NAMAL UNIVERSITY, MIANWALI

Department of Electrical Engineering

EEN-214L- Electronic Devices & Circuits (Lab)

Project Report

"XOR gate using BJTs"

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Title project:

"XOR gate using BJT"

Abstract:

The output of a BJT-based XOR gate depends on the state of inputs (A) and (B). The XOR logic dictates that output (Y) will be high (1) if only one input is high, while it will be low (0) if both inputs are equal e.g., when (A = 0) and (B =0) is the value. 0) then no current flows through the circuit, resulting in (Y = 0). Similarly, if (A = 1) and (B = 1), the circuit is designed to connect the transistors in such a way that the output is disconnected, leaving (Y = 0). But if (A = 1) and (B = 0), or (A = 0) and (B = 1), a transistor drives a high output, (Y = 1). This switching behavior is validated by the careful configuration and biasing of the BJTs to the XOR logic truth table

Background:

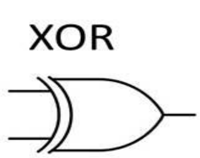
An XOR (exclusive OR) table, the fundamental logic table, produces the higher sign (1) only when its two entries are different. When BJTs are used, the XOR table uses the switching properties of the transistors to achieve this understanding. By combining multiple BJTs with resistors and biasing mechanisms, the circuit ensures a desired output depending on the input condition. This application highlights how analog devices such as BJTs can perform digital logic functions, which is a foundational model in transistor-level circuit design.

Introduction:

This work demonstrates the implementation of an XOR logic gate using bipolar junction transistors (BJTs). The circuit uses several BJTs, resistors, and diodes to achieve XOR efficiency, with the output being high (argument 1) only when the two inputs are different the operation of the circuit can be summarized as follows.

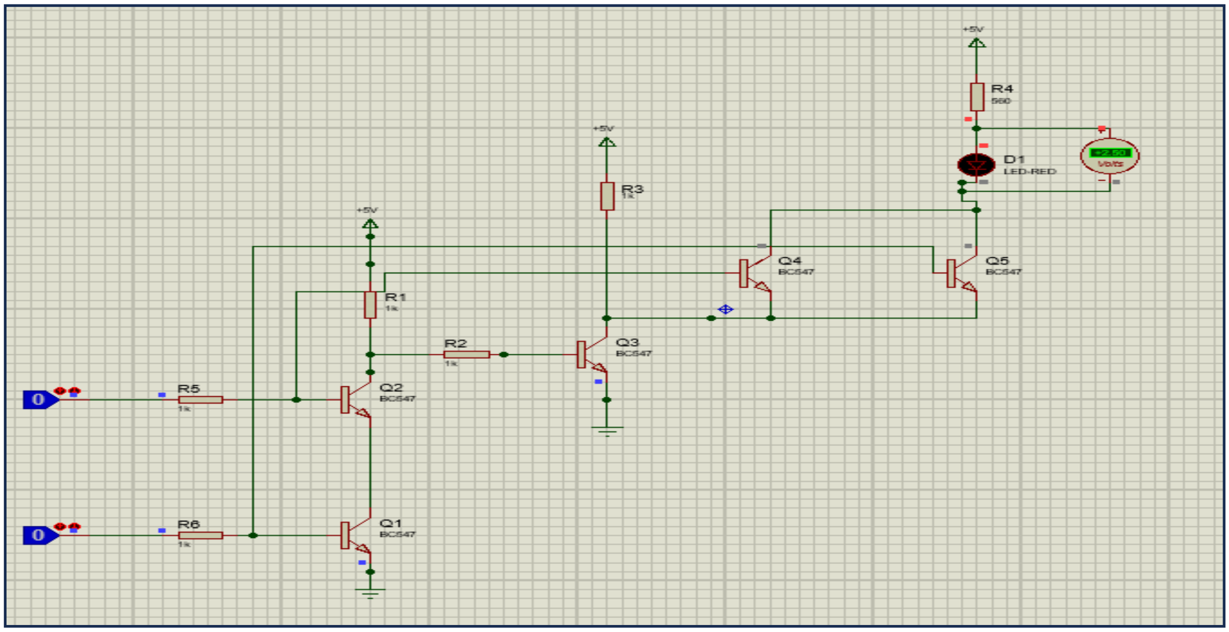
1. **Case 1:** Input A = 0, B = 0 → Output = 0
2. **Case 2:** Input A = 0, B = 1 → Output = 1
3. **Case 3:** Input A = 1, B = 0 → Output = 1
4. **Case 4:** Input A = 1, B = 1 → Output = 0

