

Chapter 2

Logic Gates and Introduction to Computer Architecture

2.1 Introduction

The basic components of an Integrated Circuit (IC) is logic gates which made of transistors, in digital system there are three basic logic operations and they are called AND, OR and NOT.

2.2 Logic Gates

AND Logic The AND Logic is represented by “.”. The most of the time, the period is left out. $X.Y$ or XY is pronounced as X AND Y .

$X \text{ AND } Y = Z$, $Z = 1$ if and only if $X = 1$ and $Y = 1$ otherwise $Z = 0$. The AND logic operation can be represented by electrical circuit of Fig. 2.1.

Assume X and Y are switches and Z is the light, $X=0$, $Y=0$ means switches are open and light off means zero and light on means one, then we can make a Table 2.1 shows the operation of Fig. 2.1.

Figure 2.2 shows 2-Input AND gate and Table 2.2 show Truth table for AND gate. The output of AND gate is one when both inputs are one.

OR Logic The OR operation is represented by a + or $\vee$, where + is the most popular symbol used. $X+Y$ is pronounced X OR Y .

$$X + Y = Z, \quad Z = 1 \text{ if } X = 1 \text{ OR } Y = 1 \text{ or both } X = 1 \text{ and } Y = 1.$$

This OR operation can be represented by the electrical circuit in Fig. 2.3. In Fig. 2.3, the light is off when both switches are off, and light is on when at least one switch is close. Figure 2.4 shows 2-Input OR gate and Table 2.3 shows truth table for 2-Input OR gate.

Fig. 2.1 Representation of AND operation

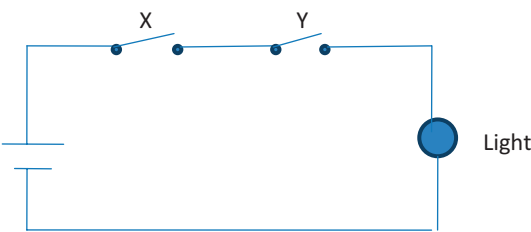


Table 2.1 Operation of Fig. 2.1

X	Y	Light
Off	Off	Off
Off	On	Off
On	Off	Off
On	On	On

Fig. 2.2 2-Input AND gate



Table 2.2 AND gate truth table

X	Y	Z
0	0	0
0	1	0
1	0	0
1	1	1

NOT Logic The NOT logic performs a complement, meaning it converts a 1 to 0 and 0 to 1. Also called an inverter, the NOT X is represented by X' or $\overline{X}$. Figure 2.5 shows NOT gate and Table 2.4 shows truth table for NOT gate (Inverter)

Fig. 2.3 Electrical circuit representation of OR operation

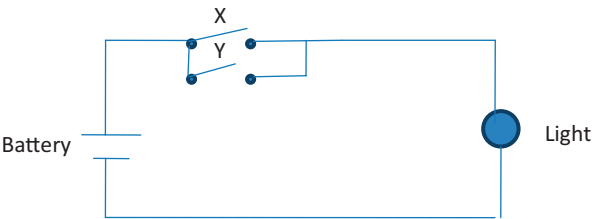


Fig. 2.4 2-Input OR gate



Table 2.3 Truth table of 2-Input OR gate

X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	1

Fig. 2.5 NOT gate

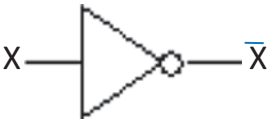


Table 2.4 Truth table for not gate

X	X'
0	1
1	0

NAND Gate Figure 2.6 shows 2-input NAND gate, The NAND gate can be made from an AND and a NOT gate as shown in Fig. 2.7, Table 2.5 shows truth table of 2-Input NAND gate

Fig. 2.6 2-Input NAND gate



Fig. 2.7 AND-NOT

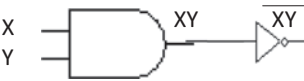


Table 2.5 Truth table of 2-Input NAND

X	Y	$\overline{XY}$
0	0	1
0	1	1
1	0	1
1	1	0

Fig. 2.8 NOR gate



Table 2.6 Truth table for 2-Input NOR gate

X	Y	$\overline{X+Y}$
0	0	1
0	1	0
1	0	0
1	1	0

NOR Gate Figure 2.8 shows a NOR logic gate. NOR gates are made of OR and NOT gates, Table 2.6 shows Truth table of 2-Input NOR gate.

