SEMICONDUCTOR MEMORY

Semiconductor memory is used in any electronics assembly that uses computer processing technology. Semiconductor memory is the essential electronics component needed for any computer based PCB assembly.

To meet the growing needs for semiconductor memory, there are many types and technologies that are used. As the demand grows new memory technologies are being introduced and the existing types and technologies are being further developed.

A variety of different memory technologies are available - each one suited to different applications. Names such as **ROM, RAM, EPROM, EEPROM, FLASH MEMORY, DRAM, SRAM**, SDRAM, as well as F-RAM and MRAM are available, and new types are being developed to enable improved performance.

Terms like DDR3, DDR4, DDR5 and many more are seen and these refer to different types of SDRAM semiconductor memory.

SEMICONDUCTOR MEMORY: MAIN TYPES

There are two main types or categories that can be used for semiconductor technology. These memory types or categories differentiate the memory to the way in which it operates:

- ***RAM - Random Access Memory:***

  As the names suggest, the RAM or random access memory is a form of semiconductor memory technology that is used for reading and writing data in any order. Data is stored and read many times to and from this type of memory.

  Random access memory is used in huge quantities in computer applications as current day computing and processing technology requires large amounts of memory. Many types of RAM including SDRAM with its DDR3, DDR4, and soon DDR5 variants are used in huge quantities.

- ***ROM - Read Only Memory:***

  A ROM is a form of semiconductor memory technology used where the data is written once and then cannot be changed. Hence the data is stored permanently, even when the power is removed.

  As a result, this type of semiconductor memory technology is widely used for storing programs and data that must survive when a computer or processor is powered down. For example the BIOS of a computer will be stored in ROM. As the name implies, **data cannot be easily written to**

ROM. Depending on the technology used in the ROM, writing the data into the ROM initially may require special hardware. Although it is often possible to change the data, this again requires special hardware to erase the data and for new data to be written in.

There is a large variety of types of ROM and RAM that are available. With technology moving forwards apace, not only are the established technologies moving forwards with SDRAM technology moving from DDR3 to DDR4 and then to DDR5, but Flash memory used in memory cards is also developing as are the other technologies.

SEMICONDUCTOR MEMORY TECHNOLOGIES:

The different memory types or memory technologies are detailed below:

➢ SRAM :

SRAM or Static Random Access Memory is a form of semiconductor memory widely used in electronics, microprocessor and general computing applications.
There are two key features to SRAM :

The data is held statically: This means that the data is held in the semiconductor memory without the need to be refreshed as long as the power is applied to the memory.

SRAM memory is a form of random access memory: A random access memory is one in which the locations in the semiconductor memory can be written to or read from in any order, regardless of the last memory location that was accessed.

SRAM memory cell operation:

The circuit for an individual SRAM memory cell comprises typically four transistors configured as two cross coupled inverters. In this format the circuit has two stable states, and these equate to the logical "0" and "1" states. In addition to the four transistors in the basic memory cell, an additional two transistors are required to control the access to the memory cell during the read and write operations. This makes a total of six transistors, making what is termed a 6T memory cell.

When the cell is selected, the value to be written is stored in the cross-coupled flip-flops. The cells are arranged in a matrix, with each cell individually addressable. Most SRAM memories select an entire row of cells at a time, and read out the contents of all the cells in the row along the column lines. Access to the SRAM memory cell is enabled by the Word Line. This controls the two access control transistors which control

whether the cell should be connected to the bit lines. These two lines are used to transfer data for both read and write operations

SRAM advantages and disadvantages:

SRAM is a little more expensive than DRAM. However SRAM is faster and consumes less power especially when idle. In addition to this, SRAM memory is easier to control than DRAM as the refresh cycles do not need to be taken into account, and in addition to this the way SRAM can be accessed is more exactly random access. A further advantage if SRAM is that it is more dense than DRAM.

As a result of these parameters, SRAM memory is used where speed or low power are considerations. Its higher density and less complicated structure also lend it to use in semiconductor memory scenarios where high capacity memory is used, as in the case of the working memory within computers.

➢ DRAM:

Dynamic RAM, or DRAM is a form of random access memory, RAM which is used in many processor systems to provide the working memory.
DRAM is widely used in digital electronics where low-cost and high-capacity memory is required.
As the name DRAM, or dynamic random access memory, implies, this form of memory technology is a type of random access memory. It stores each bit of data on a small capacitor within the memory cell. The capacitor can be either charged or discharged and this provides the two states, "1" or "0" for the cell.
Since the charge within the capacitor leaks, it is necessary to refresh each memory cell periodically. This refresh requirement gives rise to the term dynamic - static memories do not have a need to be refreshed.

DRAM advantages and disadvantages:

The advantage of a DRAM is the simplicity of the cell - it only requires a single transistor compared to around six in a typical static RAM, SRAM memory cell. In view of its simplicity, the costs of DRAM are much lower than those for SRAM, and they are able to provide much higher levels of memory density. However the DRAM has disadvantages as well, and as a result, most computers use both DRAM technology and SRAM, but in different areas.
In view of the fact that power is required for the DRAM to maintain its data, it is what is termed a volatile memory. Memory technologies such as Flash are non-volatile and retain data even when the power is removed.

