Digital Adders

➢ Objectives:

The objective for this lab is to understand the design of a **half adder** and a **full adder** using logic gates.

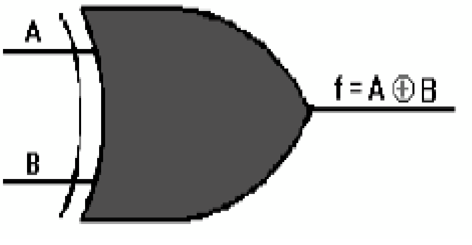
➢ Equipment & Components:

1. Breadboard (You should check out)
2. DC Power Supply
3. 74LS08 (AND)
4. 74LS32 (OR)
5. 74LS86 (XOR)
6. 220Ω Resistors
7. LED
8. 1kΩ Resistors
9. DIP Switch

➢ Introduction:

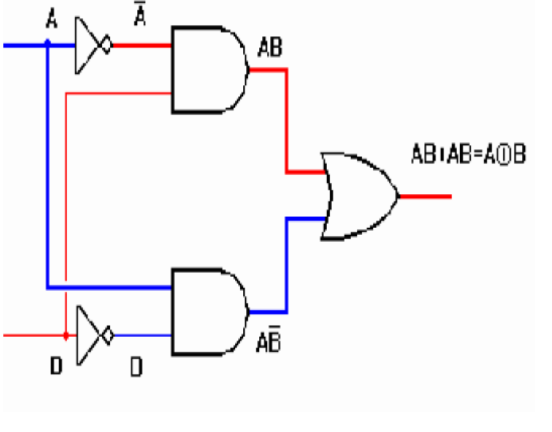
In electronics, an adder or summer is a digital circuit that performs addition of numbers. In many computers and other kinds of processors, adders are used not only in the arithmetic logic unit(s), but also in other parts of the processor, where they are used to calculate addresses, table indices, and similar. The adder is a major component of an Arithmetic Logic Unit (ALU) of a CPU.

Exclusive –OR Gates The exclusive-OR gate can be used to implement such logical operations as parity checking, binary-to-Gray number conversion, Gray-to-binary number conversion, binary-number addition and numerous others. The truth table and logical symbol for the exclusive-OR gate are shown in next figure. As can be seen from the truth table 1, the output (f) is 1 when either A or B is 1, but not both. This special feature of the exclusive –OR function is ⊕.



A	B	f
0	0	0
0	1	1
1	0	1
1	1	0

The most direct way to implement the exclusive-OR function is to connect two inverters, two AND gates, and an OR gate, as shown in next figure. The output of the bottom AND gate is AB′, and the top AND- gate output is A′B. Since there are the OR-gate inputs, the output x is clearly.

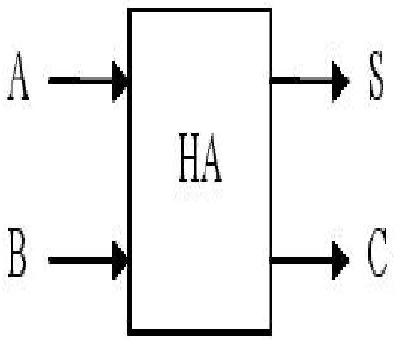


A comparison of this expression with the truth table in previous table will confirm that this expression is indeed the exclusive-OR function. Thus, we can write $X = A \oplus B = A'B + AB'$. As might be expected, the exclusive –OR function is available in an integrated circuit. For example, the 74LS86 is a small scale integrated circuit (SSI) which provides four-2-input exclusive –OR gates in one 14-pin package.

Binary Addition An interesting application for the exclusive-OR function is the binary addition. Digital arithmetic is one of the most fundamental operations to be performed by digital logic circuits.

➢ Half Adder

Half Adder is a combinational circuit that performs the addition of two bits; this circuit needs two binary inputs and two binary outputs. The block diagram of a half adder is shown below.



