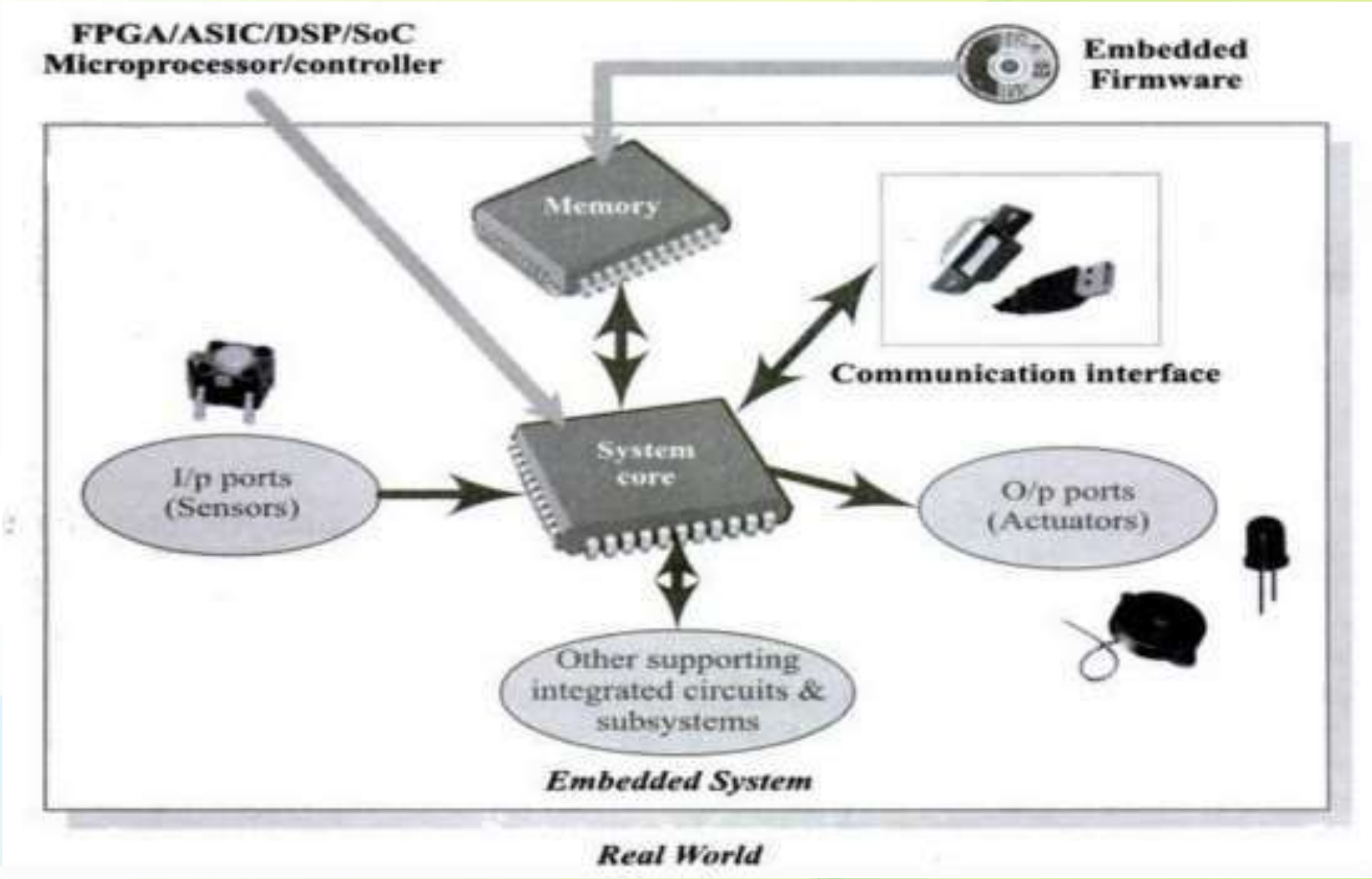
Department of Electronics & Communication Engg.