Truth table:



A	B	Output
0	0	0
1	0	1
0	1	1
1	1	0

Circuit diagram:



Equipment Required

Software

- Proteus

Hardware

- Five PN2222 Transistor
- Resistos
- Power supply
- Breadboard
- Connecting wires

Methodology

To solve the circuit first we have applied it on software to check the results and circuit.

Software implementation

By using above different components, circuit is built on proteus software.
All the components are taken from software library.

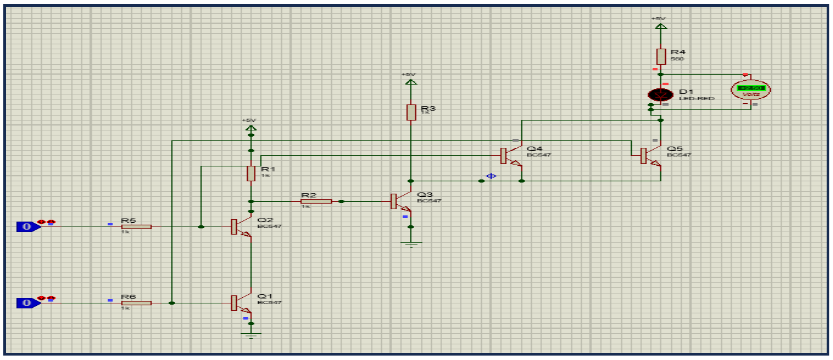
Procedure

After the software implementation we make the circuit on hardware setup. Then the results of input and output and written in report.

Simulation Results:

There are four possible are case or XOR gate using BJT each case result description is given below:

Case=1
When both Switches are off

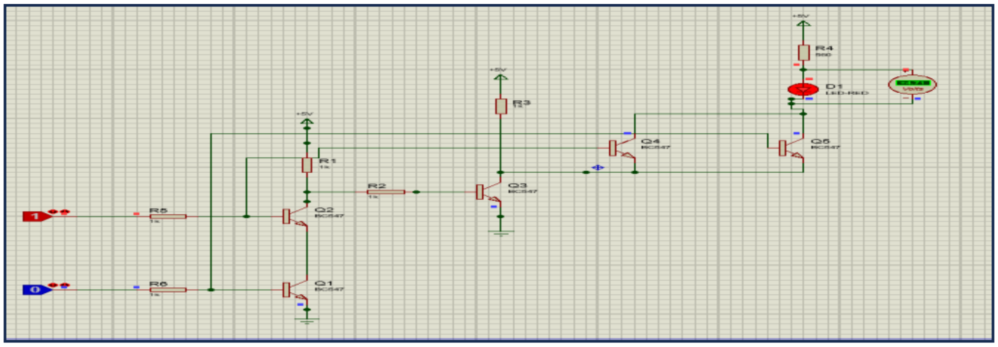


Circuit diagram

CASE=01 Results	Voltages		Currents	Regions
Transistor=01	**VE**=0	**VBE**=90.7mV	**IE**=3.2pA	Cut off region
	VB=90.7mV	**VCE**=78.57mV	**IB**=0.09pA	
	VC=78.6mV	**VBC**=12.12mV	**IC**=3.11pA	
Transistor=02	**VE**=78.8mV	**VBE**=88.69V	**IE**=3.25pA	Cut off region
	VB=167.3mV	**VCE**=3.22V	**IB**=3.18pA	
	VC=3.3V	**VBC**=3.13V	**IC**=0.07pA	
Transistor=03	**VE**=0	**VBE**=668.88mV	**IE**=12.67mA	Saturation region
	VB=668.9mV	**VCE**=34.25mV	**IB**=4.7mA	
	VC=34.4mV	**VBC**=634.63mV	**IC**=7.97mA	
Transistor=04	**VE**=34.25V	**VBE**=56.45mV	**IE**=1.08pA	Cut off region
	VB=90.7mV	**VCE**=7.97V	**IB**=0.09pA	
	VC=8V	**VBC**=7.91V	**IC**=0.99pA	
Transistor=05	**VE**=34.25mV	**VBE**=133mV	**IE**=17.3pA	Cut off region
	VB=167.3mV	**VCE**=7.97V	**IB**=0.07pA	
	VC=8V	**VBC**=7.83V	**IC**=17.22pA	