Inputs		Outputs	
X	Y	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

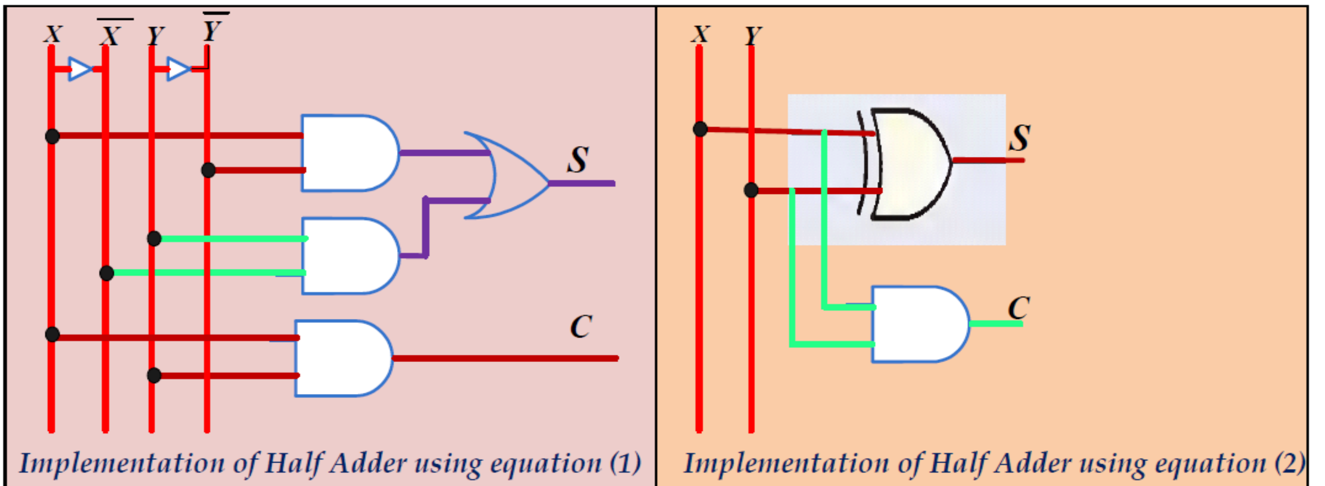
Truth table

The simplified Boolean function from the truth table:

$$\begin{cases} S = \bar{X}Y + X\bar{Y} \\ C = XY \end{cases} \quad 1\} \text{ (Using sum of product form)}$$

Where S is the sum and C is the carry.

$$\begin{cases} S = X \oplus Y \\ C = XY \end{cases} \quad 2\} \text{ (Using XOR and AND Gates)}$$



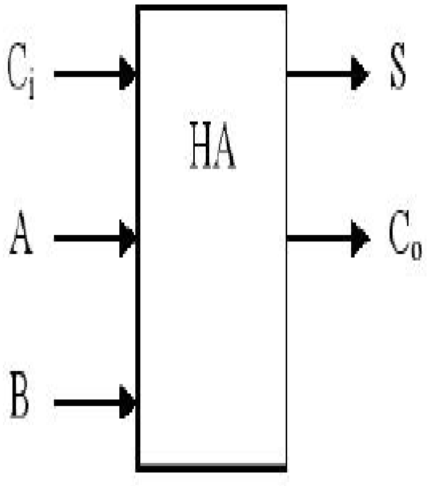
Implementation of Half Adder using equation (1) *Implementation of Half Adder using equation (2)*

➢ The implementation of half adder using ***exclusive–OR*** and an ***AND*** gates is used to show that two half adders can be used to construct a full adder.

➢ The inputs to the ***XOR*** gate are also the inputs to the ***AND*** gate.

➢ Full Adder

Full Adder is a combinational circuit that performs the addition of three bits (two significant bits and previous carry). It consists of three inputs and two outputs, two inputs are the bits to be added, the third input represents the carry form the previous position. The block diagram of a full adder is shown below.



