**Experiment 2**  Exclusive -OR-GATE, HALF ADDER, FULL ADDER

**Objective**
- To investigate the logical properties of the exclusive-OR function.
- To implement a number of different logic functions by means of exclusive-OR gates and to investigate their logical properties.

**References**
- Donald P. Leach: Experimental in Digital Principles, 3rd Edition
- Malvino/Leach: Digital Principles and Applications

**Components**
1-74LS04 hex-inverter (NOT) TTL IC
1-74LS08 Quad-two input AND TTL IC
1-74LS32 Quad-two input OR TTL IC
1-74LS86 exclusive OR (EX-OR) TTL IC
1-DC Voltmeter
1- +5V Power supply

**Introduction**

The Exclusive OR function is an interesting and useful logical operation. As the name implies, it is similar to the previously studied OR function, but it is a new and distinct operation. 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.

**Exclusive OR function**

The truth table and logical symbol for the exclusive-OR gate are shown in Fig 2-1. As can be seen from the truth table, the output (x) is 1 when either A or B is 1, but not both. This special feature of the exclusive -OR function is $\oplus$, and the logic expression for the gate is in fig 2-1.
Exclusive –OR Gates

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 fig 2-2. 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.

\[
X = A \oplus B = A'B + AB'
\]

A comparison of this expression with the truth table in table 1 will confirm that this expression is indeed the exclusive-OR function. Thus, we can write

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. Three basic digital circuits are used to perform arithmetic functions: The exclusive-OR gate (a.k.a. as a quarter-adder), the Half-Adder (H.A) and the Full-Adder (F.A).

**Half-Adder**

A Half-Adder is a logic circuit having 2 inputs (A and B) and 2 outputs (Sum and Carry) which will perform according to table 1. The half adder circuit is shown in fig 2-3b.

![Half-Adder Circuit Diagram](image)

### Table 2: Addition of 2 Binary digits

<table>
<thead>
<tr>
<th>A+B</th>
<th>Carry</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>0+0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0+1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1+0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1+1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
**Full-Adder**

A full-adder is a logic circuit having 3 inputs A, B and C (which is the carry from the previous stage) and 2 outputs (Sum and Carry), which will perform according to table 3. The full-adder can handle three binary digits at a time and can therefore be used to add binary numbers in general.

The simplest way to construct a full adder is to connect two half-adder and an OR gate as shown in Fig 2.4. The full-adder is then the fundamental logic circuit incorporated in digital computers to perform arithmetic functions.

**Table 3**

<table>
<thead>
<tr>
<th>input</th>
<th>output</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
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<tr>
<td>0</td>
<td>0</td>
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</table>
Procedure

1) Connect the circuit in fig 2-1. Using 0 = 0 V dc and 1 = +5V dc, verify that the circuit will perform the exclusive-OR function by completing the truth table.

2) Connect the circuit in fig 2-2. Using 0 = 0 V dc and 1 = +5V dc, verify that the circuit will perform the exclusive-OR function by completing the truth table.

3) Connect the half-adder circuit in fig 2-3b. Using 0 = 0 V dc and 1 = +5V dc, construct a truth table for this circuit by applying the inputs A and B as shown in table 3 and record the resulting sum and carry output measured.

4) Use the exclusive-OR gates to construct the full-adder in Fig 2-4a. Construct its truth table using the same procedure as in step1. For each input, record the sum and carry output of each half-adder as well as the OR-gate output.

Pin Connection Diagram

![Pin Connection Diagram](image-url)
74LS32 Quad-two input OR TTL IC

74LS86 exclusive OR (EX-OR) TTL IC