Combinational Logic circuits

6.1 Objectives:

- To describe the difference between combinational and sequential logic circuits.
- To describe the operation and the construction of Binary Adders.

6.2 Background Information :

Digital logic circuits can be classifies into two main types : combinational and sequential. A combinational circuit is a logic circuit made up of combinations of logic gates in which application of inputs generates the output at any time (see Figure 6.1)

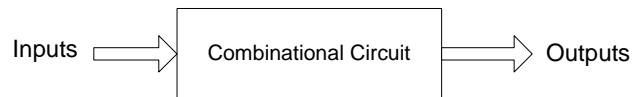Inputs ⟹ | Combinational Circuit | ⟹ Outputs

Figure 6.1 Block Diagram of Combinational circuit

Some examples of typical combinational circuits are binary adders, subtractors, comparators, decoders, encoders, multiplexers, demultiplexers. All these digital components will be discussed practically starting from this section.

A sequential circuit, on the other hard, is made up using combinational circuit and memory elements called "flip-flops". The outputs of the sequential circuits depends not only on the inputs but also on the output of the memory elements (see Figure 6.2)
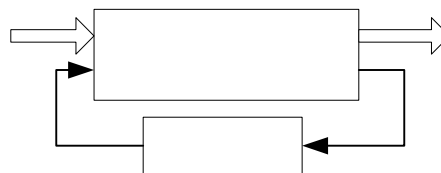
Some examples of sequential circuits are counters and shift registers.

Binary Adders & Subtractors

The binary adder & subtractor is a combinational circuit that can perform the operations of addition and subtraction with the binary numbers. In this experiment, we will study and construct the various adder and subtractors circuits.

a) Half-Adder (HA) circuit

The combinational circuit that adds only two bits is called "half-adder". Figure 6.3 shows a block diagram of the half-adder.

Since there are two inputs (x and y), only four possible combinations of inputs can applied . These four possibilities, and the resulting sums are shown in following truth table.

Inputs

Combina

x	y	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Truth6.1 Table of the Half-Adder

From the above truth table, we observe that :

$$S = x \oplus y = x'y + xy'$$
$$C = xy$$

Now, from these Boolean functions we can construct the logic circuit of the Half-Adder as shown in Figure 6.4.
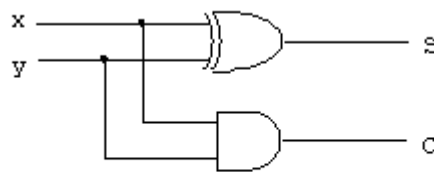

Figure6.4 Logic Diagram of the Half-Adder

b) Full-Adder (FA) circuit

To add numbers with more than one bit, we must provide a way for carries between bit positions. This basic circuit for this operation is called a full adder. Full adder is a combinational circuit that adds three bits and generates a sum and carry . Figure 6.5 shows a block diagram of the full-adder

The truth table for the full-adder circuit is as follows :

x	y	z(C_{in})	C_{out}	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

Table 6.2 Truth Table of the Full-Adder

From the truth table, we can obtain the Boolean expression of C_{out} & S outputs as follows :

$$S = x'y'z + x'yz' + xy'z' + xyz$$
$$C = x'yz + xy'z + xyz' + xyz$$

Using Map-simplification method, we can get the simplified forms as follows :

$$S = x \oplus y \oplus z$$
$$C = xy + yz + xz$$

Now, we can construct the full-adder circuit based on the simplified Boolean expression of S and C outputs . Figure 6.6 shows the logic diagram of the full-adder.
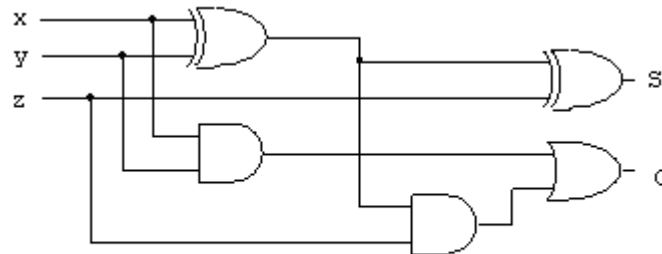