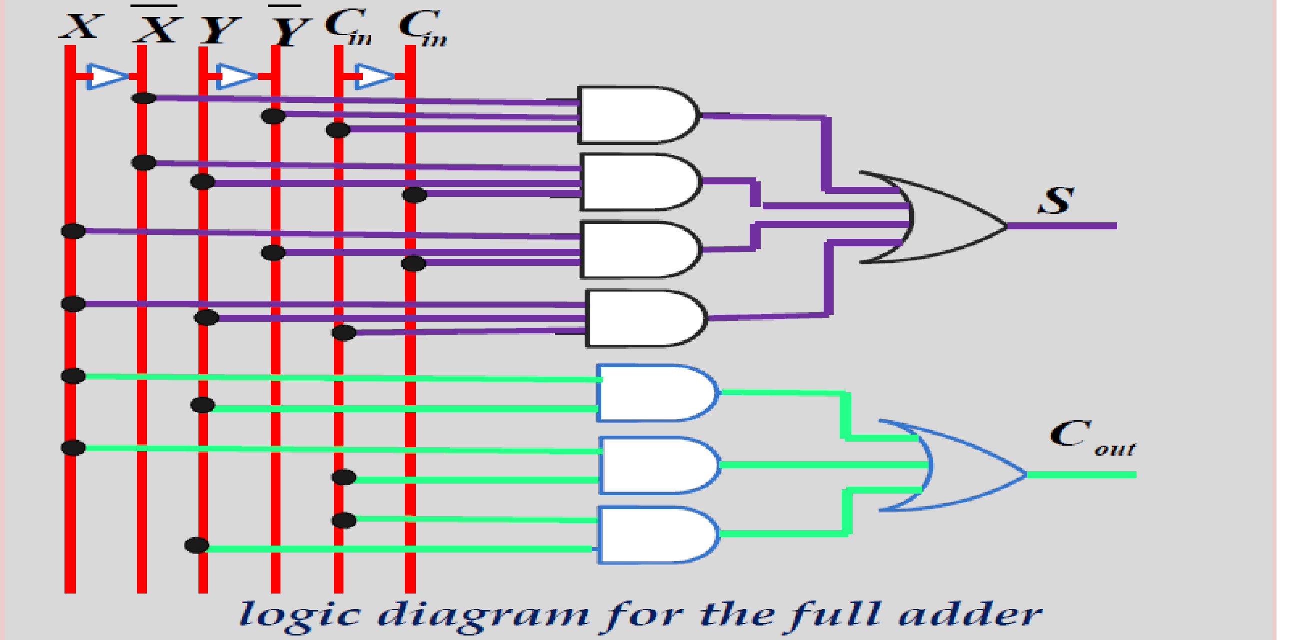
Inputs			Outputs	
X	Y	C_{in}	S	C_{out}
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Truth table for the full adder

The output S is equal to 1 when only one input is equal to 1 or when all three inputs are equal to 1. The output C_{out} has a carry 1 if two or three inputs are equal to 1.

$$\left\{\begin{array}{l} S = \overline{X}\,\overline{Y}C_{in} + \overline{X}Y\overline{C_{in}} + X\overline{Y}\,\overline{C_{in}} + XYC_{in} \\ C_{out} = XY + XC_{in} + YC_{in} \end{array}\right. \qquad 1\Big\}\ \textit{(Sum of products)}$$

The logic diagrams for the full adder implemented in sum-of-products form are the following:



logic diagram for the full adder

It can also be implemented using two half adders and one OR gate (using XOR gates).

$$\begin{Bmatrix} S = C_{in} \oplus (X \oplus Y) \\ C_{out} = C_{in} \cdot (X \oplus Y) + XY \end{Bmatrix}$$

Proof:

The sum:

$$\mathbf{S} = \overline{X}\,\overline{Y}C_{in} + \overline{X}Y\overline{C_{in}} + X\overline{Y}\,\overline{C_{in}} + XYC_{in}$$

$$= \overline{C_{in}}(\overline{X}Y + X\overline{Y}) + C_{in}(\overline{X}\,\overline{Y} + XY)$$

$$= \overline{C_{in}}(\overline{X}Y + X\overline{Y}) + C_{in}\overline{(\overline{X}Y + X\overline{Y})}$$