Course : ARM Microcontroller & ES-15EC62. . **Sem.: 6th (2017-18)**

Course Coordinator:

Prof. Sachin S Patil


FPGA/ASIC/DSP/SoC
Microprocessor/controller
Embedded
Firmware
Memory
Communication interface
I/p ports
(Sensors)
System
core
O/p ports
(Actuators)
Other supporting
integrated circuits &
subsystems
Embedded System
Real World

Memory

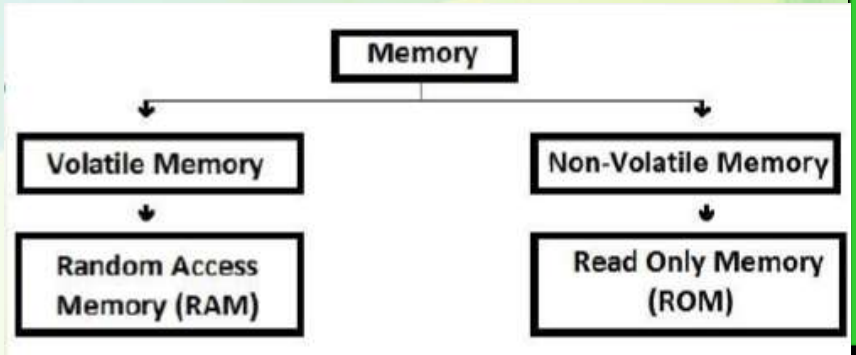
- **Memory is an important part of a processor/controller based embedded** systems.
- Some of the processors/controllers contain **built in memory and this** memory is referred as **on-chip memory.**
- Others do not contain any memory inside the chip and requires **external memory to be connected with the controller/processor to store the** control algorithm. It is called **off-chip memory.**
- There are **different types of memory used in embedded system applications:**

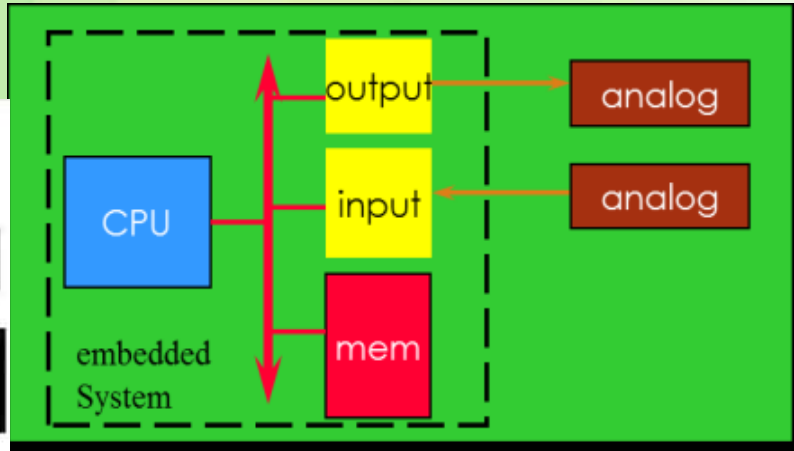
i. Program Storage Memory (ROM)

- Masked ROM (MROM)
- Programmable Read Only Memory (PROM)/ (OTP)
- Erasable Programmable Read Only Memory (EPROM)
- Electrically Erasable Programmable Read Only Memory (EEPROM)
- FLASH

ii. Read-Write Memory/Random Access Memory (RAM)

- Static RAM (SRAM)
- Dynamic RAM (DRAM)
- NVRAM





Program Storage Memory (ROM)

- **The program memory or code storage memory of an embedded system stores the program instructions and it can be** classified into **different types as per the** block diagram representation given in Figure.
- The code memory **retains its contents** even **after the power to it is turned off. It is generally known as non-volatile** storage memory.
- Depending on the fabrication, erasing and programming techniques they are classified into the following types.