Description:
In the first case, when both buttons are off, the LED is off because this corresponds to the first case of the XOR gate truth table. When both inputs are low, the output is low. In this case, transistors one and two act as open circuits because there is zero voltage at their bases. Similarly, transistors four and five, which are connected to the bases of transistors one and two respectively, also act as open circuits due to zero voltage at their bases.
Since there is no complete path for the current from the battery connected to the LED, the LED remains off. In this case, transistors one, two, four, and five operate in the cutoff region

Case=2
When 1st switch is on and 2nd switch is OFF



Circuit diagram:

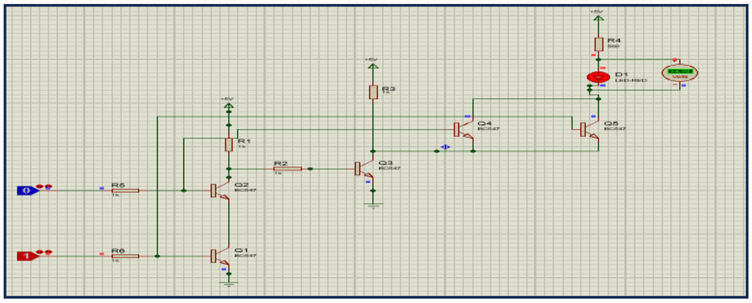
CASE=02 Results							
	Voltages		**Currents**	**Regions**
Transistor=01	**VE**=0	**VBE**=664.4mV	**IE**=7.3mA	Saturation region
	VB=664.4mV	**VCE**=17.93mmV	**IB**=7.3mA	
	VC=17.93mV	**VBC**=646.48mV	**IC**=14.11pA	
Transistor=02	**VE**=17.93mV	**VBE**=127.7mV	**IE**=14.11pA	Cut off region
	VB=145.7mV	**VCE**=7.29V	**IB**=0.04pA	
	VC=3.3V	**VBC**=3.16V	**IC**=14.07pA	
Transistor=03	**VE**=0	**VBE**=673.27mV	**IE**=15.88mA	Saturation region
	VB=673.3mV	**VCE**=38.83mV	**IB**=4.7mA	
	VC=38.83mV	**VBC**=634.4mV	**IC**=11.18mA	
Transistor=04	**VE**=38.83V	**VBE**=625.6mV	**IE**=3.19mA	Saturation region
	VB=664.4mV	**VCE**=6.03V	**IB**=31.9uA	
	VC=6.1V	**VBC**=5.41V	**IC**=3.19mA	
Transistor=05	**VE**=38.83V	**VBE**=106.36mV	**IE**=6.37pA	Cut off region
	VB=145.7mV	**VCE**=6.03V	**IB**=0.04pA	
	VC=6.1V	**VBC**=-5.93V	**IC**=6.33pA	

Description:

In the second case, when one button is on, the LED is on because this corresponds to the second case of the XOR gate truth table. When one input is high and the other is low, the output is high. In this case, there is voltage at the base of transistor one because the switch connected to its base is closed. Similarly, there is voltage at the base of transistor four because the bases of transistors one and four are connected to each other. Transistors two and five remain in an open-circuit state because the switches connected to their bases are also open. As a result, voltage reaches the base of transistor three because there is no alternate path for the current to follow. In this scenario, the current from the source connected to the LED completes its path, flowing from transistor four through transistor three to ground. The LED is on due to the complete path for current flow. In this case, transistors two and five operate in the cutoff region.

