CHAPTER I

Digital Logic Devices

1.1-Introduction

Logic devices constitute one of the three important classes of devices used to build digital electronic systems, memory devices and microprocessors being the other two. Memory devices such as ROM and RAM are used to store information such as the software instructions of a program or the contents of a database, and microprocessors execute software instructions to perform a variety of functions, from running a word-processing program to carrying out far more complex tasks. Logic devices implement almost every other function that the system must perform, including device-to-device interfacing, data timing, control, display operations and so on. [12][13]

Digital logic devices can be classified as shown in figure 1.1:

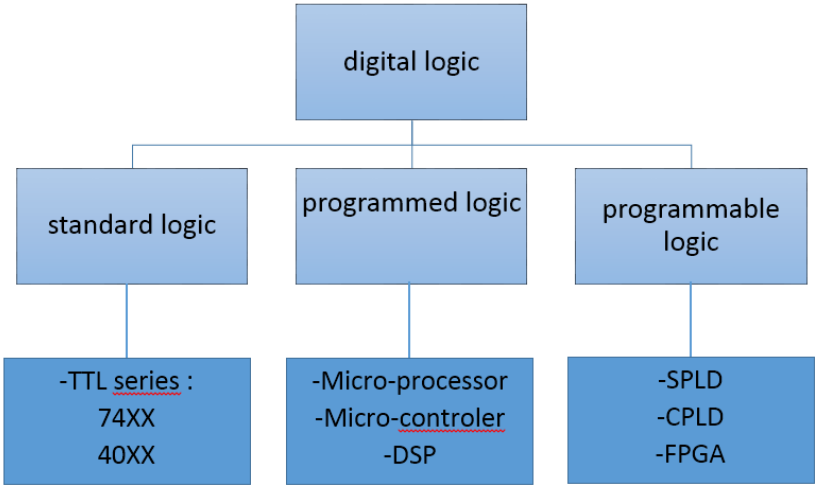

Figure 1.1: logic devices classification

1.2-Standard Logic Integrated Circuit

A collection of one or more gates fabricated on a single silicon chip is called "integrated circuit (IC)". [14]

Regarding the size and the number of gates integrated on the IC we distinguish several categories:

1) Small Scale Integration or SSI. They contain from 1 to 10 gates
2) Medium Scale Integration or MSI. They contain from 10 to 100 gates, they implement functional building blocks such as decoders, registers, counters…etc.
3) Large Scale Integration or LSI. They contain from 100 to 100,000 gates; these include small memories, processors…

Very Large Scale Integration or VLSI. These regroup all other ICs that have more than 200,000 gates. [14]

1.2.1-74XX-series

They are SSI integrated circuits that provide different types of logic. They are commonly provided in DIP (dual-inline package) as shown in figure1.2. [14]

In all the series' chips, two pins are used to connect to VCC and Gnd and the others provide connection to the internal gates as shown in figure 1.3.

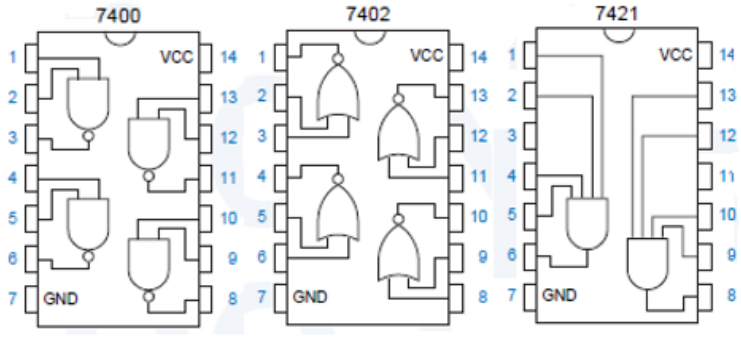

Figure.1.3: Pin diagram of some common ICs

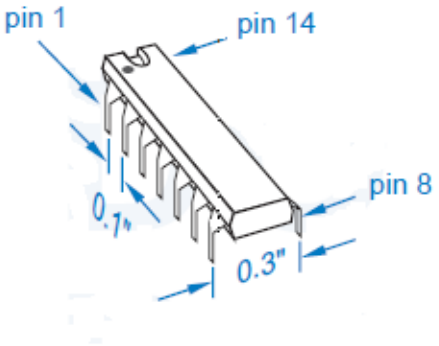

Figure 1.2: DIP package of a 14 pin IC

ICs are built using two different technologies namely Transistor-Transistor Logic or TTL; which are based on BJTs, and Complementary Metal Oxide Semi-conductor or CMOS built using Metal Oxide Semiconductors Field effect transistor (MOSFET).

For instance the 74LS00 is a TTL while the 74HC00 is a CMOS. Even if basically they perform the same logic function, the difference between the two technologies lies mostly in the cost, the amount of power consumed and the operating voltages. While TTL are cheaper with fixed operating voltage (VCC= +5, -5), CMOS consume much lower power and have a larger range of operating voltages. [15]

1.2.2-Implementing a logic circuit using 7000-series chip

As an example of how a logic circuit can be implemented using 7400-series chips, let's consider the function $f = x_1x_2 + x_3\overline{x_2}$.

A not gate is required to produce $\overline{x_2}$, as well as 2 two-Input AND gates and a two-input OR gate as shown in figure 1.4.