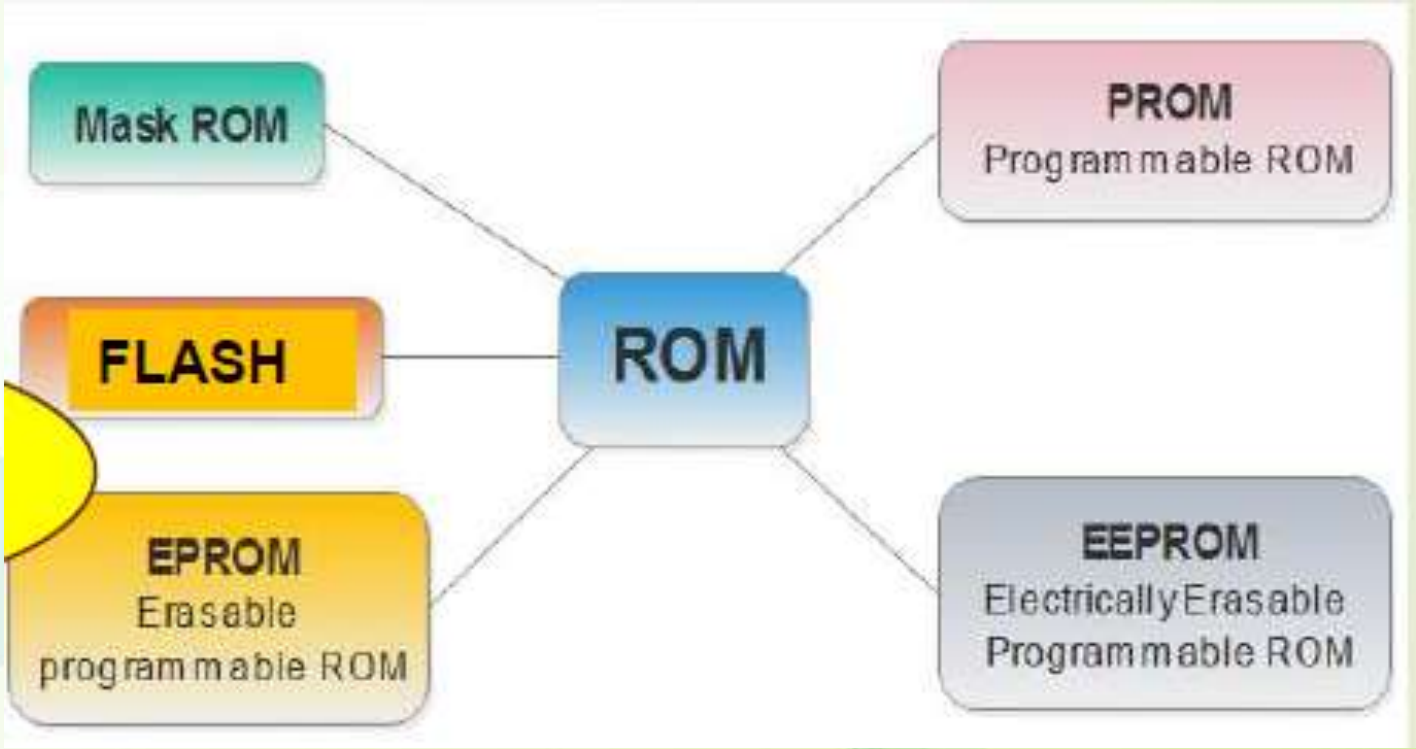


Figure. Classification of Program Memory (ROM)

