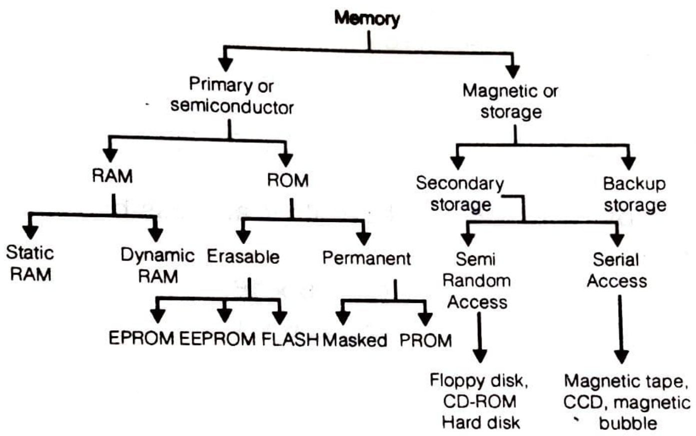
SEMICONDUCTOR MEMORIES 10

A digital processor generally requires a facility for storing information; the subsystem of a digital processor which provides this storage facility is called the **"MEMORY"**. A memory stores data for processing and instructions for execution.



Semiconductor Memory

These memories are used as the "internal memory" of a computer, where fast operation is important.

It is also called "main or working memory" and is in constant communication with the CPU as a program of instruction is being executed. The basic element of this memory is a flip-flop.

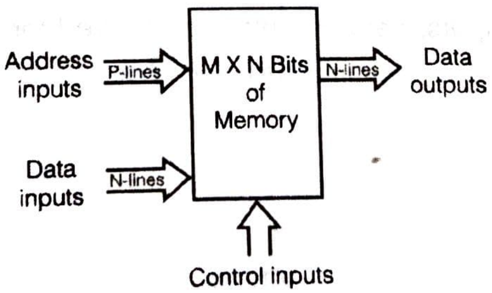


Fig. (10.1)

The size or capacity of a memory chip is specified as $(M \times N)$ bits.

where,

M = Number of locations available in the memory

N = Number of bits at each location

In other words, this means that M words of N bits each can be stored in the memory.

Each of the 'M-locations' of the memory is defined by a unique "Address" and, so, for accessing any one of the M-Locations, P inputs are required, where, $\boxed{2^P = M}$. This set of lines is referred to as address inputs or address bus.

⇒ Word organised memory capacity or size = $2^P \times N$.

⇒ Bit organised memory capacity or size = $2^P \times 2^N$.

$$\boxed{1k = 2^{10} \text{ and } 1M = 2^{20}}$$

Example 10.1

A certain semiconductor memory chip is specified as 2 k × 8. How many words can be stored on this chip? What is the word size? How many total bits can this chip store?

Solution:

$$2\text{ k} = 2 \times 1024$$
$$= 2048 \text{ words}$$

Each word is 8 bits (one byte). The total number of bits is therefore

$$2048 \times 8 = 16{,}384 \text{ bits}$$

Example 10.2

Four memory chips of 16 × 4 size have their address buses connected together. This system will be of size

(a) 64 × 4
(b) 16 × 16
(c) 32 × 8
(d) 256 × 1

[IES-2001]

Solution: (b)

Since size of memory chip = 16 × 4

Now 4 chips are connected together through address buses the the word size be incremented by 4 times

$\therefore$ system size = $16 \times (4 \times 4)$

$= (16 \times 16)$

Example 10.3

How may address inputs, data outputs are required for a 16 k × 12 memory

(a) 12,12
(b) 16,12
(c) 14,12
(d) 16,16

Solution: (c)

From the figure (10.1) we have,

$$2^P = M$$

where, P = address inputs

$$M = 16\text{ k} = 2^4 \times 2^{10}$$
$$= 2^{14}$$

$\therefore$ $\boxed{P = 14}$

Since size of memory = 16 k × 12 = M × N

$\therefore$ Data output = N = 12

Auxiliary Memory

Auxiliary memory also called as magnetic or mass storage, has the capacity to store massive amounts of data without need of electrical power. It operates at a much slower speed than internal memory, and it stores programs that are not currently being used by the CPU.

Memory Terminology

Memory cell

A device or electrical circuit used to store a single bit (0 or 1). Examples are: a flip-flop, a charged capacitor, a single spot on magnetic tape or disk.

Memory word

A group of bits (cells) in a memory that represents instructions or data of some type.