Exclusive OR Gate Figure 2.9 shows an exclusive OR gate. Exclusive OR is represented by $\odot$ and labeled XOR and Table 2.7 shows truth table for XOR gate.

Exclusive NOR Gate Figure 2.10 shows an exclusive NOR gate. Exclusive NOR is represented by $\odot$ and labeled XNOR and Table 2.8 shows Truth Table for Exclusive NOR gate.

Fig. 2.9 2-Input XOR

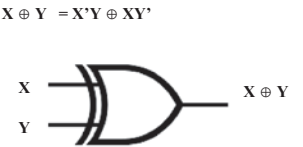


Table 2.7 Truth table for XOR gate

X	Y	$X \oplus Y$
0	0	0
0	1	1
1	0	1
1	1	0

Fig. 2.10 Exclusive NOR gate



Table 2.8 Truth table for exclusive NOR gate

X	Y	$X \odot Y$
0	0	1
0	1	0
1	0	0
1	1	1

2.3 Integrated Circuit (IC) Classification

A transistor is a basic component of Integrated Circuits (IC). The Fig. 2.11 shows a transistor with an IC. Transistors act like a switch in Integrated Circuits. An Integrated circuit is made from 100 to millions transistors.

Integrated circuit classified based on number of the gates such SSI, MSI, LSI and VLSI.

Small Scale Integration (SSI) SSI refers to an IC that has less than 10 gates.

Medium Scale Integration (MSI) Refers to an IC that contains between 10 and 100 gates such as Decoders and Multiplexers.

Fig. 2.11 Transistor (*left*),
IC (*right*)



Large Scale Integration (LSI) Refers to an IC that contains between 100 to 1000 gates.

Very Large Scale integration (VLSI) Refers to an IC that contains more than 1000 gates.

2.4 Registers

The registers are read/write memory that holds information inside the CPU. Each bit of a register is made of a D-flip flop as shown in Fig. 2.12 and Table 2.9 shows characteristic table for D-flip flop.

D Flip-Flop Operation As shown in Fig. 2.12, if the input of the flip flop is $D=0$ then by applying a clock pulse the output is set to zero. If $D=1$, applying a clock pulse sets the output to 1. The data will be stored in the flip-flop after applying a clock pulse. A register uses multiple D flip-flops that have a common clock pulse. Figure 2.13 shows 4 bit register.

If 32 D flip-flops use a common clock then it is called a 32-bit register.

Tri-State Device Figure 2.14 shows the diagram of tri-state device, the control line controls the operation of tri state device.

In Fig. 2.14 if control line set to zero there is no connection between input and output. If control line set to one the output value is equal to the input value.

2.5 Introduction to Computer Architecture

Just as the architecture of a building defines its overall design and functions, so computer architecture defines the design and functionality of a computer system. The components of a microcomputer are designed to interact with one another, and this interaction plays an important role in the overall system operation.