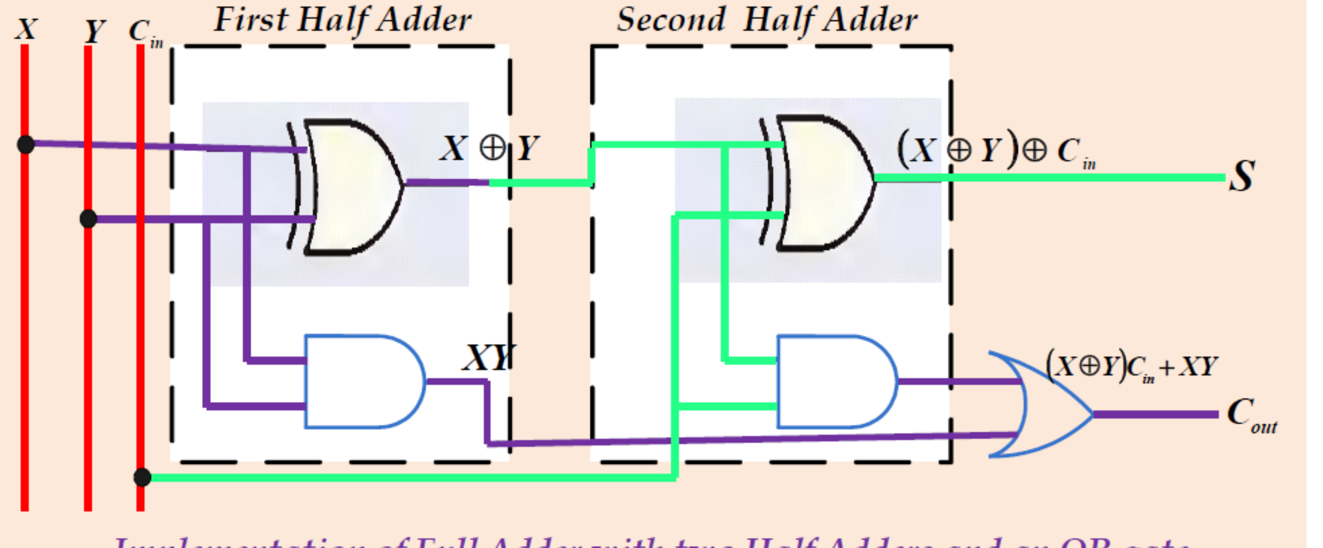
$$S = C_{in} \oplus (X \oplus Y)$$

The carry output:

$$C_{out} = \overline{X}YC_{in} + X\overline{Y}C_{in} + XYC_{in} + XY\overline{C_{in}}$$

$$= C_{in}(\overline{X}Y + X\overline{Y}) + XY(C_{in} + \overline{C_{in}})$$

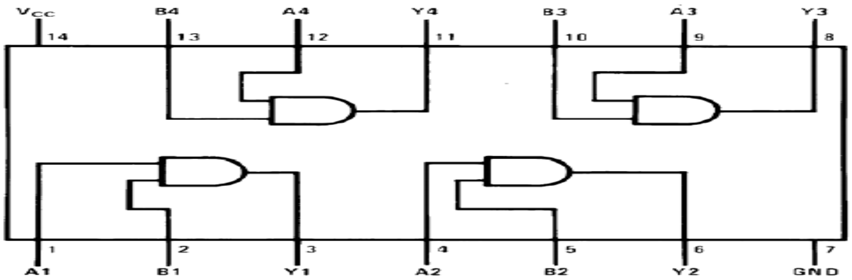
$$C_{out} = C_{in} \cdot (X \oplus Y) + XY$$



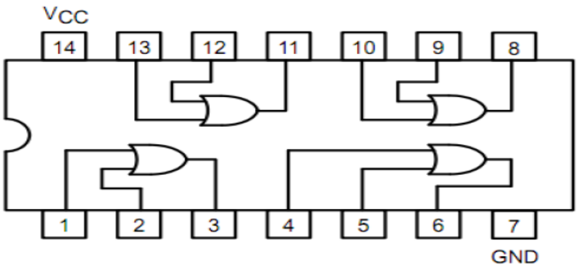
Implementation of Full Adder with two Half Adders and an OR gate

➢ The full adder is usually a component in a cascade of adders, which add 8, 16, etc, binary numbers.