Density

When we say that one memory device has a greater density than another, means it can store more bits in the same amount of space.

Address

A number that identifies the location of word in memory.

Read operation

The operation whereby the binary word stored in a specific memory location (address) is sensed and then transferred to another device. it is often called a "Fetch operation", since a word is being fetched from memory.

Write operation

The operation whereby a new word is placed into a particular memory location. It is also referred to as a "store operation".

Access time

It is a measure of a memory device's operating speed. Also, it is the time required to select a word and either read or write it. The symbol "t_{ACC}" is used for access time.

Volatile memory

Memory units whose components lose stored information with time or when the power is turned OFF.

Sequential-Acess Memory (SAM)

In the SAM, the access time depends on the position of the word at the time of request. Access time in a SAM is variable.

Read/Write Memory (RWM)

Any memory that can be read from or written into with equal ease.

Compiler

Programs that converts a high level language into the machine language of a computer.

Interpreter

It translates one statement at a time from a source code to an object code.

Assembler

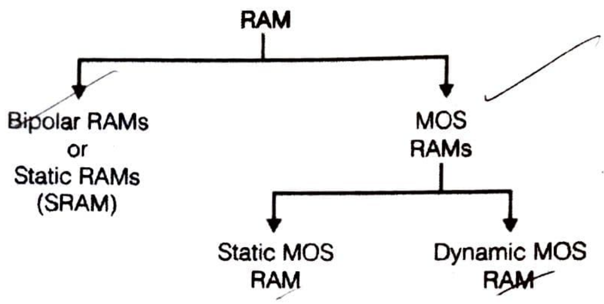
Program that translates an assembly language program from mnemonics to the binary machine code of a computer.

Direct Memory Access (DMA)

DMA interface is used for transferring data directly between an external device and memory.

Random Access Memory (RAM)

In RAM, the memory locations are organised in such a way so that any memory location requires equal time for writing or reading. It is generally called "Read-write memory" (RWM). It is a volatile memory. It can be easily programmed, erased and reprogrammed by the user. It is a "primary memory" of computer.



Static RAM (SRAMs)

- This is a semiconductor memory device in which data will be stored permanently.
- Data stored in flip-flops like structure.
- Implemented by BJT or MOSFET.
- It dissipates more power.
- It has low density.
- Operating speed is faster.
- It has fast access time of 5 to 50 ns order.
- No refreshment is required.
- It is a volatile memory.

Circuit diagram and Operation of BJT-RAM or STATIC RAM

[IES-2002]

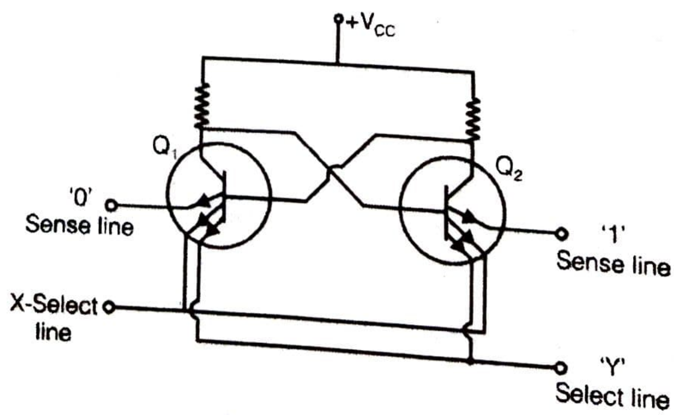


Fig. (10.2)

Storing the data in BJT RAM:

- The cell is first selected by keeping the X-and Y-select lines high.
- To write a '1' at position Y, the '1' sense line is grounded.
- Q_2 goes to saturation and then X and Y select lines are returned to low.
- A '1' is then latched in the cell so that a '1' is written into the cell at position Y.
- To write a '0' in the cell, the '0' sense line is grounded.

Retrieve the data in BJT RAM:

- The '0' and '1' sense lines are grounded.
- If the cell contains '1', then Y = 1. Transistor Q_2 goes to the saturation and the current will then be present in the '1' sense line.
- Q_1 remains in the cut-off condition and no current is present in the '0' sense line.
- The READ operation is non-destructive. Once the READ operation has been performed, the contents in the cell remain intact.
- The current present in a particular sense line is then amplified and the bit corresponding to that current will be stored in a shift register.

Note:

In SRAM cells it contains basically 6-BJTs (2 BJT → flip-flop structure + 4 BJT → control circuit).

