IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

MICROELECTRONICS: DEVICES TO CIRCUITS

Memory Design

SUDEB DASGUPTA

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING



Outline

- Introduction-Memory
- Memory Classification
- Memory Architectures and Building Blocks
- The Memory Core

a) Read-only Memories
b) Nonvolatile Read-Write Memories
c) Read-Write Memories (RAM)

- Recapitulation

Introduction: Memory

- More than half of the transistors in today's high performance microprocessors are devoted to cache memories, and this ratio is expected to further increase.
- Memory cells are combined into large arrays, which minimizes the overhead caused by peripheral circuitry and increases the storage density.
- Reliability and power dissipation are two major concerns of the semiconductor memory designer.

Memory Classification

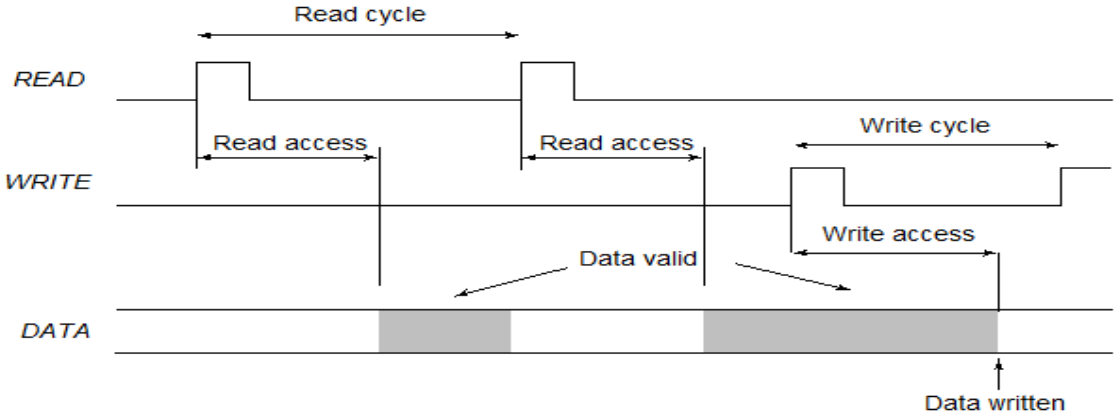
❑ Size

- The circuit designer tends to define the size of the memory in terms of bits that are equivalent to the number of individual cells needed to store the data.
- The chip designer express the memory size in bytes (group of 8 or 9 bits) or its multiple-kilobytes, megabytes, gigabytes etc.
- The system designer quotes the storage requirements in terms of words, which represent a basic computational entity.

❑ Timing Parameters

Cont…

- The time require to retrieve from the memory is called Read-Access Time, which is the delay between the read request and the moment the data is available at the output.
- The time elapsed between a write request and the final writing of the input data into the memory is called Write-Access Time.



Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

❑ Functions

- Based on memory functionality it is classified as Read-Only memory (ROM) and Read-Write Memory (RWM).
- RWM uses active circuitry to store the data, so it belong to the class of volatile memory, in which data is lost when the supply voltage is turned off.
- ROM belongs to the category of non-volatile memories. Disconnection of the supply voltage does not result in the loss of the stored data.
- The EPROM and E^2PROM provides the facilities of both read-write functionality but comes under the category of non-volatile memories.

❑ Access pattern

Cont…

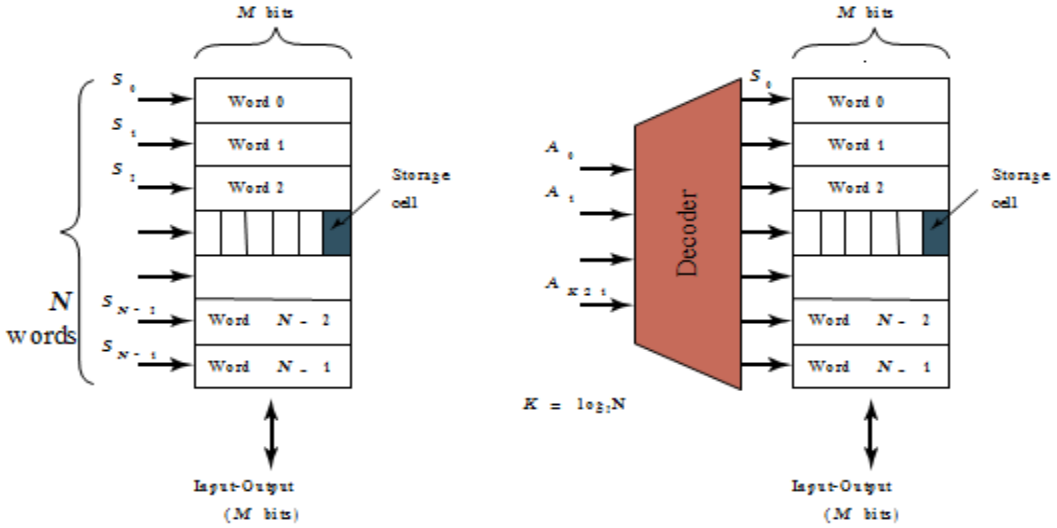
- Most of the memories are random-access memories in which memory location can be read and written in a random order.
- Some memories are restricts the order of access, which results in either fast access time, smaller area or a memory with a special functionality. Examples of such memory are FIFO, LIFO etc.