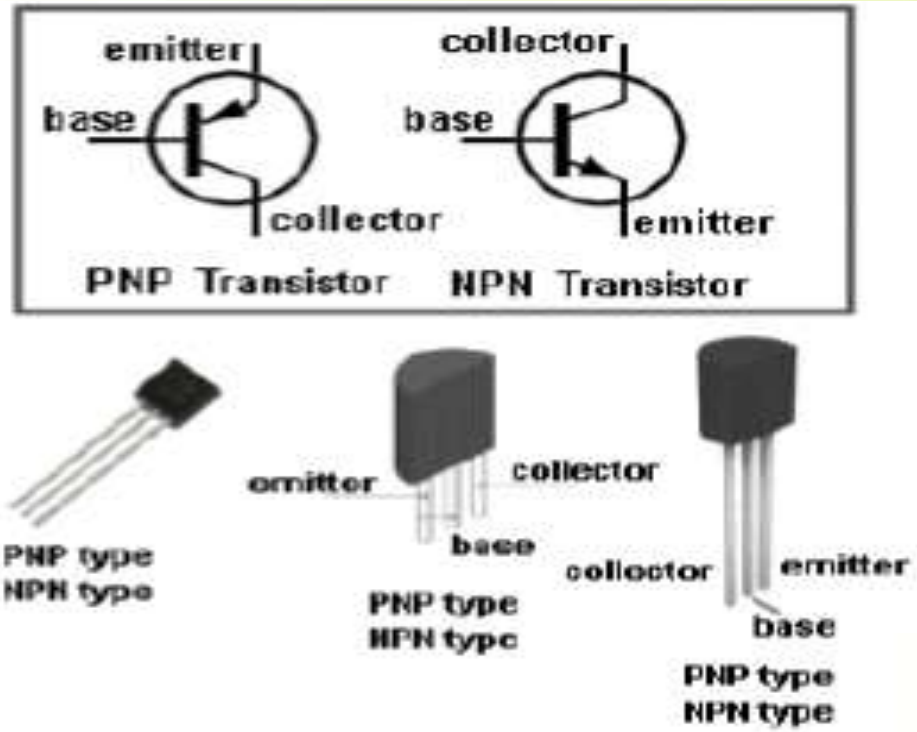
Classification of ROM

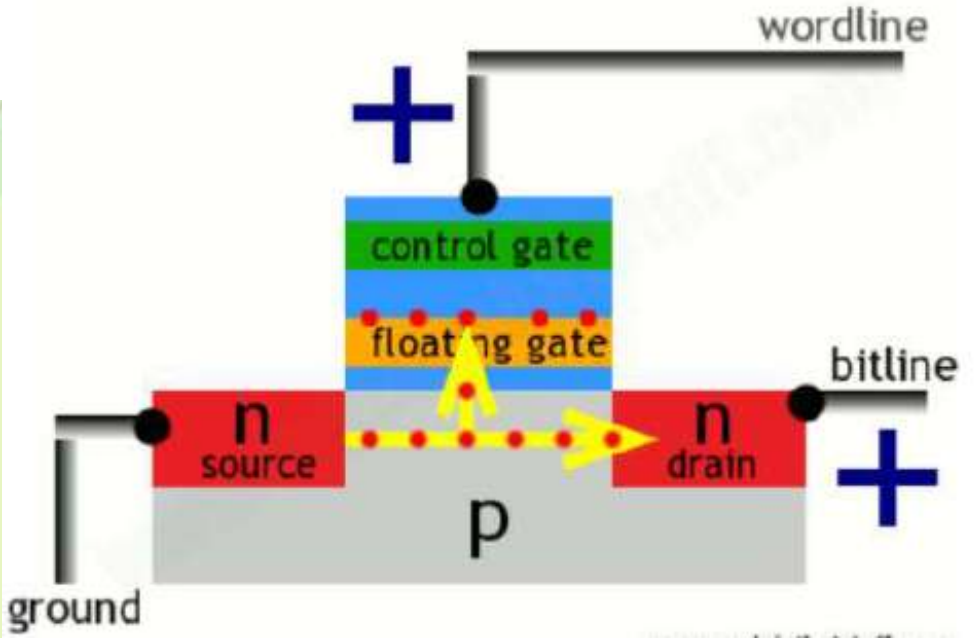
- **Mask ROM : Masked ROM is a static ROM which comes programmed into an integrated** circuit by its manufacturer. Masked ROM makes **use of the hardwired technology for** storing data. It is a **good candidate for storing the embedded firmware for low cost** embedded devices. The **primary advantage of this is low cost for high volume production.** The **limitation with MROM based firmware storage is the inability to modify the device** firmware against firmware upgrades. They are **used in network operating systems, server** operating systems, storing of fonts for laser printers, sound data in electronic musical instruments.
- **PROM/ OTP : Unlike MROM, One Time Programmable Memory (OTP) or PROM is not pre-programmed by the manufacturer. The end user is responsible for programming** these devices. They have several different **applications, including cell phones, video game** consoles, RFID tags, medical devices, and other electronics.