Dynamic MOS RAM (DRAM)

- This is a semiconductor memory device in which stored data will not be permanently stored.
- Data is stored in capacitor.
- Implemented by MOSFET.
- It dissipates less power.
- Density is high.
- Operating speed is slower.
- It has less access time of 50 to 100ns order.
- Refreshment is required.
- It is a volatile memory.

Circuit Diagram and Operation of DRAM cells

Figure (10.3) shows the diagram of DRAM cells. The switches S_1 through S_4 are actually MOSFETs that are controlled by various address decoder outputs and $R/\overline{W}$ signal. The capacitor; of course is the actual storage cell.

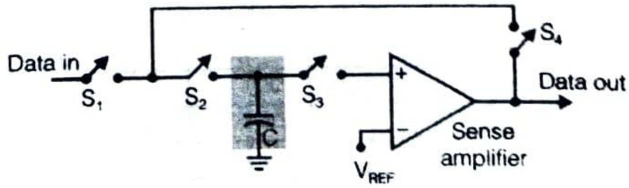


Fig. (10.3)

To write data to the cell, signals from the address decoding and read/write logic will close switches S_1 and S_2, while keeping S_3 and S_4 open. This connects the input data to C. A logic 1 at the data input charges C, and a logic 0 discharges it.

To read data from the cell, switches S_2, S_3, and S_4 are closed and S_1 is kept open. This connects the stored capacitor voltage to the sense amplifier. The sense amplifier compares the voltage with some reference value to determine if it is a logic 0 or 1, and produces a solid 0 V or 5 V for the data output. This data output is also connected to C (S_2 and S_4 are closed) and refreshes the capacitor voltage by recharging or discharging. In other words, the data bit in a memory cell is refreshed each time it is read.

Read-Only Memory (ROM)

ROM is a semiconductor memory that is designed to hold data that either are permanent or will not change frequently. During normal operation, no new data can be written into ROM but data can be read from ROM. All ROMs are Non-volatile. A major use for ROMs is in the storage of program in microcomputers. It is constructed by diodes, bipolar cells or MOSFETs.

(16 × 8 ROM)

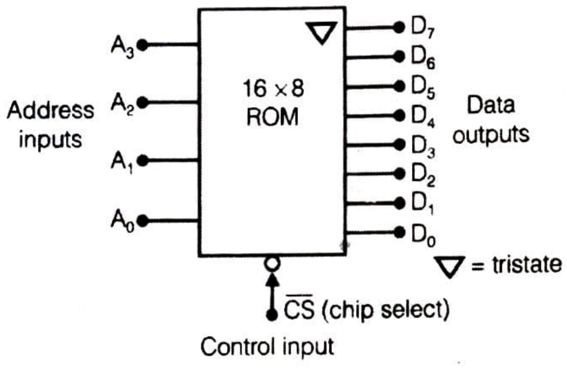


Fig. 10.4(a)

$\Rightarrow$ Possible address = $2^4 = 16$

Length of data = 8 bits

$\therefore$ Capacity of ROM = (16×8)

Note:

"ROM" is nothing but "DECODER" followed by an "ENCODER". So, it is AND-gate followed by an OR-gate.

DIODE ROM

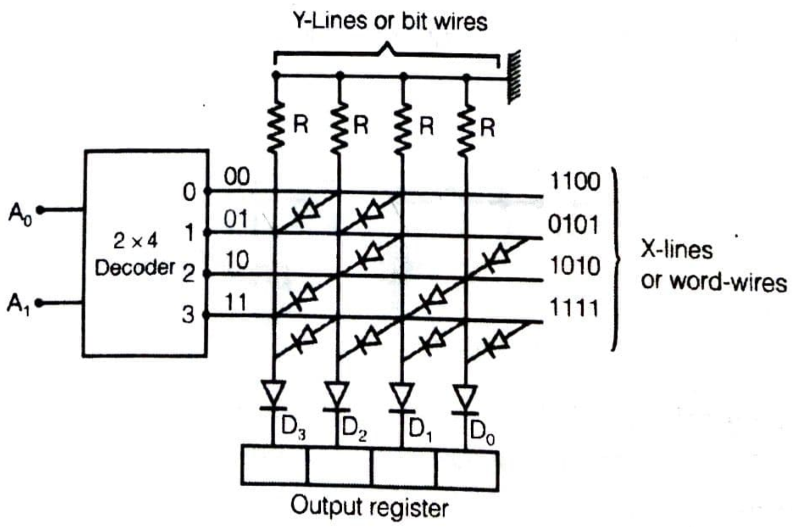


Fig. 10.4(b)

Truth table for the ROM in figure (10.4)

Inputs		Outputs			
A_1	A_0	D_3	D_2	D_1	D_0
0	0	1	1	0	0
0	1	0	1	0	1
1	0	1	0	1	0
1	1	1	1	1	1

$$Y = D_3 D_2 \bar{D}_1 \bar{D}_0 + \bar{D}_3 D_2 \bar{D}_1 D_0 + D_3 \bar{D}_2 D_1 \bar{D}_0 + D_3 D_2 D_1 D_0$$

Example 10.4

Implement the logic function as given below by using diode ROM.