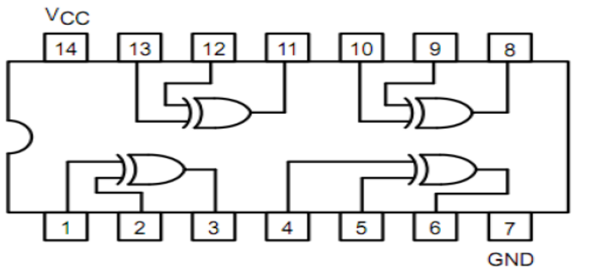
➢ Pin Connection Diagram



74LS08 Quad-two input AND TTL IC



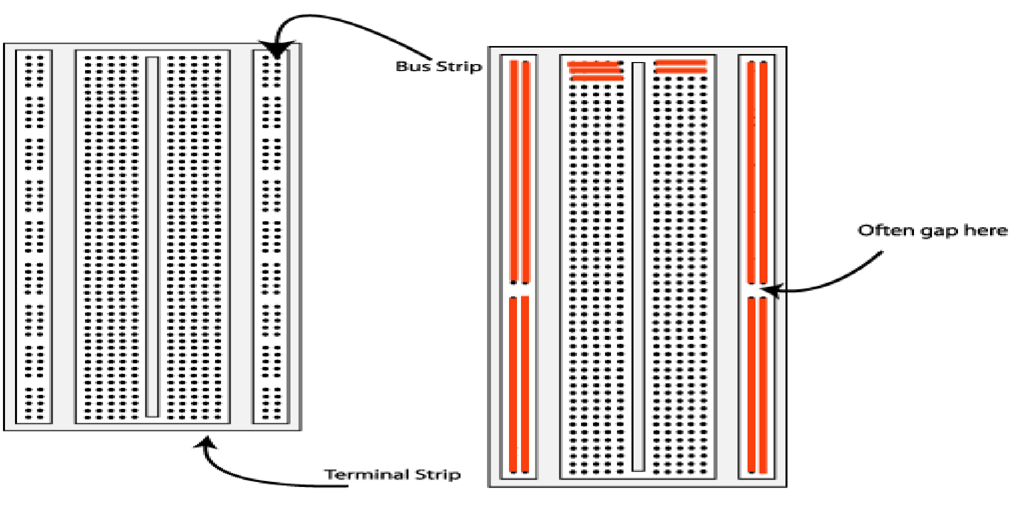
74LS32 Quad-two input OR TTL IC



74LS86 exclusive OR (EX-OR) TTL IC

➢ Introduction to BreadBoard

The breadboard consists of two terminal strips and two bus strips (often broken in the centre). Each bus strip has two rows of contacts. Each of the two rows of contacts is a node. That is, each contact along a row on a bus strip is connected together (inside the breadboard). Bus strips are used primarily for power supply connections, but are also used for any node requiring a large number of connections. Each terminal strip has 60 rows and 5 columns of contacts on each side of the centre gap. Each row of 5 contacts is a node.



The breadboard: The orange lines indicate connected holes.

The 5V supply must not be exceeded since this will damage the ICs (Integrated circuits) used during the experiments. Incorrect connection of power to the ICs could result in them exploding or becoming very hot - with the possible serious injury occurring to the people working on the experiment. Ensure that the power supply polarity and all components and connections are correct before switching on power.