 EPROM : EPROM gives the flexibility to re-program the same chip. EPROM stores the bit information **by charging the floating gate of an FET and contains a quartz crystal window for** erasing the stored information. Even though the EPROM chip is flexible in terms of reprogrammability, it needs to be taken out of the circuit board and put in a UV eraser device for 20 to 30 minutes. So it is a **tedious and time-consuming process.**

 EEPROM : The information contained in the EEPROM memory can be altered by using electrical signal at the register/Byte level. They **can be erased and reprogrammed in-circuit. These chips** include **a chip erase mode and in this mode they can be erased in a few milliseconds. It provides greater flexibility for system design. The only limitation is their capacity is limited when** compared with the standard ROM (a few kilobytes). It is **used for storing the computer system** BIOS.

How MOS-FET Transistor works?





- **FLASH : It is an enhanced version of EEPROM. It combines the re-programmability of** EEPROM and the high capacity of standard ROMs. FLASH memory is organized as sectors (blocks) or pages. FLASH memory stores information in an array of floating gate MOS-FET transistors. The erasing of memory can be done at sector level or page level without affecting the other sectors or pages. Each sector/ page should be erased before re-programming. The typical erasable capacity of FLASH is **1000 cycles. Many modern PCs have their BIOS** stored on a flash memory chip, called as **flash BIOS and they are also used in memory cards, USB flash drives, modems as well.**

Read-Write Memory/Random Access Memory (RAM)

- The **Random Access Memory (RAM) is the data memory or working memory of the** controller/processor.
- Controller/processor can **read from** it and **write to it.**
- RAM is **volatile, meaning when the** power is turned off, all the contents are destroyed.
- RAM generally falls into **three categories: Static RAM (SRAM),** dynamic RAM (DRAM) and nonvolatile RAM (NVRAM).

