Chapter Nine

9.1 Introduction:

We are living nowadays in a civilisation that produces a lot of information which are intended to be stored: movies, pictures, data base concerning criminality, information to be used for meteorological previsions, programs controlling computers (operating systems), software in various domains of study etc…To be efficient and reliable, the storage of those in formations should be done using systems or tools which are resistant to corruption and are flexible. In fact, those systems should permit the storage of huge quantity of information over a long period of time without any losses or destruction. We should also be able to modify eventually the information stored. Traditional tools of storage like paper (information written in books) have shown their limits and have been replaced by new systems which are digital storage devices. Many technologies of digital storage exist, each having advantages and also disadvantages.

9.2 General structure of digital storage systems:

All the memories, no matter their types have the same general principle of functioning. They are surrounded by many lines having the following functions:

1. Select the address of de data within the memory;
2. Choose the type of operation which is to be achieved: read or write;
3. Lines intended to transfer the information to be written into the memory;
4. Lines intended to transfer information out of the memory…

The figure below illustrates those functions using a 32 X 8 memory. That is a memory which is able to store 32 memory words of one byte each (1 byte = 8 bits). Given that there are 32 memory locations, 5 address lines are needed ($32 = 2^5$).

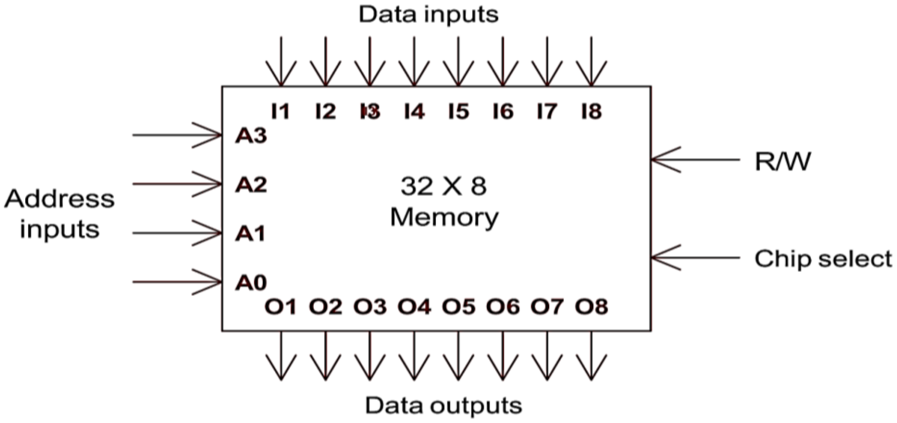

Figure 9.1: General principle of a memory.

The information is sent in using 8 lines, the same number of lines is used to send out data. The R/W line permits to determine the type of operation to be done: either writing or reading. The chip selects terminal permits to allow or to prevent the memory from functioning.

9.3 Terms and concepts related to digital storage:

There are many concepts and specific terms which are used while dealing with digital storage world. These are some of those terms:

Elementary memory or memory cell: This is an electrical circuit or a system which is able to store one bit of information. A flip-flop is an elementary memory.

Memory word: Group of bits which can be stored in one register of a memory. The length of a memory word in nowadays computers goes from 4 bits to 64 bits (eventually 128). But the most common length is 8 bits, which is a byte.

Capacity of a memory: It is the quantity of information that a memory device can store. The capacity of a memory is expressed in terms of bytes. It can also be expressed in terms of multiples of byte such as kilobyte (KB), megabyte (MB), gigabyte (GB) and even terabyte (TB).

1B = 8 bits;

1KB = 2^{10} bytes = 1024 bytes;

1MB = 2^{10} KB =2^{20} bytes;

1GB = 2^{10} MB = 2^{30} bytes;

1TB = 2^{10} GB = 2^{40} bytes.

Exercise 9.1:

The following information is written on a memory: 4MB X 8. Give the length of a memory word in that memory and determine its capacity in terms of bytes and in terms of bits.

Solution:

1. The length of a memory word is 8 bits.
2. The capacity of the memory is calculated as follows:

C = 4 X 2^{20} X 8 B = 33 554 432 B = 268 435 456 bits.

Remark 9.1: Length of the memory word.

The capacity of a memory is most of the time given using the following format: C = A X L, where L is the length of the memory word. For example, if we consider a memory on which it is written 4KB X 8, we can simply deduce that the length of the memory word 8 bits.

Exercise 9.2:

The following information is written on a digital storage device: 4GB X 4.

a. Give the length of the memory word in that device;
b. Determine the capacity of the memory in terms of bytes and also in terms of bits.

Address: Number used to specify the location of a word in a memory. The address is normally a binary number but computer engineer use to convert them in hexadecimal or octal while working theoretically, in order to reduce the number of ciphers to handle (binary number are expressed in a large number of cipher).

Reading operation: Operation during which a word located at a given address is found and transferred to another location.

Writing operation: Operation during which a new word is installed at a given address of a memory.

Volatile memory: It is a memory that saves the information that it contains only when supplied with electrical current. Once the supply is removed, all the information is lost.

Read only memory: Memory which is particularly designed for reading operation. There are however special ROM which can be written and also read.

Static memory: Semiconductor memory which saves data as long as they are supplied; data don't need to be rewritten periodically.

Dynamic memory: Semiconductor memory for which data to be saved need to be rewritten periodically. The process of rewriting data periodically is called refreshment.