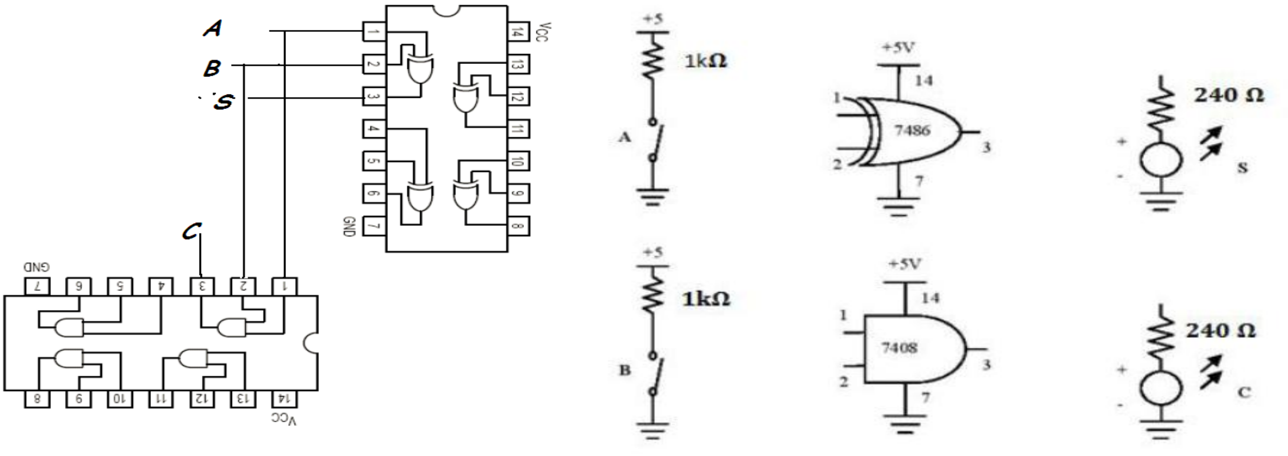
➢ Building the Circuit

The steps for wiring a circuit should be completed in the order described below:

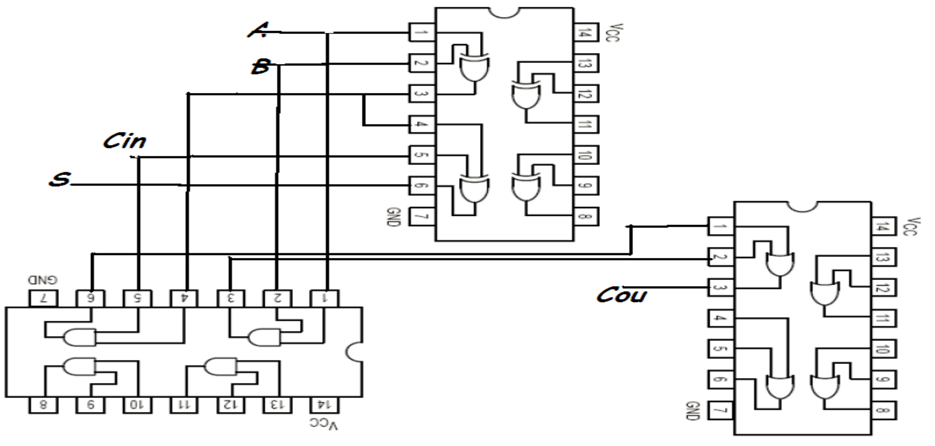
1) Make sure the power is off before anything build
2) Connect the +5V and ground (GND) leads of the power supply to the power and ground bus strips on breadboard. Before connecting up, use a voltmeter to check that the voltage does not exceed 5V.
3) Plug the chips using for making circuit into the breadboard. Point all the chips in the same direction with pin 1 at the upper-left corner. (Pin 1 is often identified by a dot or a notch next to it on the chip package)
4) Connect +5V and GND pins of each chip to the power and ground bus strips on the breadboard.
5) Select a connection on schematic and place a piece of hook-up wire between corresponding pins of the chips on breadboard. It is better to make the short connections before the longer ones.
6) If an error is made and is not spotted before power on. Turn the power off immediately before you begin to rewire the circuit.
7) At the end of the laboratory session, collect hook-up wires, chips and all equipment and return them to the demonstrator.
8) Tidy the area that you were working in and leave it in the same condition as it was before you started