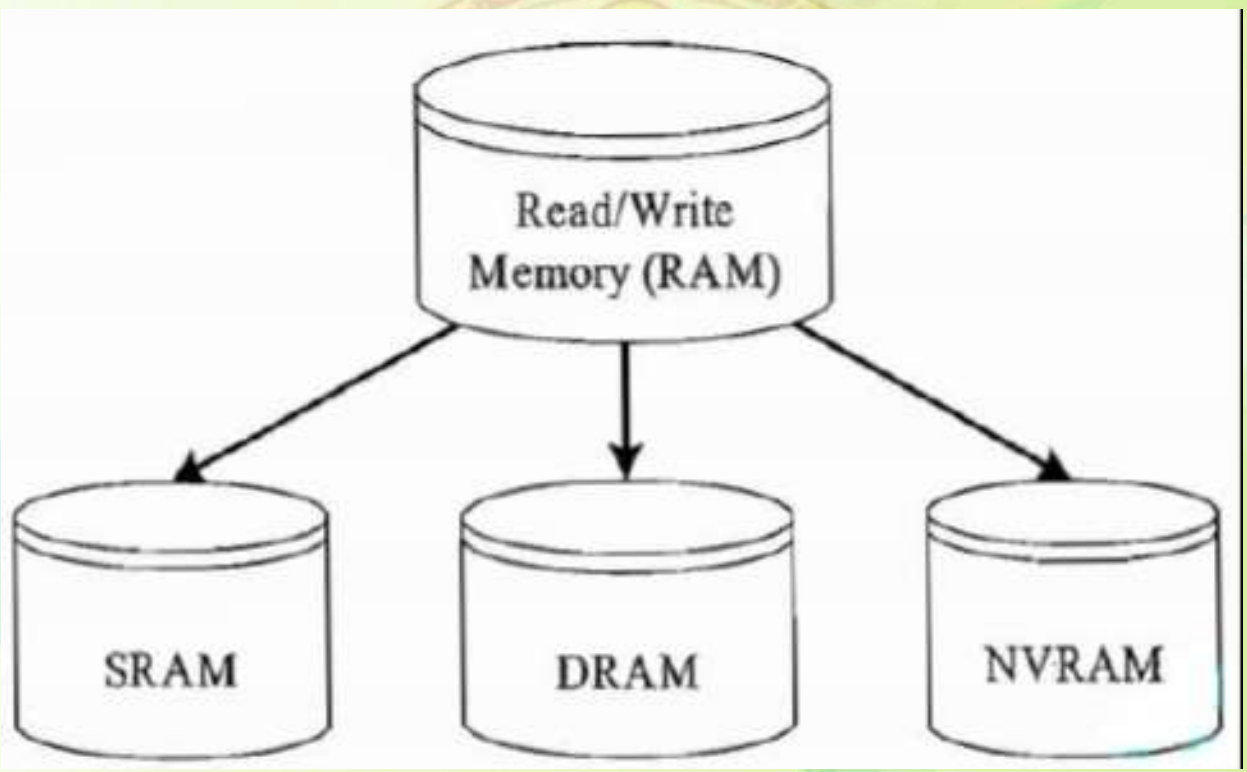


Figure. Classification of Working Memory (RAM)

Static RAM (SRAM)

SRAM : SRAM stores data in the form of voltage. They are made up of **flip-flops. A flip-flop for a** memory cell takes **four or six transistors (or 6 MOSFETs) along** with some wiring, four of the transistors are used **for building