9.4 Technologies of semiconductor memories:

As far as technology is concerned, semiconductor memories can be classified in two groups: Bipolar memories (memories containing bipolar transistors) and MOS memories (memories containing MOS transistors). The following chart gives an overview of various technologies of semiconductor memories.

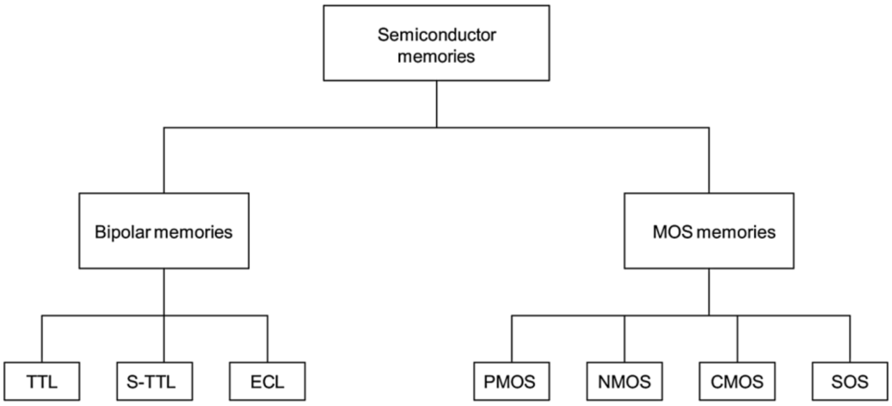

Figure 9.2: Semiconductor memory technologies.

Each type of semiconductor memory has its particular characteristics; however, they can be compared using following criteria:

- Density (scale of integration);
- Speed;
- Power consumption;
- Cost;
- Immunity to noise.

Any type of semiconductor memory has advantages but also disadvantages, however it is generally known that bipolar memories are faster than MOS memories and that the performances of MOS memories are better than those of bipolar memories for all the other criteria specified above.

9.4.1 Technologies of bipolar memories:

Bipolar memories use electronic components such as resistance, diodes, and bipolar transistor to form their memorisation circuit on integrated circuit chips. Because of the high complexity of those circuits, a great number of them cannot be integrated on a chip. That is why bipolar technology does not permit to obtain great capacity of memory.

TTL and S-TTL technologies (TTL: Transistor Transistor Logic; S-TTL: Schottky TTL) are mostly used in the realisation of bipolar memories. TTL memories are characterised by:

- High speed;
- Capacity of medium size;
- High power consumption;

- High cost;
- Low noise immunity;
- Low integration density (SSI, MSI)

S-TTL memories have almost the same performances with TTL memories. The only difference is that S-TTL memories work faster than TTL memories. TTL memories are suitable for applications requiring high speed, medium size capacities and for which high power consumption is not a hindrance to the functioning.

ECL memories (ECL: Emitted Coupled Logic) work faster than TTL and Schottky TTL memories; however, their characteristics are poorer in all the other domains. ECL memories are therefore used essentially for applications which require very high speed without being disturbed by the poor performances in all the other domains.

9.4.2 Technologies of MOS memories:

Memorisation circuits of MOS memories are realized using MOS transistors. Generally, MOS technology memories have the following characteristics:

- Low speed;
- Low power consumption;
- High capacity;
- High immunity to noise;
- Low cost,
- High density of integration (LSI, VLSI, ULSI)

SOS technology (Silicium On Saphir) is an amelioration of CMOS technology having the best performances among all the MOS memories; however, its cost is the highest. Thefollowing table summaries and compares the performances of semiconductor memories:

Technology	**Speed**	**Power consumption**	**Capacity**	**Immunity to noise**	**Cost**
TTL/S-TTL	Fast	High	Low	Low	High
ECL	Very fast	Very high	Very low	Very low	Very high
NMOS	Medium (near to that of TTL)	Low	Very high	High	Very low
CMOS/SOS	Very low	Very low	High	Very high	Low

Remark 9.1: Scale of integration of ICs

The scale of integration indicates the number of transistor integrated on one chip of IC. There are many scales of integration:

- SSI: Small scale integration;
- MSI: Medium scale integration;
- LSI: Large scale integration;
- VLSI: Very large scale integration;
- ULSI: Ultra large scale integration.

9.5 Read only memories:

These are memories in which data can only be read; in fact, once data are stored in the memory, they are saved permanently and are not supposed to be often modified. However, there are some types of read only memories in which data can be written and read several times. There are many types of read only memories:

MROM: Read Only Memory programmable by Mask. Data are written during the process of fabrication of the memory using a mask, according to the specifications of the client (program given by the client).

PROM: Programmable Read Only Memory. This type of memory is programmed by the user himself (not by the manufacturer as for the MROM). However, once a PROM is programmed, it can no more be modified.

EPROM: Erasable Programmable Read Only Memory. This memory can be erased several times by the user and reprogrammed. The inconvenient of this type of memory is that not part but the entire program has to be cancelled anytime the used want to modify the program.

EEPROM: Electrically Erasable PROM. This type of memory can be erased several times by the user. Its major advantage is that; it allows the programmer to modify the program without be obliged to cancel the entire program as it is the case for the EPROM.

9.6 Random Access Memory:

Data can be written and read in random access memories as long as they are supply by an electrical voltage. There are two principal types of RAM: Static RAM and DRAM. A static RAM save data as long as it is supplied by an electrical voltage, without any need of rewrite the information periodically. SRAM should be periodically refreshed in order to save data stored within it.