLES

- Cache memory is designed to combine the memory access time of expensive, high- speed memory combined with the large memory size of less expensive, lower- speed memory.
- It works on the phenomenon of locality of reference.



Working


START
Receive address RA from CPU
Is block containing RA in cache?
No
Yes
Access main memory for block containing RA
Fetch RA word and deliver to CPU
Allocate cache line for main memory block
Load main memory block into cache line
Deliver RA word to CPU
DONE

Elements of Cache Design

Cache Addresses
- Logical
- Physical

Cache Size

Mapping Function
- Direct
- Associative
- Set associative

Replacement Algorithm
- Least recently used (LRU)
- First in first out (FIFO)
- Least frequently used (LFU)
- Random

Write Policy
- Write through
- Write back

Line Size

Number of Caches
- Single or two level
- Unified or split

Semiconductor Main Memory

- The basic element of a **semiconductor memory** is the memory cell.

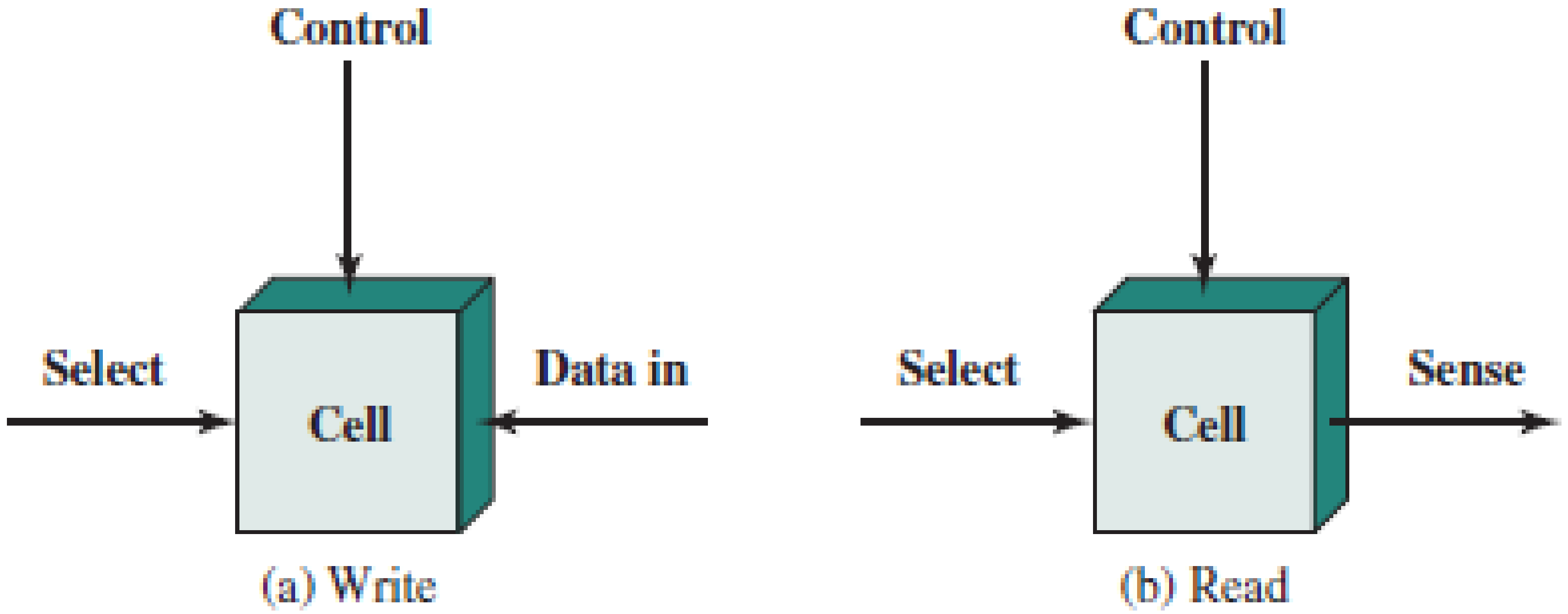


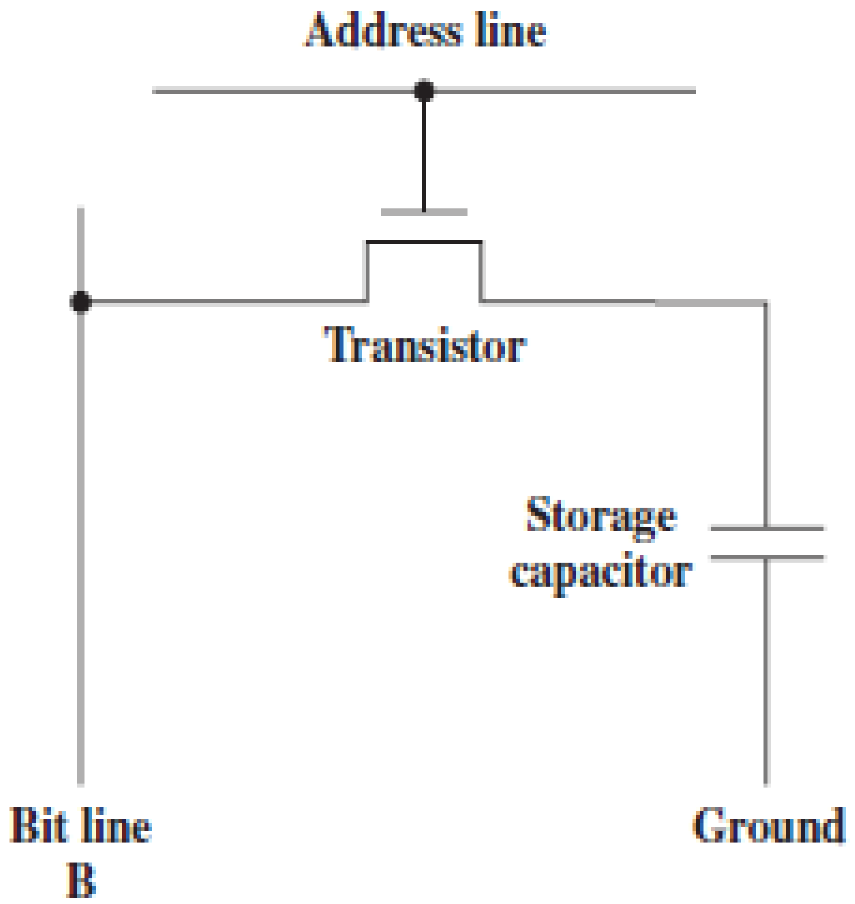
Figure 5.1 Memory Cell Operation

RAM

- The characteristic of traditional RAM is that it is volatile.
- A RAM must be provided with a constant power supply. If the power is interrupted, then the data are lost.
- RAM can be used only as temporary storage.
- The two traditional forms of RAM used in computers are DRAM and SRAM.