Figure6.6 Logic Diagram for the Full-Adder

c) Ripple Adder

Two binary numbers, each of n bits, can be added using a ripple adder, a cascade of n full adders; each full adder handles one bit. Each C_{out} of a full adder is connected to the C_{in} of the higher full adder. The C_{in} of the least significant full adder is set to 0.

d) Adder-Subtractor circuit

The subtraction of two binary numbers can be done by taking the 2's complement of the subtrahend and adding it to the minued. The 2's complement can be obtained by taking the 1's complement and adding 1. To perform A - B, we complement the four bits of B, add them to the four bits of A, and add 1 to the input carry.

We may use XOR gate as an inverter if placing a logic "1" at one of the inputs. This helps in getting the 1's complement of the subtrahend; then we add "1" to get the 2's complement; which in turn is added to the minued to get the final result of the subtraction.

Figure 6.7 shows adder-subtractor circuit; the mode input M controls the operation; when M=0, the circuit is an adder. When M=1, the circuit becomes a subtractor. This circuit can be cascaded for any number of inputs.
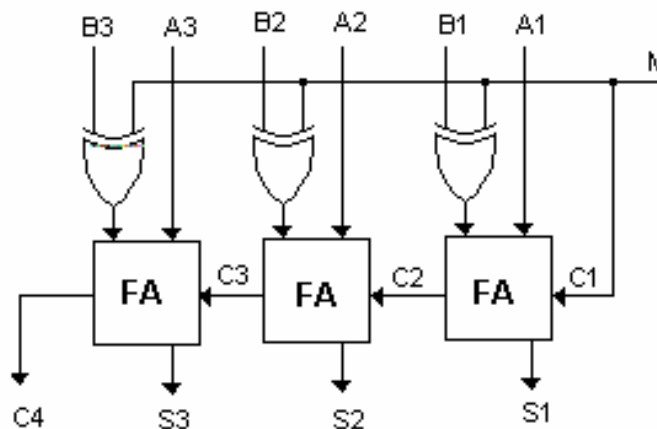

Figure 6.7 Logic Diagram of 3-bit Adder-Subtractor Circuit

Note: During subtraction, when A $\geq$ B, the subtraction operation gives the correct answer; and the output carry is equal to 1. But, when A < B, the subtraction gives the 2's complement of B-A and the output carry is equal to 0. This is because when A < B, the result will be negative with absolute value of $|B-A|$, so it is represented as negative with 2's complement.

6.3 Equipments Required :

Universal Breadboard
Jumper wire kit
1x 7408 QUAD 2-INPUT AND
1x 7432 QUAD 2-INPUT OR
1x 7486 QUAD 2-INPUT XOR
1x 74283 4-BIT FULL ADDER
9X Toggle switches
5x Carbon-film Resistors (470Ω)
5x LEDs

6.4 Procedure :

Step 1 :

1. Construct the logic circuit of full adder that shown in Figure 6.6.
2. Apply all possible combinations of inputs, and fill in the following truth table

x	y	z	C_{out}	S
0	0	0		
0	0	1		
0	1	0		
0	1	1		
1	0	0		
1	0	1		
1	1	0		
1	1	1		

3. Compare your practical results with Table4.2.

Step 2 :

1. Construct a 4-bit Adder-Subtractor circuit.
2. Complete the following table :

	M=0 (Addition)			M=1 (Subtraction)		
$A_3A_2A_1A_0$	1010	1011	0110	1010	1011	0110
$B_3B_2B_1B_0$	0110	1110	0110	0110	1110	0110
$C_OS_3S_2S_1S_0$						

Questions:

1) Prove the logic expressions for the S and the C for the full-adder.

2) Draw a block diagram for a 4-bit binary adder using four full-adders.

3) Draw a block diagram for a 4-bit binary decrementer using four half-adders.

4) Give a summary of the points that you learned from this experiment.