the latch (flip-flop) part of the memory cell and two for controlling the access. SRAM is fast in operation** due to its resistive networking and switching capabilities. In its simplest representation an SRAM cell can be visualized as shown in Figure.

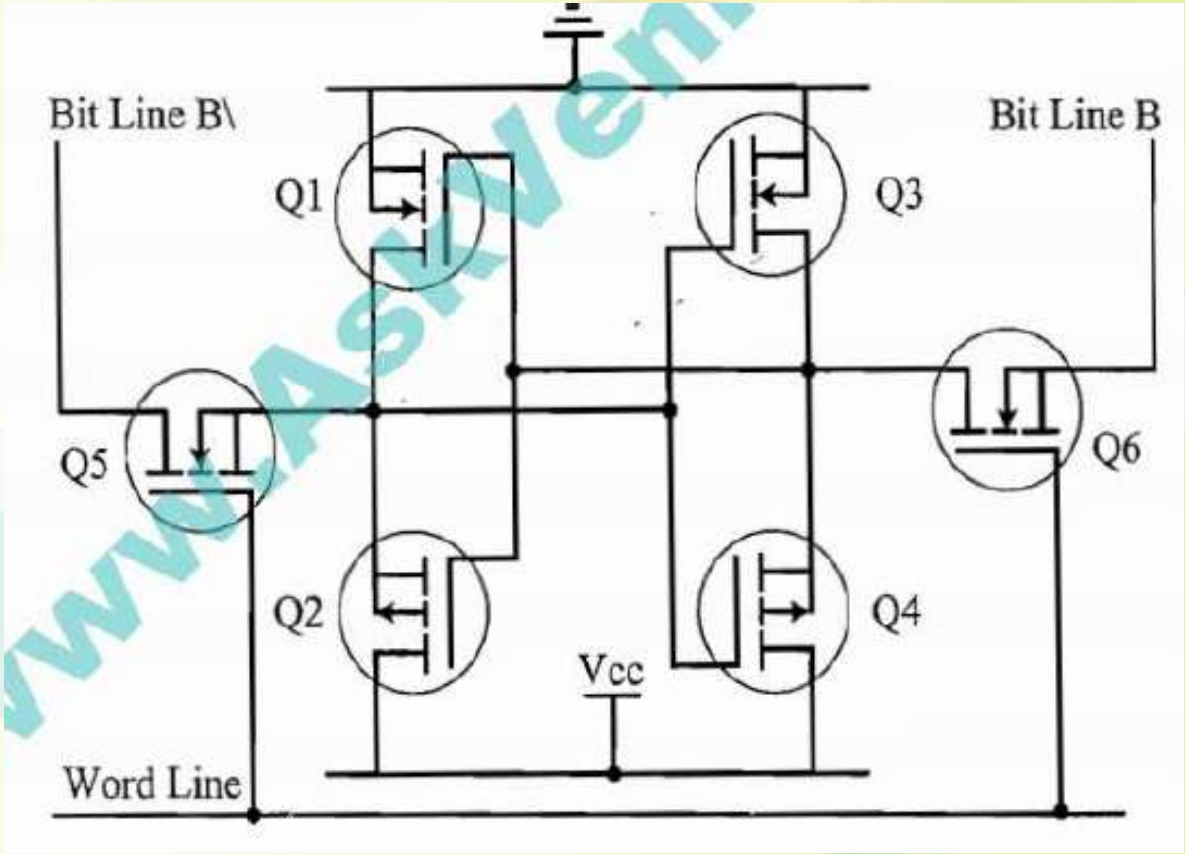
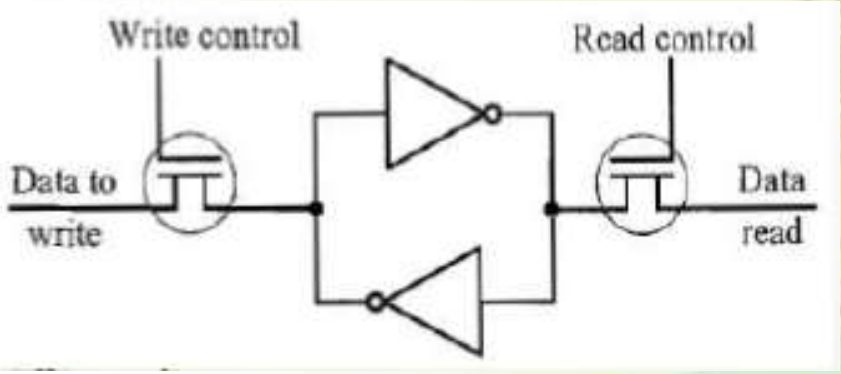


