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Experiment 5

Bipolar Junction transistors

Basic Logic Circuits

Introduction:

The focus of this laboratory experiment is to investigate the practical application of Bipolar Junction Transistors (BJTs) in the creation of NAND, AND, and NOR logic gates, which are crucial components in digital electronics. Our goal is to not only construct these basic logic gates but also to comprehend the underlying principles that enable BJTs to perform logical operations. We will delve into the behavior of BJTs as switches—how a high enough voltage at the base allows current flow and represents a logical '1', while a low voltage inhibits current flow, representing a logical '0'. By examining these states and their outcomes in various configurations, we intend to demonstrate the fundamental operation of digital logic as it applies to computing and circuit design. This hands-on experience will serve to bridge the gap between theoretical concepts learned in lectures and the tangible aspects of electronic circuitry, enhancing our understanding of the binary logic that forms the bedrock of all digital systems.

Bench Parts and Equipment List:

Components:

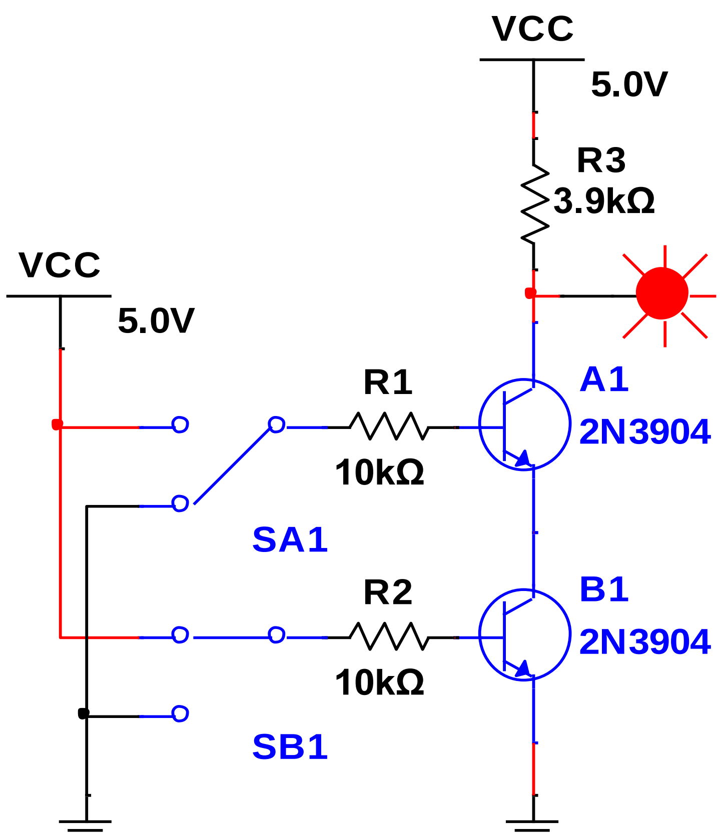
1. Bipolar Junction Transistors (BJTs) - Model 2N3904
2. Resistors:
    - One 3.9 kΩ resistor
    - One 1 kΩ resistor
    - Two 10 kΩ resistors

Equipment:

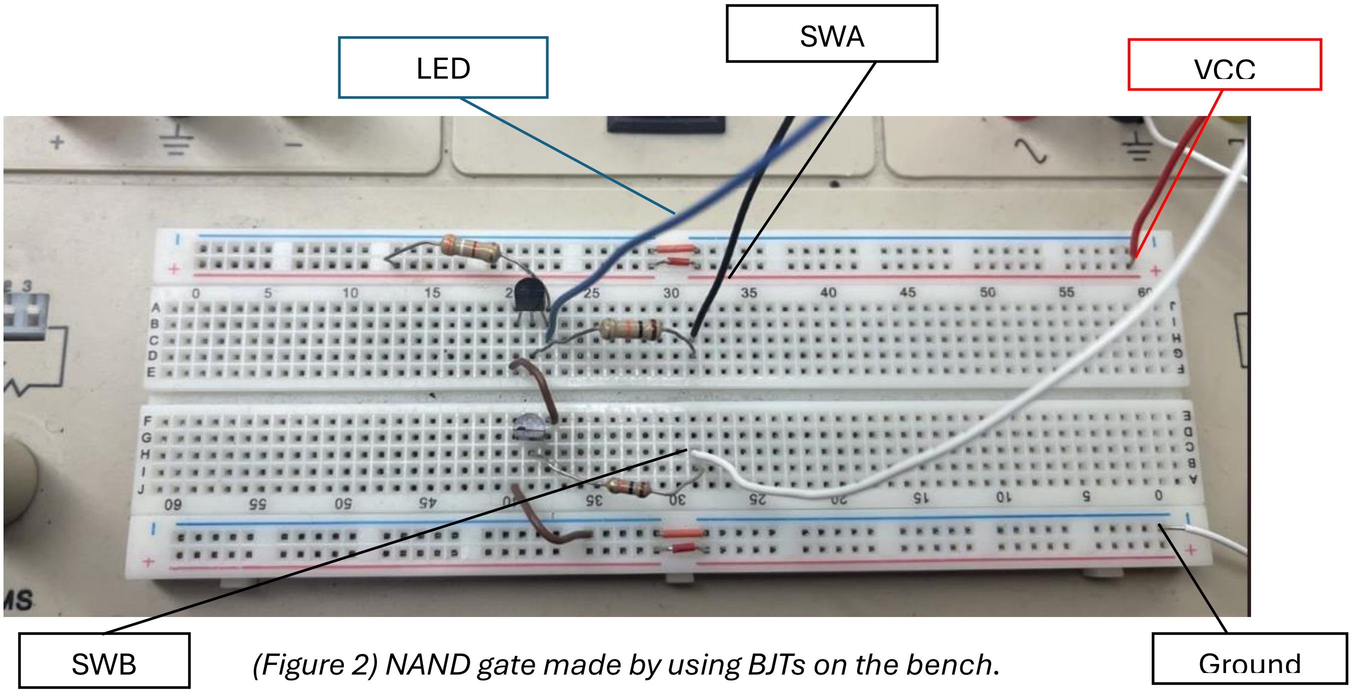
1. Power supply
2. Digital Multimeter (DMM)
3. Breadboard
4. Connecting wires/jumpers
5. Elenco Trainer.

Discussion:

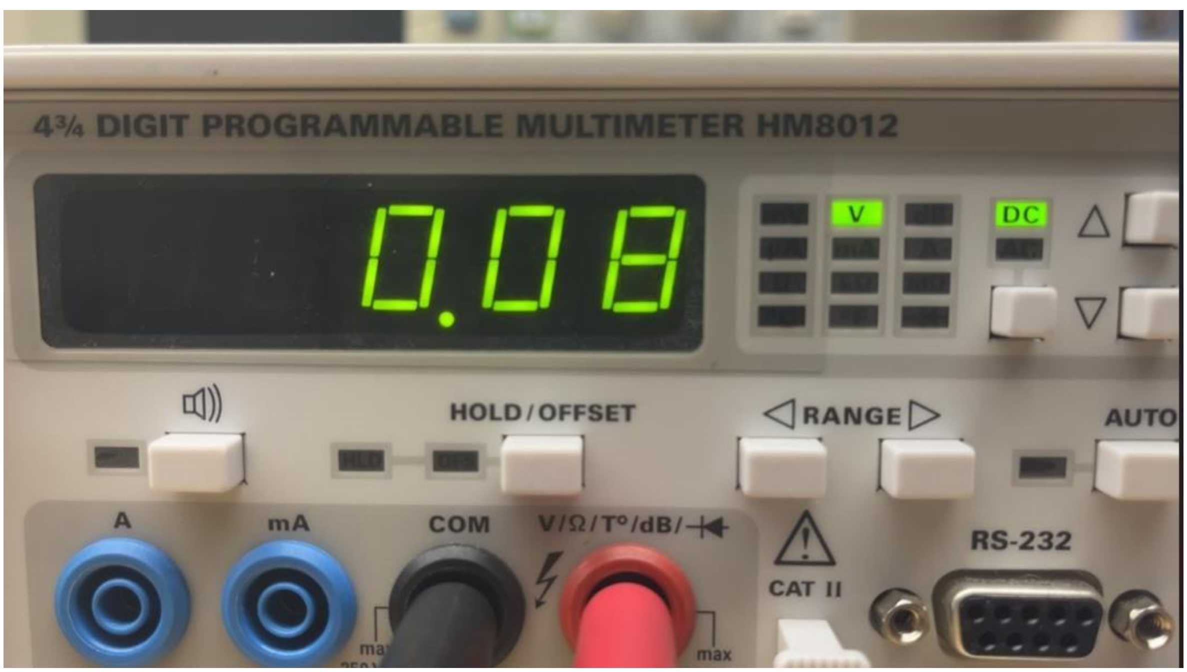
NAND Gate: The data collected from the NAND gate experiment exhibited a clear trend that aligns with the expected behavior of a NAND gate: the output is high unless both inputs are high. This observation supports the theoretical understanding of a NAND gate, which is an AND gate followed by a NOT gate. The BJTs in this configuration are designed to saturate and conduct when the input conditions are low, creating a path to ground and hence a low output. Only when both BJTs are off (corresponding to both inputs being high), the output is pulled high by the resistor, confirming the fundamental logic of the NAND operation.