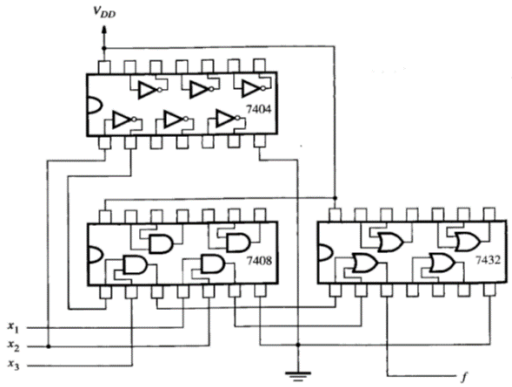

Figure1.4: implementation of $f = x_1x_2 + x_3\overline{x_2}$

1.2.3-ICs Applications

Although they are still sometimes used as "glue" to tie together larger scale elements in complex systems and work around bugs in larger-scale components or their interfaces, they have been largely supplanted by programmable logic devices.

In present days, the most popular remaining use of SSI especially in DIP packages, is in educational labs. Where students have the opportunity to dirty their hands while wiring up simple circuits. [16]

1.2.4-Problems related with standard ICs

Using standard ICs in logic design has proven a lot of inconveniences.

1) Requirement of hundreds of thousands of these ICs.
2) Considerable amount of circuit board space.
3) A great deal of time and cost in inserting, soldering, and testing.
4) Growth of node interconnection complexity, and increase in interferences due to large number of connections.

A simple solution for that are Programmable logic devices (PLDs).

1.3- programed logic

Programmed logic devices are devices that are programmed (hardwired) at the time of manufacture to execute a specific task. This is known as full custom ICs (all logic cells are customized).

As such devices we have Micro-processors, Micro-controllers and Digital Signal Processors or DSPs.

- A micro-controller is a small computer on a single IC containing a processor core, memory, and programmable input/output peripherals. It is specialized micro-processor used in automatically controlled products such as automobile engine control systems, remote controls, medical devices…etc. [21][22]

- A DSP is a specialized microprocessor with an architecture optimized for the operational needs of digital signal processing.
- A microprocessor is a single chip device that implements the function of a computer's central processing unit or CPU. A hardware that performs the basic arithmetical, logical, and input/output operations of a computer's system. It is composed of two main components, namely the arithmetic logic unit (ALU), which performs arithmetic and logical operations, and the control unit (CU), which extracts instructions from memory, decodes and executes them, calling on the ALU when necessary. [27]

1.4-programmable logic devices:

A programmable logic device (PLD) is an electronic component used to build reconfigurable digital circuits. Unlike standard logic, which has a fixed function, a PLD has an undefined function at the time of manufacture. Before the PLD can be used in a circuit it must be programmed, that is reconfigured. [16][15][14]

PLDs were introduced in the mid-1970s .The idea was to construct combinational logic circuits that were programmable. Contrary to microprocessors, which can run a program but possess a fixed hardware, the programmability of PLDs was intended at the hardware level .In other words, a PLD is a general purpose chip whose hardware can be reconfigured to meat particular specifications. [18]

1.4.1-PLD types

PLDs are divided regarding their complexity and architecture. Figure 1.5 shows the main divisions.

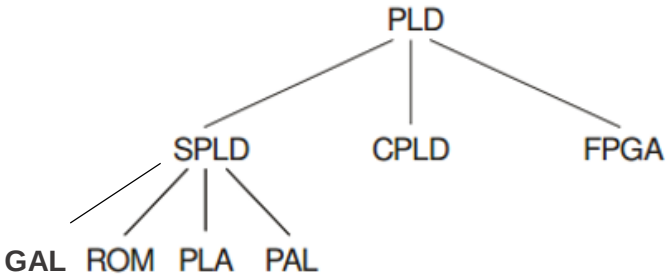

Figure 1.5: Types of PLDs

Programmable logic devices will be covered in details in the next chapters. In here a brief introduction to each type is given as follow.

- SPLD — refers to any type of Simple PLD, usually either a PLA or PAL
- CPLD — a more Complex PLD that consists of an arrangement of multiple SPLD-like blocks on a single chip.

- FPGA — a Field-Programmable Gate Array. It is a field programmable device featuring a general structure that allows very high logic capacity. Whereas CPLDs feature logic resources with a wide number of inputs (AND planes), FPGAs offer more narrow logic resources. FPGAs also offer a higher ratio of flip-flops to logic resources than do CPLDs. [18]

1.4.2-Fixed VS Programmable Logic

1. Building fixed logic devices to perform a specific task could easily take several months to a year whereas PLD-based design requires much less time from design cycle to production run.

2. In the case of fixed logic devices, the process of design validation followed by incorporation of changes, if any, involves substantial nonrecurring engineering (NRE) costs, which leads to an enhanced cost of the initial prototype device. In the case of PLDs, inexpensive software tools can be used for quick validation of designs. The programmable feature of these devices allows quick incorporation of changes and also a quick testing of the device in an actual application environment.

In this case, the device used for prototyping is the same as the one that would qualify for use in the end equipment.

3. In the case of programmable logic devices, users can change the circuit as often as they want to until the design operates to their satisfaction. PLDs offer to the users much more flexibility during the design cycle. Design iterations are nothing but changes to the programming file.

4. Fixed logic devices have an edge for large-volume applications as they can be mass produced more economically. They are also the preferred choice in applications requiring the highest performance level.

1.5-conclusion

There are two broad categories of logic devices, namely fixed logic devices and programmable logic devices. Whereas a fixed logic device such as a logic gate, a multiplexer or a flip-flop, performs a given logic function that is known at the time of device manufacture, a programmable logic device can be configured by the user to perform a large variety of logic functions. In terms of the internal schematic arrangement of the two types of devices, the circuits or building blocks and their interconnections in a fixed logic device are permanent and cannot be altered after the device is manufactured for PROM based PLD, while they can be modified any number of times by the user for EEPROM based PLDS..