Figure. SRAM Cell Implementation

- This implementation in its simpler form can be visualized as **two-cross coupled inverters** with read/write control through transistors. The **four transistors in the middle form the** cross-coupled inverters. This can be visualized as shown in Figure.
- The major limitations of SRAM are **low capacity and high cost.**



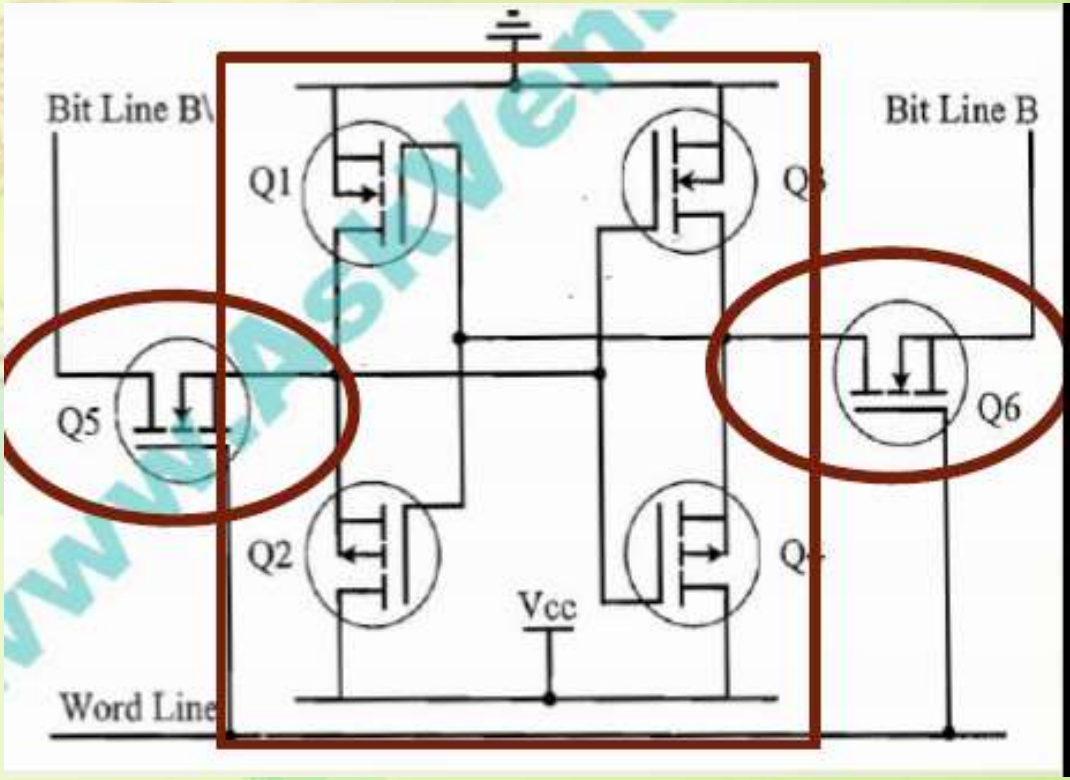


Figure. Visualization of SRAM cell

Dynamic RAM (DRAM)

- **DRAM : DRAM stores data in the form of charge. They are made up** of **MOS transistor gates.**
- The advantages of DRAM are its **high density and low cost compared** to SRAM.
- The disadvantage is that since the information is stored as charge it gets **leaked off with time and to prevent this they need to be refreshed periodically.**
- Special circuits called DRAM controllers are used for the **refreshing operation.**
- The refresh operation is done periodically **in milliseconds interval.**
- The MOSFET acts as the gate for the incoming and outgoing data whereas the capacitor acts as the bit storage unit.

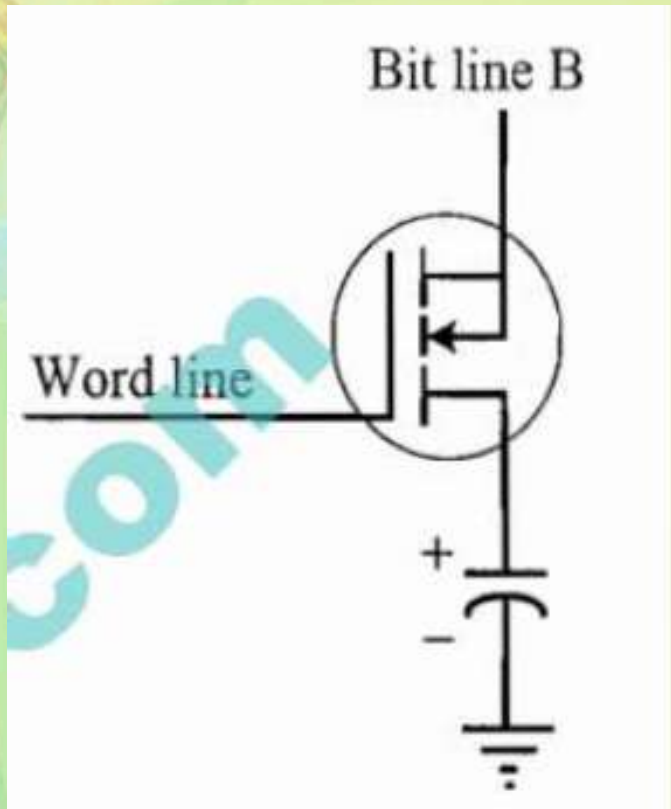


Figure. DRAM Cell Implementation

Summary of the relative merits and demerits of SRAM and DRAM technology

SRAM Cell	DRAM Cell
Made up of 6 CMOS transistors (MOSFET)	Made up of a MOSFET and a capacitor
Doesn't require refreshing	Requires refreshing
Low capacity (Less dense)	High capacity (Highly dense)
More expensive	Less expensive
Fast in operation. Typical access time is 10 ns.	Slow in operation due to refresh requirements. Typical access time is 60 ns. Write operation is faster than read operation.

NVRAM

- **NVRAM: Non-volatile RAM is a random access memory with battery backup.**
- It contains **static RAM based memory and a minute battery for providing supply to the** memory in the absence of external power supply.
- The memory and battery are **packed together in a single package.**
- NVRAM is used for the **non-volatile storage of results of operations.**
- The **life span of NVRAM is expected to be around 10 years.**
- **DS1744 from Maxim/Dallas is an example for 32 KB NVRAM**

Queries …?