Fig. 2.12 D-Flip Flop

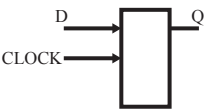


Table 2.9 Characteristic table of D-Flip Flop

CLOCK	D	Q
CK	0	0
CK	1	1

Fig. 2.13 4 bit register

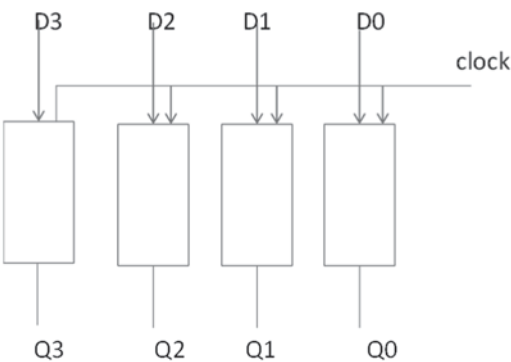
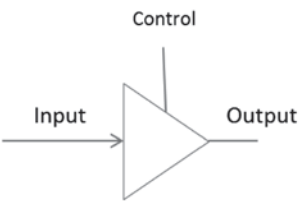


Fig. 2.14 Tri-State device



2.5.1 Components of a Microcomputer

A standard microcomputer consists of a microprocessor (CPU), buses, memory, parallel input/output, serial input/output, programmable I/O interrupt and direct memory access DMA. Figure 2.15 shows components of microcomputer.

Central Processing Unit (CPU) The central processing unit (CPU) is the “brain” of the computer and is responsible for accepting data from input devices, processing the data into information, and transferring the information to memory and output devices. The CPU is organized into the following three major sections:

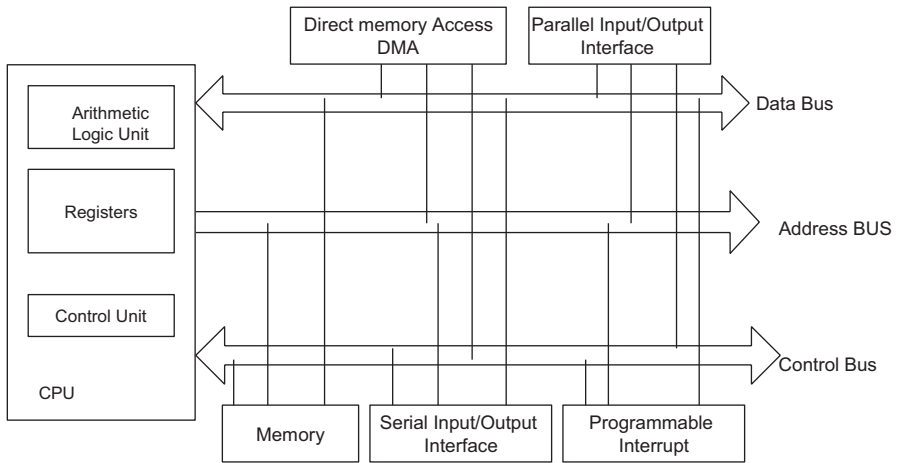


Fig. 2.15 Components of a microcomputer

1. Arithmetic Logic Unit (ALU)
2. Control Unit
3. Registers

Arithmetic Logic Unit (ALU): The function of the **Arithmetic Logic Unit (ALU)** is to perform arithmetic operations such as addition, subtraction, division and multiplication, and logic operations such as AND, OR and NOT. Figure 2.16 shows block diagram of ALU

Control Unit The function of the **control unit** is to control input/output devices, generate control signals to the other components of the computer such as read and write signals, and perform instruction execution. Information is moved from memory to the registers; the registers then pass the information to the ALU for logic and arithmetic operations.

It should be noted that the function of the microprocessor and CPU are the same. If the control unit, registers and the ALU are packaged into one integrated circuit (IC), then the unit is called a microprocessor, otherwise the unit is called a CPU. The difference in packaging is shown in Fig. 2.17.

There are two types of technology used to design a CPU: Reduced Instruction Set Computer (RISC) and Complex Instruction Set Computer (CISC).

CISC Architecture In 1978, Intel developed the 8086 microprocessor chip. The 8086 was designed to process a 16-bit data word; it had no instruction for floating point operations. At the present time, the Pentium processes 32-bit and 64-bit words and it can process floating-point instructions. Intel designed the Pentium processor in such a way that it can execute programs written for earlier 80×86 processors.