Case=3

When 2nd Switch is on and 1st is OFF



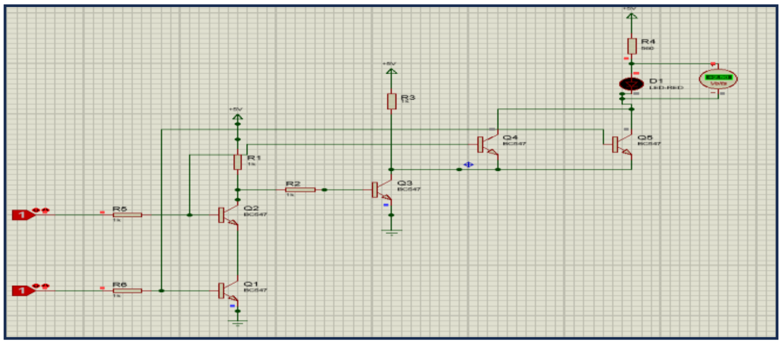
Circuit diagram:

CASE=03 Results				
	Voltages		Currents	Regions
Transistor=01	**VE**=o	**VBE**=100.6mV	**IE**=5.04pA	Cut off region
	VB=100.6mV	**VCE**=635.56mV	**IB**=0.05pA	
	VC=635.6mV	**VBC**=500.97mV	**IC**=4.99pA	
Transistor=02	**VE**=635.6mV	**VBE**=100.86mV	**IE**=5.09pA	Cut off region
	VB=736.4mV	**VCE**=2.68V	**IB**=0.05pA	
	VC=3.3V	**VBC**=2.98V	**IC**=5.04pA	
Transistor=03	**VE**=0	**VBE**=688.92mV	**IE**=33.01mA	Saturation region
	VB=688.9mV	**VCE**=55.51mV	**IB**=4.70mA	
	VC=55.52mV	**VBC**=633.4mV	**IC**=28.31mA	
Transistor=04	**VE**=55.52mV	**VBE**=45.06mV	**IE**=0.43pA	Cut off region
	VB=100.6mV	**VCE**=35mV	**IB**=0.05pA	
	VC=90.55mV	**VBC**=10mV	**IC**=0.38pA	
Transistor=05	**VE**=55.52mV	**VBE**=681mV	**IE**=20.26mA	Saturation region
	VB=736.4mV	**VCE**=35.02mV	**IB**=7.26mA	
	VC=90.55mV	**VBC**=645.87V	**IC**=13.1mA	

Description:

In the third case, when the second button is on, the LED is on because this corresponds to the third case of the XOR gate truth table. When one input is high and the other is low, the output is high. In this case, there is voltage at the base of transistor two because the switch connected to its base is closed. Similarly, there is voltage at the base of transistor five because the bases of transistors one and five are connected to each other. Transistor one remains in a short-circuit state because the switch connected to its base is open. As a result, voltage reaches the base of transistor three because there is no alternate path for the current to follow. In this scenario, the current from the source connected to the LED completes its path, flowing from transistor five through transistor three to ground. The LED is on due to the complete path for current flow. In this case, transistors one and four operate in the cutoff region.