Read-Write Memory		Non-Volatile Read-Write Memory	Read-Only Memory
Random Access	Non-Random Access	EPROM E^2PROM FLASH	Mask-Programmed Programmable (PROM)
SRAM DRAM	FIFO LIFO Shift Register CAM		

Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

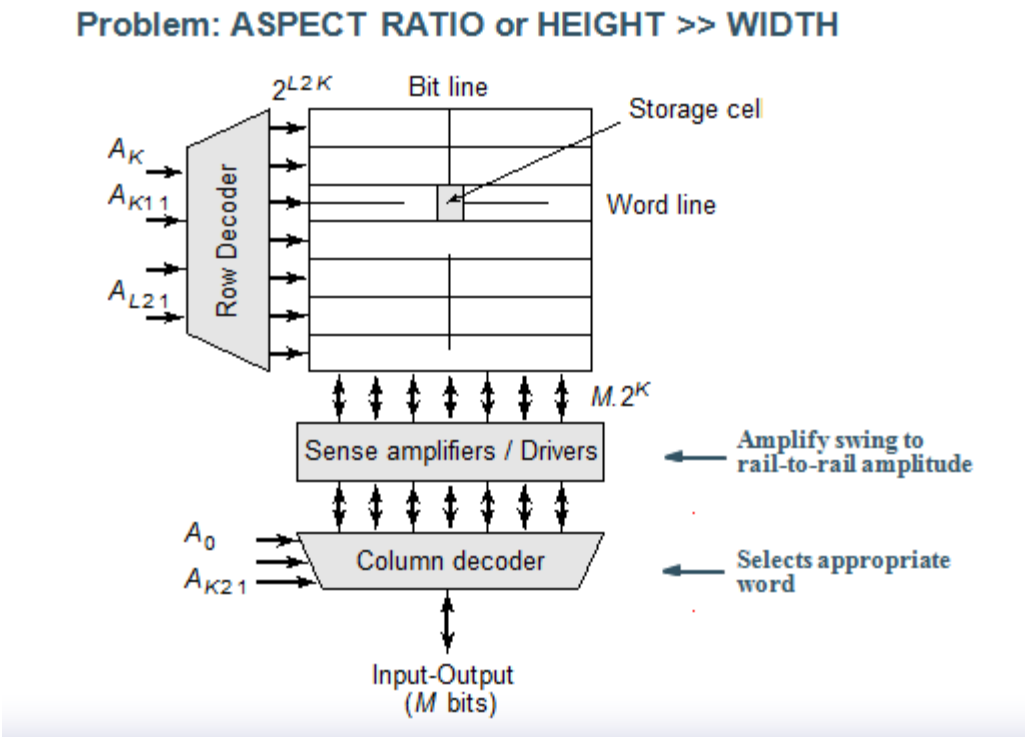
Memory Architecture and Building Blocks

- To implement an N-word memory where each word is M bits wide, then the most intuitive approach is to stack the subsequent memory words in a linear fashion.