[IES Conventional]

$$f_1 = \Sigma m\,(0, 1, 3, 5, 7)$$
$$f_2 = \Sigma m\,(1, 2, 4, 6)$$
$$f_3 = \Sigma m\,(0, 2, 4, 5, 7)$$
$$f_4 = \Sigma m\,(1, 2, 3, 5, 7)$$

Solution:

From the given logic function, it is clear that we have three inputs i.e. A, B, C

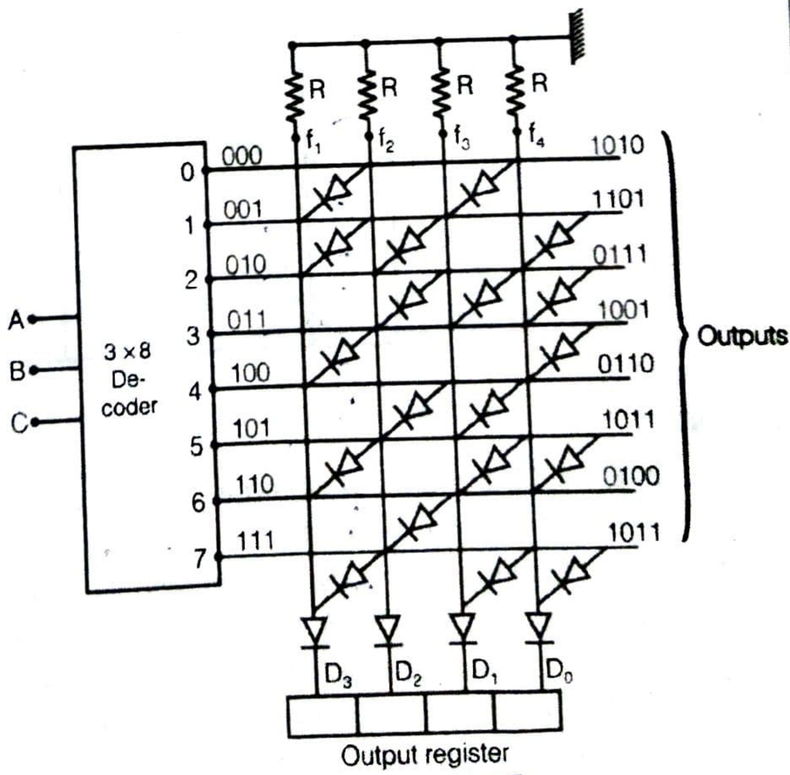
So, we require a (3 × 8) decoder.

Firstly we draw a "Look up Table" as

Inputs				Outputs			
A	B	C	→	f_1	f_2	f_3	f_4
0	0	0	→	1	0	1	0
0	0	1	→	1	1	0	1
0	1	0	→	0	1	1	1
0	1	1	→	1	0	0	1
1	0	0	→	0	1	1	0
1	0	1	→	1	0	1	1
1	1	0	→	0	1	0	0
1	1	1	→	1	0	1	1

Now, diode ROM circuit is,

- Here we assume Horizontal OR-array and Vertical AND-array.
- User can't change any memory location, hence it is known as 'MASKED ROM'.



Programmable Logic Device (PLDs)

These are LSI devices,

⇒ PROM (Programmable ROM)

⇒ PAL (Programmable array logic)

⇒ PLA (Programmable logic array)

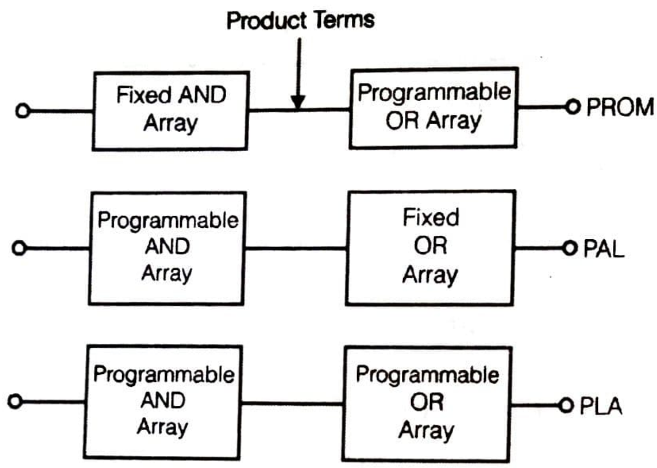


Fig. (10.5)

A combinational PLD is an IC with programmable gates divided into AND array and OR array to provide AND-OR or SOP realisation of a particular Boolean expression.