Case=4
When Both Switches are ON



Circuit diagram

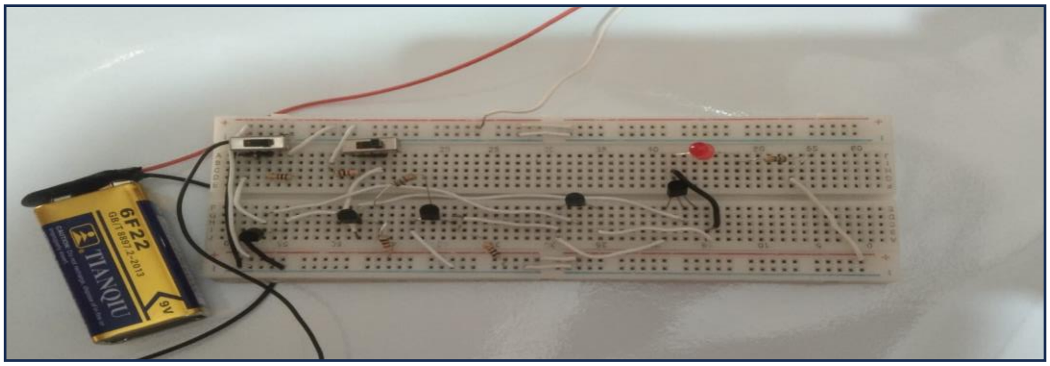
CASE=04 Results				
	Voltages		**Currents**	**Regions**
Transistor=01	**VE**=0V	**VBE**=682.9mV	**IE**=22.54A	Saturation region
	VB=682.9mV	**VCE**=36.91mV	**IB**=7.32mA	
	VC=36.91mV	**VBC**=645.98mV	**IC**=15.22mA	
Transistor=02	**VE**=36.91mV	**VBE**=675.6mV	**IE**=15.22mA	Saturation region
	VB=712.5mV	**VCE**=29.45mV	**IB**=7.29mA	
	VC=66.7mV	**VBC**=646.14mV	**IC**=7.93mA	
Transistor=03	**VE**=0V	**VBE**=66.37mV	**IE**=1.49pA	Cut off region
	VB=66.7mV	**VCE**=8V	**IB**=0.09pA	
	VC=8V	**VBC**=7.93V	**IC**=1.4pA	
Transistor=04	**VE**=8V	**VBE**=7.32V	**IE**=0.2pA	Saturation Region
	VB=682.9mV	**VCE**=0V	**IB**=0.1pA	
	VC=8V	**VBC**=7.2V	**IC**=0.1pA	
Transistor=05	**VE**=8V	**VBE**=7.29V	**IE**=0.2pA	Saturation Region
	VB=712.5mV	**VCE**=0V	**IB**=0.1pA	
	VC=8V	**VBC**=7.29V	**IC**=0.1pA	

Description:
In the fourth case, when both buttons are closed, the LED remains off. This corresponds to the fourth case of the XOR gate truth table, where both inputs are high, resulting in a low output. In this case, there is voltage at the base of transistors one and two because both switches connected to their bases are closed. Similarly, there is voltage at the bases of transistors four and five because their bases are connected to transistors one and two, respectively. However, no voltage reaches the base of transistor three because there is a shorter path for the current to flow through transistors one and two. As a result, the current from the source connected to the LED cannot complete its path because transistor three acts as an open circuit. The LED does not light up because there is no complete path for current flow. In this scenario, transistor three operates in the cutoff region.

Hardware:

There are also four possible are case or XOR gate using BJT each case result description is given below:

Case=1
When both the switches are OFF

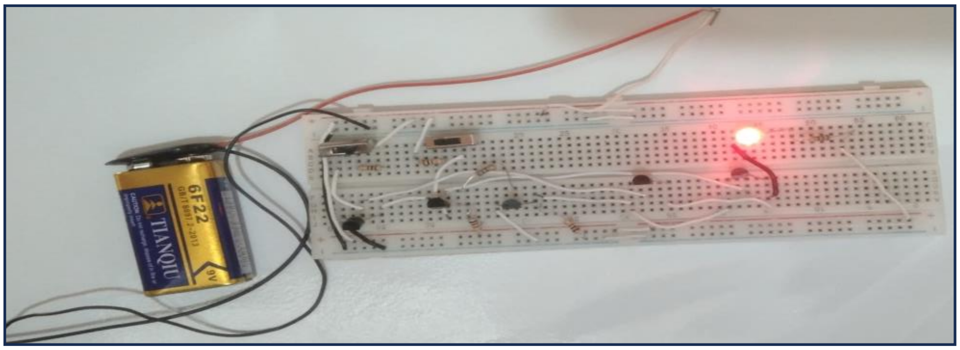


Circuit diagram:

CASE=01 Result				
	Voltages		**Currents**	**Regions**
Transistor=01	**VE**=0V	**VBE**=0.15V	**IE**=0A	Cut off region
	VB=0.25V	**VCE**=.0.02V	**IB**=0A	
	VC=0V	**VBC**=0.002V	**IC**=0A	
Transistor=02	**VE**=0.005V	**VBE**=0.129V	**IE**=0A	Cut off region
	VB=0.141V	**VCE**=0.004V	**IB**=0A	
	VC=3.414V	**VBC**=2.887V	**IC**=0A	
Transistor=03	**VE**=0V	**VBE**=0.775V	**IE**=12.4mA	Saturation region
	VB=0.776V	**VCE**=0.008V	**IB**=4.6mA	
	VC=0.01V	**VBC**=0.766V	**IC**=8mA	
Transistor=04	**VE**=0.01V	**VBE**=0.07V	**IE**=0A	Cut off region
	VB=0.054V	**VCE**=6.63V	**IB**=0A	
	VC=6.62V	**VBC**=6.03V	**IC**=0A	
Transistor=05	**VE**=0.01V	**VBE**=0.12V	**IE**=0A	Cut off region
	VB=0.16V	**VCE**=6.64V	**IB**=0A	
	VC=6.64V	**VBC**=5.8V	**IC**=0A	