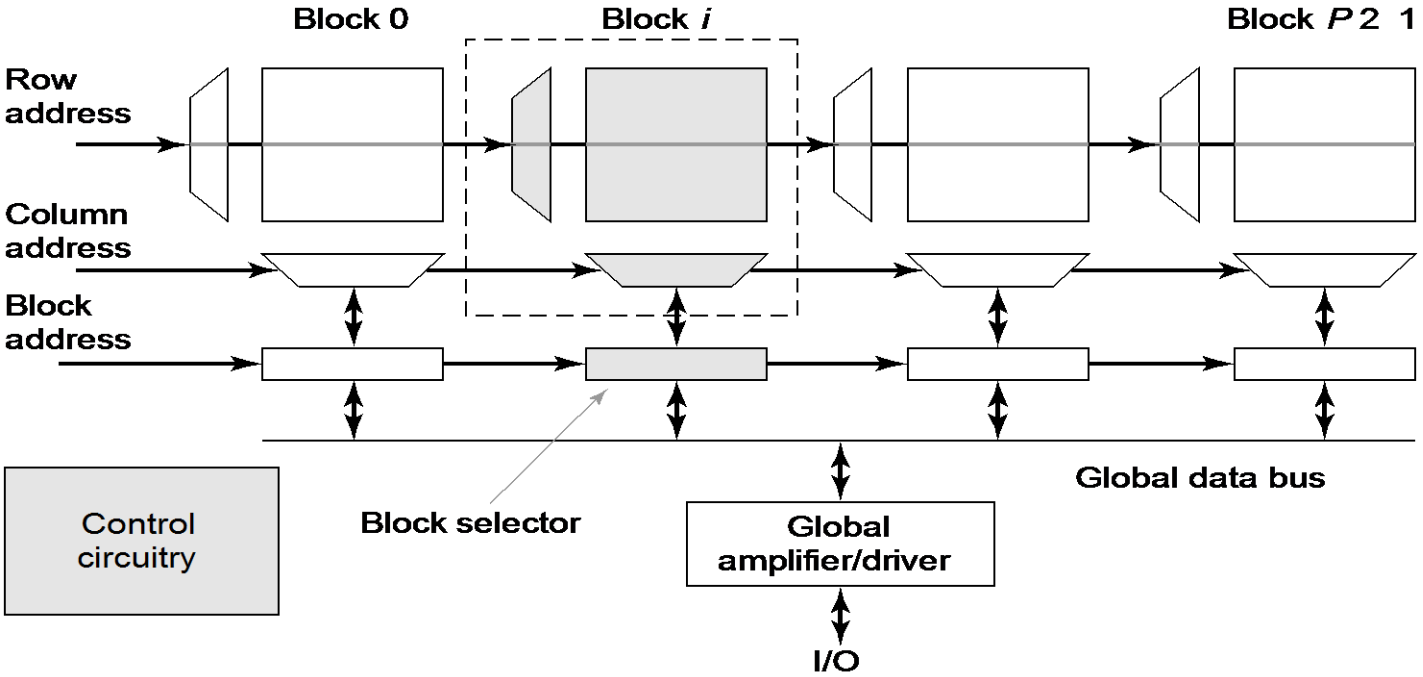
Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