Comparison between PROM, PLA and PAL

S.No.	PROM	PLA	PAL
1.	AND array is fixed and OR array is programmable.	Both AND and OR arrays are programmable.	OR array is fixed and AND array is programmable.
2.	Cheaper and simple to use.	Costliest and complex than PAL and PROM.	Cheaper and simpler.
3.	Only Boolean functions in standard SOP form can be implemented.	Any Boolean function in SOP form can be implemented.	Any Boolean function in SOP form can be implemented.
4.	All minterms are decoded and it is generally fusible links.	AND array can be programmable to get desired minterm.	AND array can be programmable to get desired minterm.

EPROM

- In EPROM, the data is stored in floating gates and the technology used is FAMOS (Floating gate avalanche injection-MOS).
- Programming is done by electric signals and erasing is through ultra-violet rays.
- To erase data in EPROM, 15-20 minutes is to required.
- It is not possible to change particular location or group of location by users.
- EPROM is used to store data for a long time.
- EPROM is also called UV-ROM.

EEPROM

- In EEPROM programming is done through electrical signal and erasing is also done by electric signal.
- The technology used in this ROM is MNOS (Metal Nitride Oxide Semiconductor).
- In this ROM, user can change any location or group of locations without affecting others.
- EEPROM is also known as EAROM or FLASH-ROM or NOVRAM.

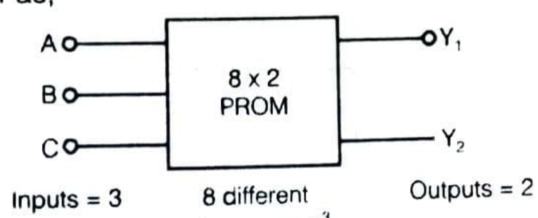
Example 10.5

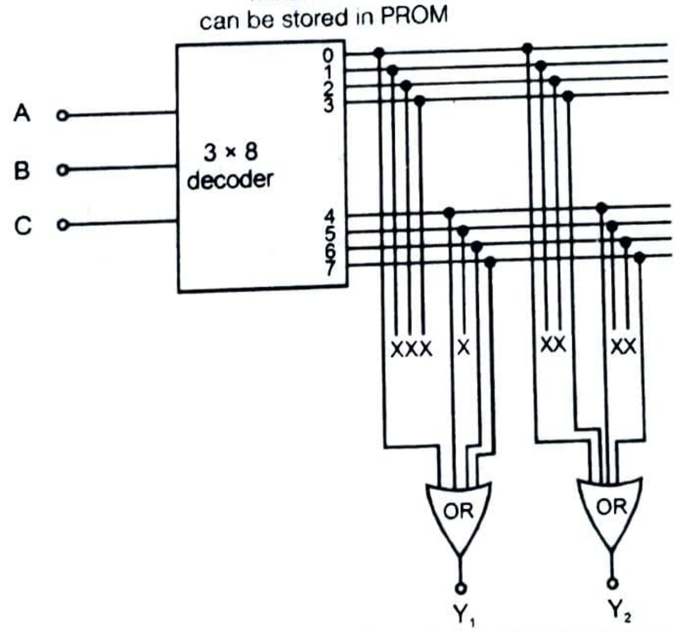
Realise boolean expression using a PROM.

$$Y_1 = f(A, B, C)$$
$$= \Sigma(0, 4, 6, 7)$$
$$Y_2 = \Sigma(0, 3, 4, 7)$$

Solution:

We use 8 × 2 PROM as,





Example 10.6

What is a ROM? Write the truth table of a 2 to 4 decoder with output polarity control and built with discrete gates and with an 8 × 4 ROM.