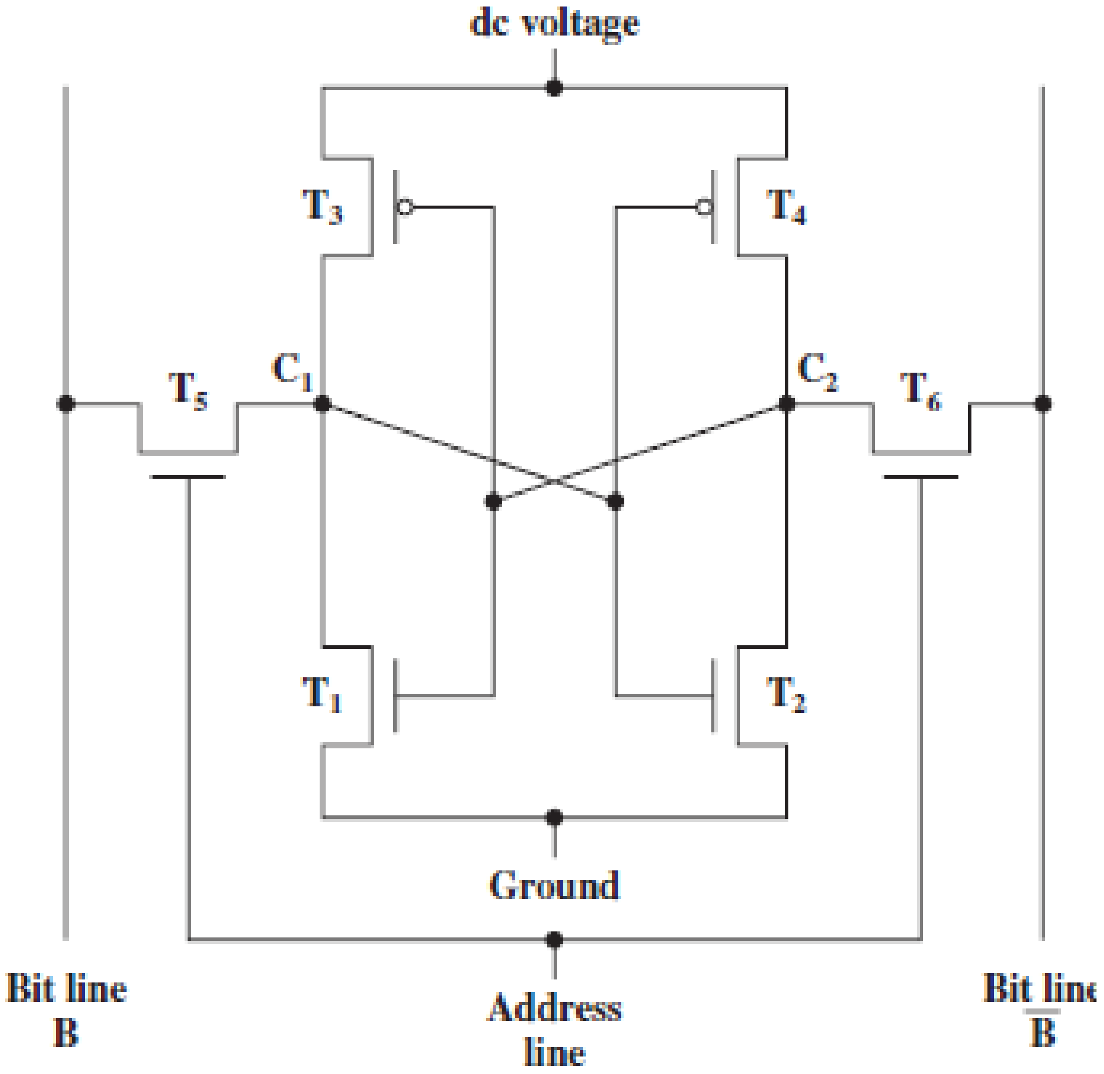
DRAM

- A dynamic RAM (DRAM) is made with cells that store data as charge on capacitors.
- The presence or absence of charge in a capacitor is interpreted as a binary 1 or 0.
- Because capacitors have a natural tendency to discharge, dynamic RAMs require periodic charge refreshing to maintain data storage.
- Although the DRAM cell is used to store a single bit (0 or 1), it is essentially an analog device.



SRAM

- In a SRAM, binary values are stored using traditional flip-flop logic-gate configurations



SRAM versus DRAM

- Both static and dynamic RAMs are volatile; that is, power must be continuously supplied to the memory to preserve the bit values.
- A dynamic memory cell is simpler and smaller than a static memory cell.
- A DRAM is more dense (smaller cells = more cells per unit area) and less expensive than a corresponding SRAM.
- A DRAM requires the supporting refresh circuitry. The fixed cost of the refresh circuitry is more than compensated for by the smaller variable cost of DRAM cells.
- DRAMs tend to be favored for large memory requirements.
- SRAMs are somewhat faster than DRAMs. Because of these relative characteristics, SRAM is used for cache memory (both on and off chip), and DRAM is used for main memory.

Flash Memory

- Flash memory is used both for internal memory and external memory applications.
- Like EEPROM, flash memory uses an electrical erasing technology. An entire flash memory can be erased in one or a few seconds, which is much faster than EPROM.
- In addition, it is possible to erase just blocks of memory rather than an entire chip.
- Like EPROM, flash memory uses only one transistor per bit, and so achieves the high density (compared with EEPROM) of EPROM.
- There are two distinctive types of flash memory, designated as NOR and NAND

Nonvolatile Solid-State Memory Technologies

- There have been breakthroughs in developing new forms of nonvolatile semiconductor memory that continue scaling beyond flash memory.
- The most promising technologies are spin-transfer torque RAM (STT-RAM), phase change RAM (PCRAM), and resistive RAM (ReRAM).