Array Structured Memory Organization



Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

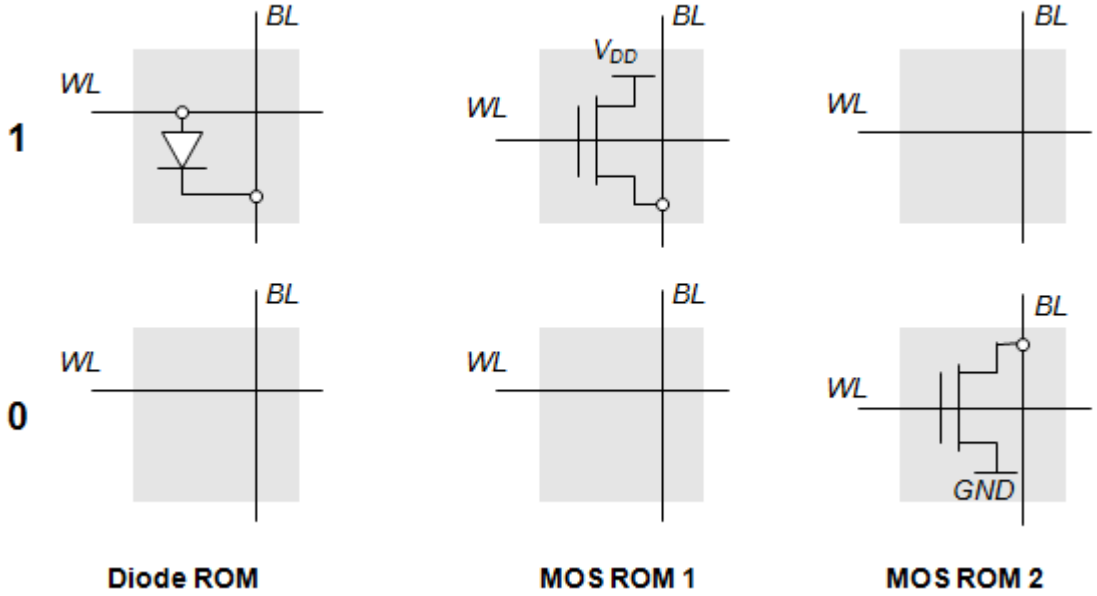
Hierarchical Memory Architecture



Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

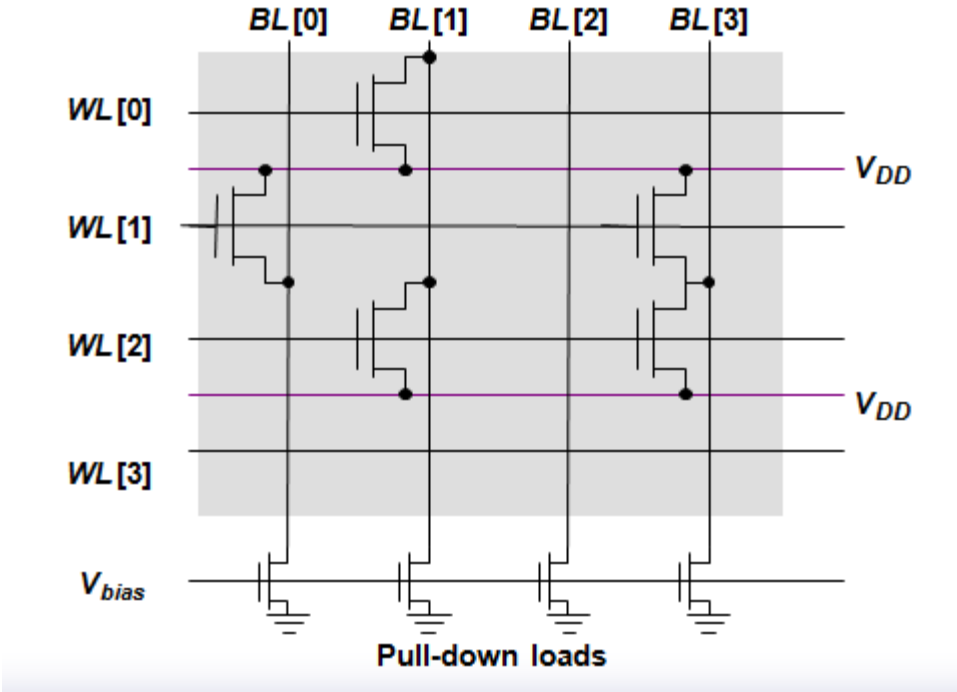
The Memory Core

❑ Read only Memories



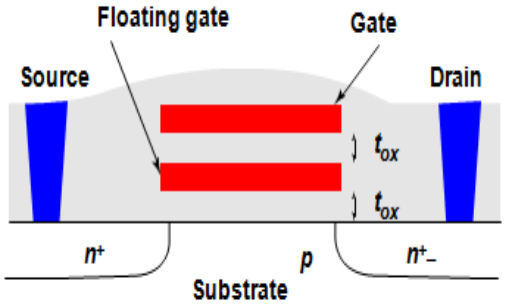
Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, “Digital Integrated Circuit,” PHI Learning Pvt. Ltd., 2011.

A 4×4 OR ROM Array

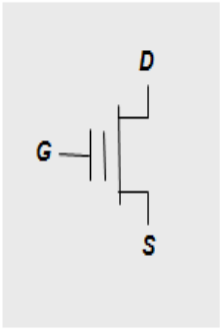


Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, “Digital Integrated Circuit,” PHI Learning Pvt. Ltd., 2011.