Advantages of DRAM

- Very dense
- Low cost per bit
- Simple memory cell structure

Disadvantages of DRAM

- Complex manufacturing process
- Data requires refreshing
- More complex external circuitry required (read and refresh periodically)
- Volatile memory
- Relatively slow operational speed

➢ ***PROM:***

This stands for **Programmable Read Only Memory**. It is a semiconductor memory which can only have data written to it once - the data written to it is permanent. These memories are bought in a blank format and they are programmed using a special PROM programmer.

Typically a PROM will consist of an array of fuseable links some of which are "blown" during the programming process to provide the required data pattern.

➢ ***EPROM:***

This is an **Erasable Programmable Read Only Memory**. These semiconductor devices can be programmed and then erased at a later time. This is normally achieved by exposing the semiconductor device itself to ultraviolet light. To enable this to happen there is a circular window in the package of the EPROM to enable the light to reach the silicon of the device. When the PROM is in use, this window is normally covered by a label, especially when the data may need to be preserved for an extended period.

The PROM stores its data as a charge on a capacitor. There is a charge storage capacitor for each cell and this can be read repeatedly as required. However it is found that after many years the charge may leak away and the data may be lost.

Nevertheless, this type of semiconductor memory is used widely in applications where a form of ROM was required, but where the data needed to be changed periodically, as in a development environment, or where quantities were low.

➢ ***EEPROM:***

The initials EEPROM stand for **Electrically Erasable Programmable Read Only Memory.** ***EEPROM also written as E^2PROM*** is a type of non-volatile memory used to store relatively small amounts of data that can allow individual bytes to be erased & reprogrammed/ programmed electrically.
The advantage of an EEPROM memory, apart from the fact that the data stored is non-volatile, is that it is possible to read data from it and also erase it and write data to it. To erase the data, a relatively high voltage is required.

EEPROM memory uses the same basic principle that is used by EPROM memory technology. Although there are several different memory cell configurations that can be used,the basic principle that is behind each memory cell is the same.

Often the memory cell will comprise two field effect transistors. One of these is the storage transistor. This has what is termed a floating gate. Electrons can be made to become trapped in this gate, and the presence or absence of electrons then equates to the data stored there.

The other transistor generally in the memory cell is what is known as the access transistor and it is required for the operational aspects of the EEPROM memory cell.

➢ ***FLASH MEMORY:***

Flash memory is a non-volatile form of electronic data storage and as a result it is used in many areas where short and medium term data storage is needed.

Flash memory was first introduced in the 1980s and since then it has been used in many applications and products: USB memory sticks, Compact Flash cards, SD memory cards, computer non-volatile memory, solid state hard drives and more.

Flash memory storage is a form of non-volatile memory that was born out of a combination of the traditional EPROM and E2PROM. These two forms of memory are only seen occasionally these days and other forms of memory, including Flash have taken over.

In essence Flash memory uses the same method of programming as the standard EPROM and the erasure method of the E^2PROM.

One of the main advantages that flash memory has when compared to EPROM is its ability to be erased electrically.

However it is not possible to erase each cell in a flash memory individually unless a large amount of additional circuitry is added into the chip. This would add significantly to the cost and accordingly most manufacturers dropped this approach in favour of a system whereby the whole chip, or a large part of it is block or flash erased - hence the name.

Today most flash memory chips have selective erasure, allowing parts or sectors of the flash memory to be erased. However any erasure still means that a significant section of the chip has to be erased.

Flash memory advantages & disadvantages

As with any technology there are various advantages and disadvantages. It is necessary to consider all of these when determining the optimum type of memory to be used.

Flash Memory Advantages

- Non-volatile memory
- Easily portable (e.g. USB memory sticks, camera flash cards, etc)
- Mechanically robust

Flash Memory Disadvantages

- Higher cost per bit than hard drives
- Slower than other forms of memory
- Limited number of write / erase cycles
- Data must be erased before new data can be written
- Data typically erased and written in blocks

Flash memory types:

There are two basic types of Flash memory. Although they use the same basic technology, the way they are addressed for reading and writing is slightly different. They two flash memory types are:

- ***NAND Flash memory:*** NAND Flash memories have a different structure to NOR memories. This type of flash memory is accessed much like block devices such as hard disks. When NAND Flash memories are to be read, the contents must first be paged into memory-mapped RAM. This makes the presence of a memory management unit essential.

- ***NOR Flash memory:*** NOR Flash memory is able to read individual flash memory cells, and as such it behaves like a traditional ROM in this mode. For the erase and write functions, commands are written to the first page of the mapped memory, as defined in "common flash interface" created by Intel.

- ***NAND / NOR tradeoff :*** NAND Flash memories and NOR Flash memories can be used for different applications. However some systems will use a combination of both types of Flash memory. The NOR memory type is used as ROM and the NAND memory is partitioned with a file system and used as a random access storage area.