Fig. 2.16 Block diagram of ALU

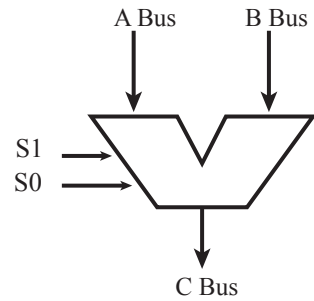
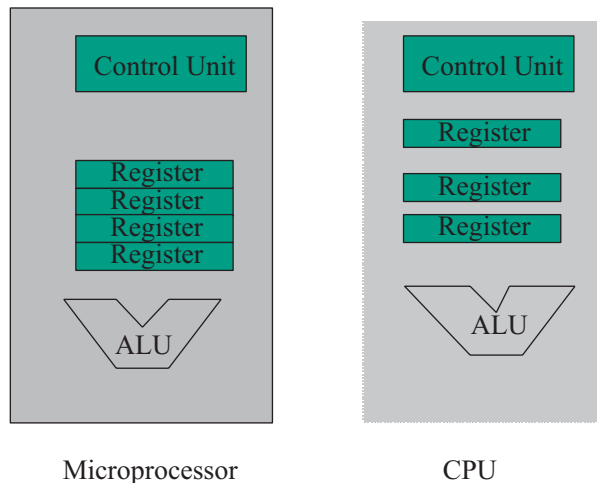


Fig. 2.17 Block diagram of microprocessor and CPU



The characteristics of 80×86 are called Complex Instruction Set Computers (CISC), which include instructions for earlier Intel processors. Another CISC processor is VAX 11/780, which can execute programs for the PDP-11 computer. The CISC processor contains many instructions with different addressing modes, for example: the VAX 11/780 has more than 300 instructions with 16 different address modes.

The major characteristics of CISC processor are:

1. A large number of instructions
2. Many addressing modes
3. Variable length of instructions
4. Most instruction can manipulate operands in the memory
5. Control unit is microprogrammed

RISC Architecture Until the mid-1990s, computer manufacturers were designing complex CPUs with large sets of instructions. At that time, a number of computer manufacturers decided to design CPUs capable of executing only a very limited set of instructions.

One advantage of reduced-instruction set computer is that they can execute their instructions very fast because the instructions are simple. In addition, the RISC chip requires fewer transistors than the CISC chip. Some of the RISC processors are the PowerPC, MIPS processor, IBM RISC System/6000, ARM and SPARC.

The major characteristics of RISC processors are:

1. All instructions are the same length (they can be easily decoded)
2. Most instructions are executed in one machine clock cycle
3. Control unit is hardwired
4. Few address modes
5. A large number of registers

Computer Bus When more than one wire carries the same type of information, it is called a bus. The most common buses inside a microcomputer are the address bus, the data bus, and the control bus.

Address Bus The address bus defines the number of addressable locations in a memory IC by using the 2^n formula, where n represents the number of address lines. If the address bus is made up of three lines then there are $2^3 = 8$ addressable memory locations, as shown in Fig. 2.18. The size of the address bus directly determines the maximum numbers of memory locations that can be accessed by the CPU.

Data Bus The data bus is used to carry data to and from the memory and represents the size of each location in memory. In Fig. 2.14 each location can hold only four bits. If a memory IC has eight data lines, then each location can hold eight bits. The size of a memory IC is represented by $2^n \times m$ where n is the number of address lines and m is the size of each location. In Fig. 3.3, where $n=3$ and $m=4$, the size of the memory is:

$$2^3 * 4 = 32 \text{ bits}$$

Control Bus The control bus carries control signals from the control unit to the computer components in order to control the operation of each component. In addition, the control unit receives control signals from computer components. Some of the control signals are as follows:

Read signal The read signal is used to read information from memory or input/output (I/O) devices.

Write signal The write line is used to write data into the memory.

Interrupt Indicates an interrupt request.

Bus request The device is requesting to use the computer bus.

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