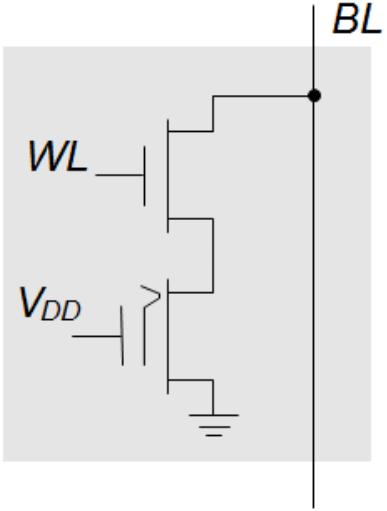
❑ Non-volatile Read-Write Memories-

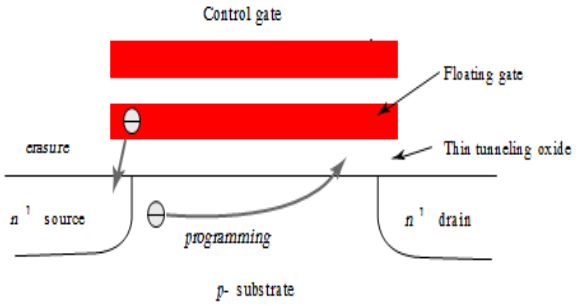


Device cross-section



Schematic symbol





Floating-Gate Transistor

EPROM

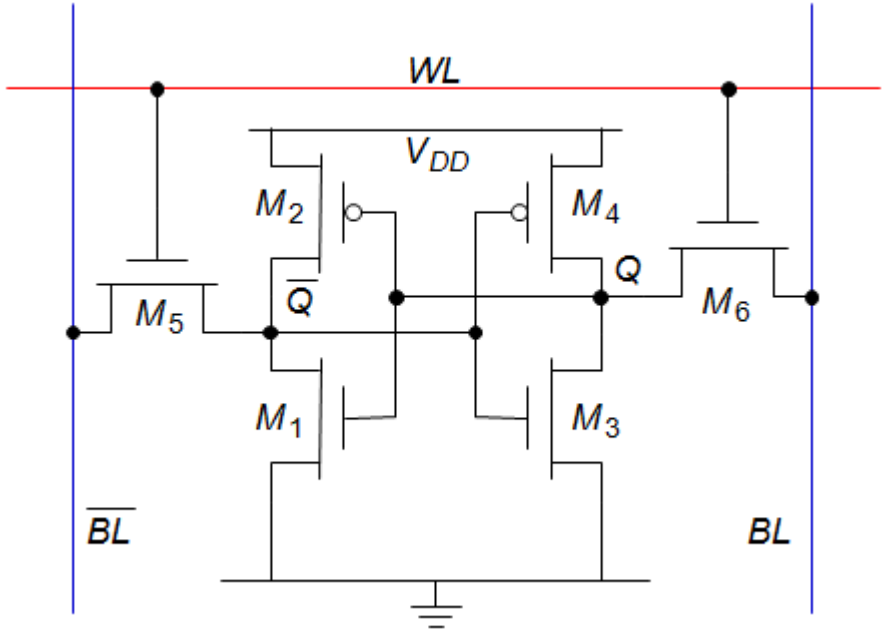
Flash-EPROM

Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

Read Write Memories (RAM)

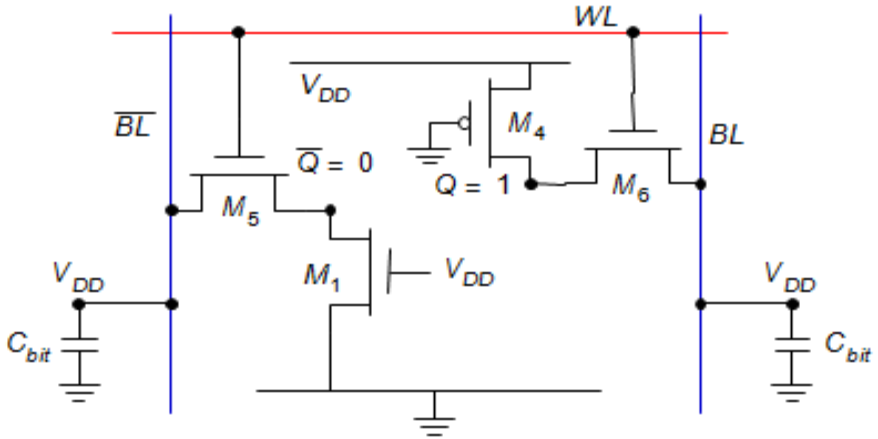
- Storage in RAM memories is based on either positive feedback or capacitive charge.