[IES-1999]

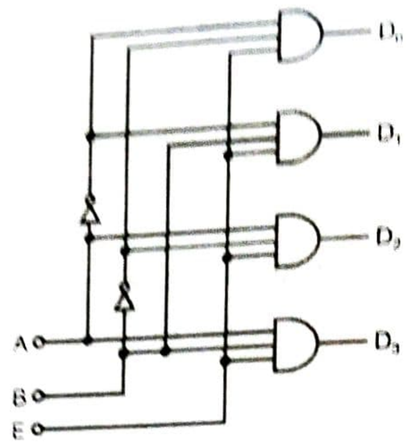
Solution:

ROM:

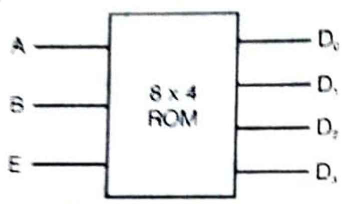
- The read-only memory is a type of semiconductor memory which stores information permanently.
- It is a non-volatile memory. Its contents are not lost when its power supply is switched off.
- It is not accessible to user, and hence we cannot write anything into it.

Truth table of a 2 × 4 decoder:

E	A	B	D_0	D_1	D_2	D_3
0	×	×	0	0	0	0
1	0	0	1	0	0	0
1	0	1	0	1	0	0
1	1	0	0	0	1	0
1	1	1	0	0	0	1



Here, A and B are the inputs.
E is the output polarity control signal or enabled signal.
D_0, D_1, D_2 and D_3 are decoder outputs.



2-to-4 decoder using 8 × 4 ROM

Applications of ROM

- For look up tables.
- In wave form generator.
- In combinational logic circuit.
- In pocket calculater.
- In sequence generator.
- In seven segment decoder for display.
- As character generator.

Flash Memory

- This is a memory which is ideally suited for low power system.
- Power supply requirement is around 12 V.
- It must be erased at the sector (block) level.

Magnetic core memory

It uses magnetic cores to store binary information. The signal that excites the core is a "current pulse" in a wire passing through the core. The binary data stored is represented by the direction of magnetic flux within the core [as in figure 10.6 (a)].

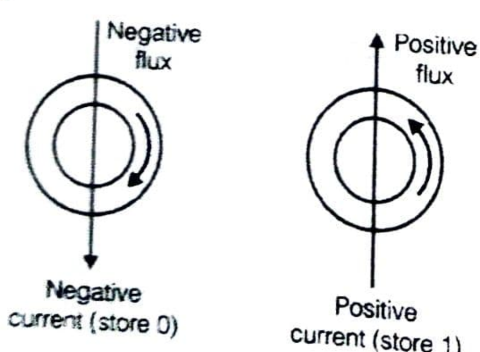


Fig. 10.6(a)

The output binary data from the core is in the form of a "**voltage pulse**". Reading a stored bit from a magnetic core memory is shown in fig. 10.6 (b).

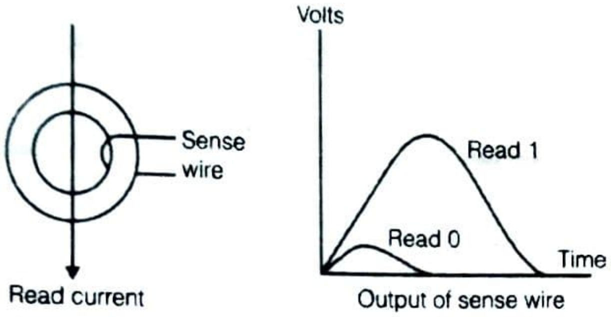


Fig. 10.6(b)

Floppy Disks (FDs)

This is a semi-random access memory that can be accessed with the sector and track addresses. It is made up of thin magnetic material (Iron oxide). It stores binary data (0's and 1's) in the form of magnetic directions.

Hard Disks (HDs)

It is an expensive memory circuit whose storage capacity ranges from several MB to GB and available in various size. Constructionaly same as FDs, except magnetic material is coated on a rigid aluminium base and enclosed in a sealed container.

Magnetic Bubble

It is a non-volatile, semi-random access type memory devices. It possesses non-destructive readout property. It is a solid state device having high reliability, small size, light weight, ruggedness and limited power dissipation.

Charged Coupled Device (CCD)

It is an array of MOS capacitors operating as a dynamic shift register for storing digital data.

Its operation involved following steps:

- Convert digital data into charges.
- Transfer these charges through various, stages in a sequential manner.
- Again convert the charge at the output into digital information.

Magnetic Drum

It is a cylindrical shaped drum having surface coated with magnetic material. It provides larger storage capacity but it has larger access time.

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