Description:
In the first case, when both buttons are off, the LED is off because this corresponds to the first case of the XOR gate truth table. When both inputs are low, the output is low. In this case, transistors one and two act as open circuits because there is zero voltage at their bases. Similarly, transistors four and five, which are connected to the bases of transistors one and two respectively, also act as open circuits due to zero voltage at their bases.
Since there is no complete path for the current from the battery connected to the LED, the LED remains off. In this case, transistors one, two, four, and five operate in the cutoff region.

Case=2
When 1st switch is on and 2nd switch is OFF



Circuit Diagram

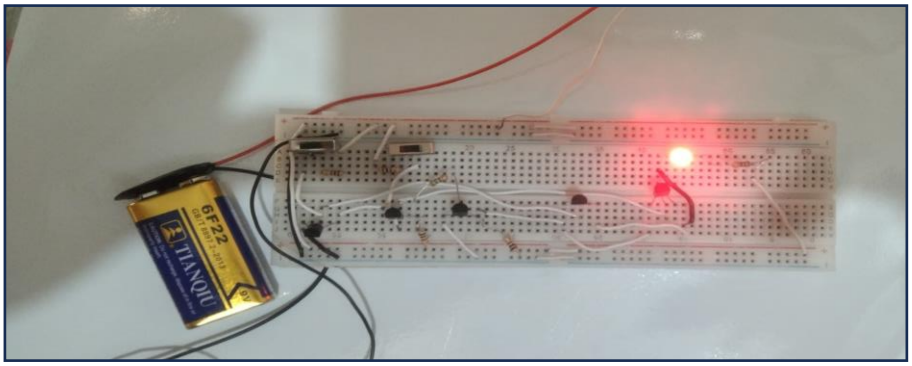
CASE=02 Results				
	Voltages		Currents	Regions
Transistor=01	**VE**=0V	**VBE**=0.765V	**IE**=3.3 mA	Saturation region
	VB=.765V	**VCE**=0.002V	**IB**=3. 3 mA	
	VC=0.002V	**VBC**=0.762V	**IC**=0 mA	
Transistor=02	**VE**=0.002V	**VBE**=0.261V	**IE**=0 mA	Cut off region
	VB=0.21V	**VCE**=3.41V	**IB**=0 mA	
	VC=3.417V	**VBC**=2.94V	**IC**=0 mA	
Transistor=03	**VE**=0V	**VBE**=0.782V	**IE**=13.6 mA	Saturation region
	VB=0.784V	**VCE**=0.017V	**IB**=4.6 mA	
	VC=0.019V	**VBC**=0.764V	**IC**=10.8 mA	
Transistor=04	**VE**=0.021V	**VBE**=0.74V	**IE**=7.5 mA	Saturation region
	VB=0.765V	**VCE**=0.15V	**IB**=1.3 mA	
	VC=0.065V	**VBC**=0.730V	**IC**=10.1 mA	
Transistor=05	**VE**=0.020V	**VBE**=0.09V	**IE**=0 mA	Cut off region
	VB=0.17V	**VCE**=0.01V	**IB**=0 mA	
	VC=0.32V	**VBC**=0.052V	**IC**=0 mA	

Description:

In the second case, when one button is on, the LED is on because this corresponds to the second case of the XOR gate truth table. When one input is high and the other is low, the output is high. In this case, there is voltage at the base of transistor one because the switch connected to its base is closed. Similarly, there is voltage at the base of transistor four because the bases of transistors one and four are connected to each other. Transistors two and five remain in an open-circuit state because the switches connected to their bases are also open. As a result, voltage reaches the base of transistor three because there is no alternate path for the current to follow. In this scenario, the current from the source connected to the LED completes its path, flowing from transistor four through transistor three to ground. The LED is on due to the complete path for current flow. In this case, transistors two and five operate in the cutoff region.