a) Static RAM

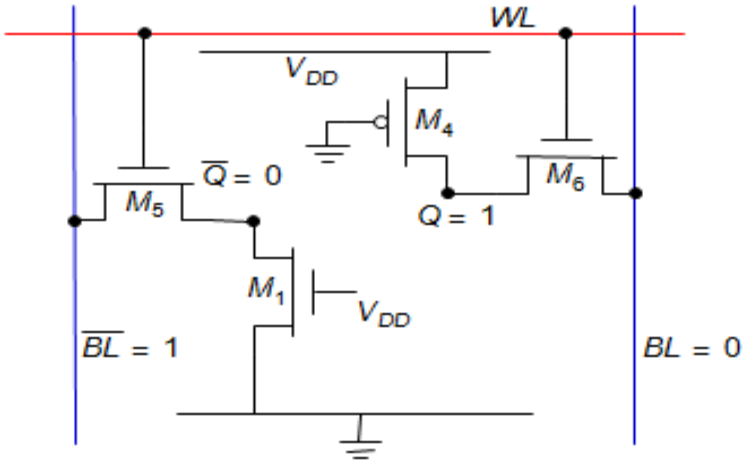


Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

SRAM Read & Write Operation



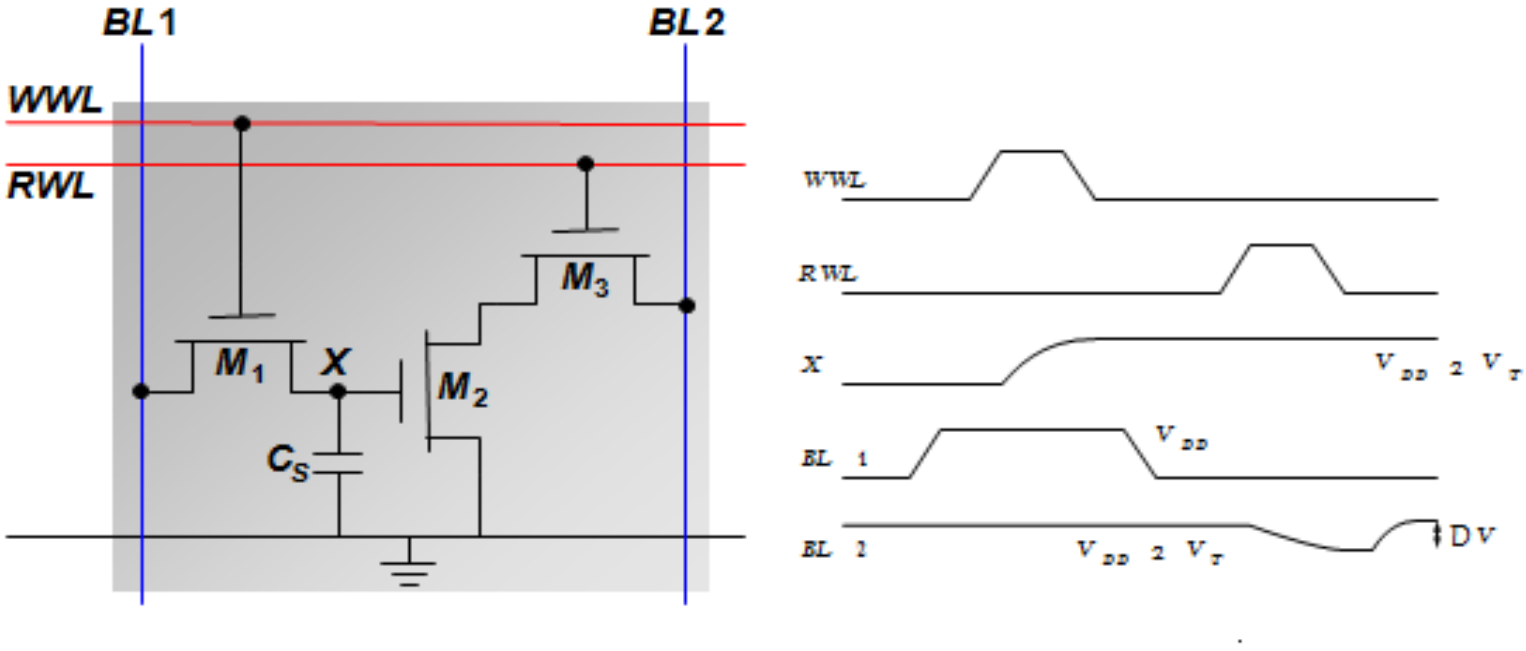
Read Operation



Write Operation

Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

b) Dynamic RAM



Source: J. M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated Circuit," PHI Learning Pvt. Ltd., 2011.

Recapitulation

- The type of memory unit that us preferable for a given application is a function of required memory size, the time it takes to access the stored data, the access pattern, the application and the system requirements.
- RWM belong to the class of volatile memory while ROM belongs to the category of non-volatile memories.
- EPROM and E2PROM are the memories which offer both read and write functionality even that are of non-volatile in nature.
- RAM can be classified as Static RAM and Dynamic RAM based on the storage concept.

Thank You