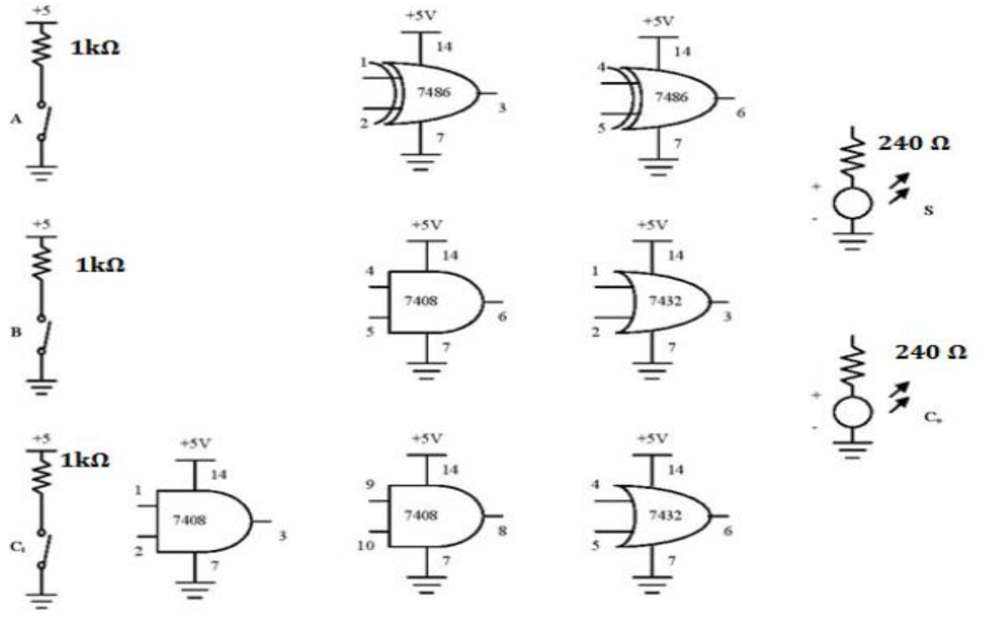
➢ Pin Diagram:

- Half Adder:



- **Full adder:**





➢ Procedure:

1. Collect the components necessary to accomplish this experiment.
2. Plug the IC chip into the breadboard.
3. Connect the supply voltage and ground lines to the chips. PIN7 = Ground and PIN14 = +5V.
4. According to the pin diagram of each IC mentioned above, make the connections according to circuit diagram.
5. Connect the inputs of the gate to the input switches of the LED.
6. Connect the output of the gate to the output LEDs.
7. Once all connections have been done, turn on the power switch of the breadboard
8. Operate the switches and fill in the truth table (Write "1" if LED is ON and "0" if LED is OFF. Apply the various combinations of inputs according to the truth table and observe the condition of Output LEDs.

➢ Observation Table:

Half Adder Input Variable: A , B - Output Variable: S, C
LED ON: Logic 1
LED OFF: Logic 0

INPUTS(SWITCH)		OUTPUT(LEDS)	
A	**B**	**S**	**C**

Full adder: Input Variable: A ,B, C_{in} - Output Variable: SUM(S), Carry(C_{out})
LED ON: Logic 1
LED OFF: Logic 0

INPUT(SWITCH)			OUTPUT(LED)	
A	**B**	**Ci**	**Sum S**	**Carry Co**

➢ Lab Tutorials:

1. Half Adder adds:
   a) 2 bits
   b) 1 bit
   c) 3 bit
   d) 4 Bit

2. Full Adder adds:
   a) 1 Bit
   b) 2 Bits
   c) Three Bits
   d) None of above

3. The expression for sum of A, B in the half adder is given by:
   a) AB
   b) $A \oplus B$
   c) A+ B
   d) none of these

4. Which expression for the sum of full adder circuit.:
   a) AB
   b) A+B
   c) $A \oplus B \oplus Ci$
   d) none of these

5. The expression for carry of A, B in the half adder is given by:

a) AB
b) A + B
c) $A \oplus B$
d) none of these

6. Which expression for the Carry of full adder circuit.

a) AB
b) A+B
c) $AB+Ci(A \oplus B)$
d) none of these

7. The sum of 111010_2 and 11011_2 in decimal form will be

a) 65
b) 75
c) 85
d) 95

8. The digit 0 with carry of 1 is the sum of binary addition:

a) 1 + 1
b) 1 + 0
c) 0 + 1
d) 0 + 0

9. Full adder requires:

a) Two Half adders
b) One Half Adder
c) Three half adder
d) None of the above