Case=3

When 2nd Switch is on and 1st is OFF



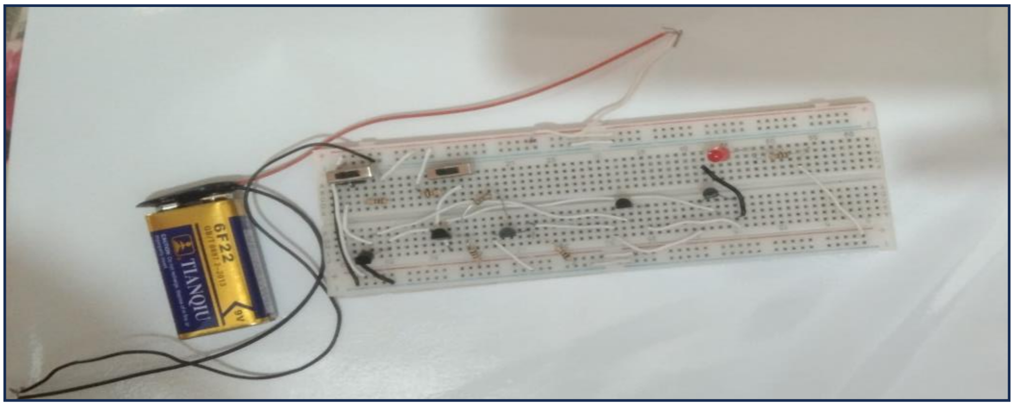
Circuit Diagram

CASE=03 Result				
	Voltages		**Currents**	**Regions**
Transistor=01	**VE**=0V	**VBE**=0.21V	**IE**=0 mA	Cut off region
	VB=0.17V	**VCE**=0.58V	**IB**=0 mA	
	VC=0.64V	**VBC**=0.36V	**IC**=0 mA	
Transistor=02	**VE**=0.61V	**VBE**=0.1V	**IE**=0 mA	Cut off region
	VB=0.798V	**VCE**=0.001V	**IB**=0 mA	
	VC=4.17V	**VBC**=2.6V	**IC**=0 mA	
Transistor=03	**VE**=0V	**VBE**=0.784V	**IE**=29.1 mA	Saturation region
	VB=0.786V	**VCE**=0.21V	**IB**=4.6 mA	
	VC=0.024V	**VBC**=0.762V	**IC**=24.9 mA	
Transistor=04	**VE**=0.024V	**VBE**=0.1V	**IE**=0 mA	Cut off region
	VB=0.13V	**VCE**=0.01V	**IB**=0 mA	
	VC=0.036V	**VBC**=0.105V	**IC**=0 mA	
Transistor=05	**VE**=0.025V	**VBE**=0.77V	**IE**=17.1 mA	Saturation region
	VB=0.795V	**VCE**=0.01V	**IB**=7.1 mA	
	VC=0.035V	**VBC**=0.76V	**IC**=10.2 mA	

Description:

In the third case, when the second button is on, the LED is on because this corresponds to the third case of the XOR gate truth table. When one input is high and the other is low, the output is high. In this case, there is voltage at the base of transistor two because the switch connected to its base is closed. Similarly, there is voltage at the base of transistor five because the bases of transistors one and five are connected to each other. Transistor one remains in a short-circuit state because the switch connected to its base is open. As a result, voltage reaches the base of transistor three because there is no alternate path for the current to follow. In this scenario, the current from the source connected to the LED completes its path, flowing from transistor five through transistor three to ground. The LED is on due to the complete path for current flow. In this case, transistors one and four operate in the cutoff region.

Case=4
when both switches are ON



Circuit Diagram:

CASE=04 Results				
	Voltages		**Currents**	**Regions**
Transistor=01	**VE**=0V	**VBE**=0.78V	**IE**=2.2 mA	Saturation region
	VB=781V	**VCE**=0.011V	**IB**=7.1 mA	
	VC=0.01V	**VBC**=0.769V	**IC**=15.2 mA	
Transistor=02	**VE**=0.12V	**VBE**=0.768V	**IE**=15.1 mA	Saturation region
	VB=0.78V	**VCE**=0.08V	**IB**=7.2 mA	
	VC=0.021V	**VBC**=0.759V	**IC**=4.8 mA	
Transistor=03	**VE**=0V	**VBE**=0.021V	**IE**=0 mA	Cut off region
	VB=0.021V	**VCE**=8.09V	**IB**=0 mA	
	VC=8.07V	**VBC**=8.04V	**IC**=0 mA	
Transistor=04	**VE**=8.07V	**VBE**=7.29V	**IE**=0 mA	Saturation Region
	VB=0.77V	**VCE**=0V	**IB**=0 mA	
	VC=6.61V	**VBC**=5.87V	**IC**=0 mA	
Transistor=05	**VE**=8.05V	**VBE**=7.3V	**IE**=0 mA	Saturation Region
	VB=0.77V	**VCE**=0V	**IB**=0 mA	
	VC=6.62V	**VBC**=5.89V	**IC**=0 mA	

Description:

In the fourth case, when both buttons are closed, the LED remains off. This corresponds to the fourth case of the XOR gate truth table, where both inputs are high, resulting in a low output. In this case, there is voltage at the base of transistors one and two because both switches connected to their bases are closed. Similarly, there is voltage at the bases of transistors four and five because their bases are connected to transistors one and two, respectively. However, no voltage reaches the base of transistor three because there is a shorter path for the current to flow through transistors one and two. As a result, the current from the source connected to the LED cannot complete its path because transistor three acts as an open circuit. The LED does not light up because there is no complete path for current flow. In this scenario, transistor three operates in the cutoff region.

Application [4]

- **Arithmetic operations:** XOR gates are used in half-adders and full-adders to calculate the sum and carry of two- or three-bit numbers.
- **Parity checking:** XOR gates can determine if a binary number has an odd or even number of 1's. This is called the parity bit, and it can be used to check for errors in transmitted data.
- **Cryptography:** XOR logic can be used as a simple cipher to encrypt and decrypt messages.
- **Pseudo-random number generation**: A suitable XOR gate can be used to generate pseudo-random numbers.
- **Programmable inverter:** XOR gates can function as an inverter that can be activated or deactivated by a switch.
- **Comparators:** XOR gates are used in comparators.
- **Subtractors:** XOR gates are used in subtractors.
- **Boolean equations:** XOR gates can be used to simplify Boolean equations.

DISCUSSION OF RESULTS

All possible input combinations of the XOR table using BJTs were tested, and the results were checked to confirm the XOR logic. The circuit exhibited the expected behavior as follows.

Case 1: Inputs A = 0, B = 0 → Inputs = 0 (LED off):

When both inputs were set to 0, no current flowed through the output stage, as expected. The LED remained off, representing the lowest output (logic 0).

Case 2: Input A = 0, B = 1 → Output = 1 (LED on):

With this input combination, the circuit activated only one transistor, allowing current to flow in the output stage. The LED turned on, indicating a high output (logic 1). This XOR corresponds to the truth table.

Case 3: Inputs A = 1, B = 0 → Inputs = 1 (LED on):

Similar results were obtained with this design, providing a transistor, allowing current to flow in the output stage. The LED flashes, confirmed as high (logic 1).

Case 4: Inputs A = 1, B = 1 → Inputs = 0 (LED off):

In this case, both transistors were used simultaneously, leaving the output stage intact due to the design of the circuit. The LED remained off, confirming a low output (logic 0).

These results are in good agreement with the XOR truth table, where the results increase only when the inputs are different. The circuit demonstrated the ability to reliably implement XOR logic through BJTs. The use of LEDs for output visualization made it easier to verify the logic in real time. This successful application highlights the efficient use of BJTs in digital logic circuits and.

Conclusion:

In conclusion, we constructed an XOR gate using five transistors, which efficiently fulfills the XOR gate truth table. In the simulation, we provided an input of five volts, and in the hardware implementation, we used eight volts. We implemented the design in both cases hardware and software and observed the results of current flow and the region of operation of the transistors under different conditions. The output efficiently matched the XOR gate truth table.

REFERNCES:

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