(Figure 1) This is a NAND gate made by using two BJTs (Multisim).



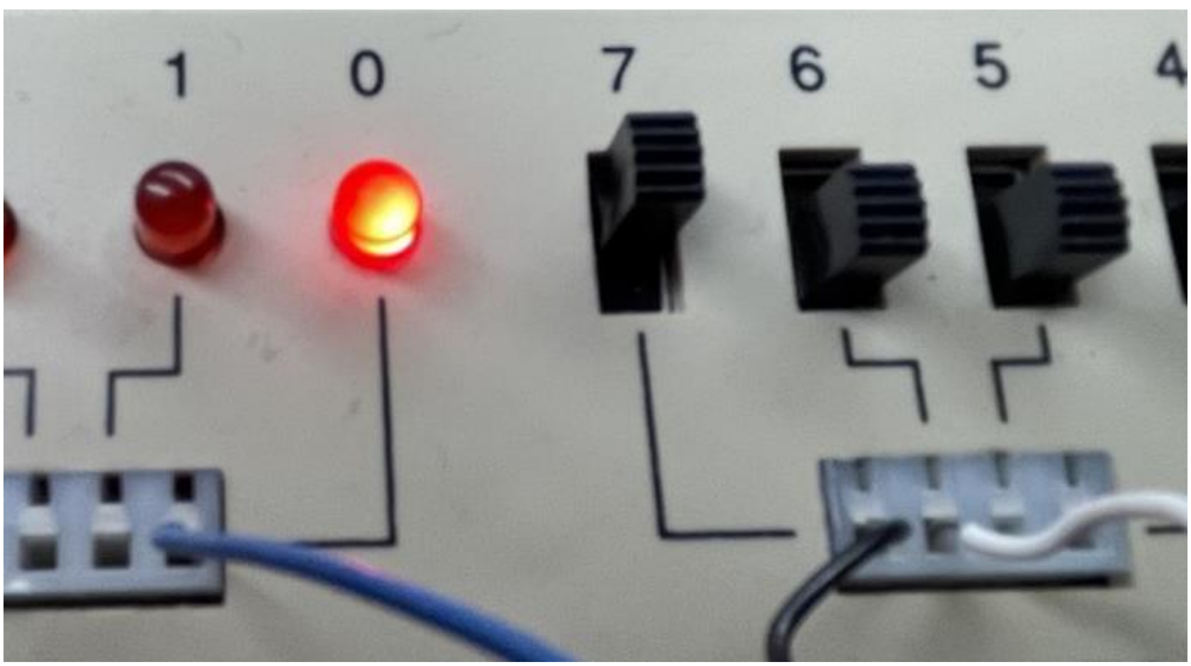
(Figure 2) NAND gate made by using BJTs on the bench.



(Figure 3) Voltage at the LED when both Transistor are logic high and providing a direct path to ground.

(Figure 4) Voltage at the LED when either or both Transistors are logic Low, causing Pull-up Resistor effect.

VCC → Pull-Up Resistor 3.9 kΩ (R_C) → LED → Ground

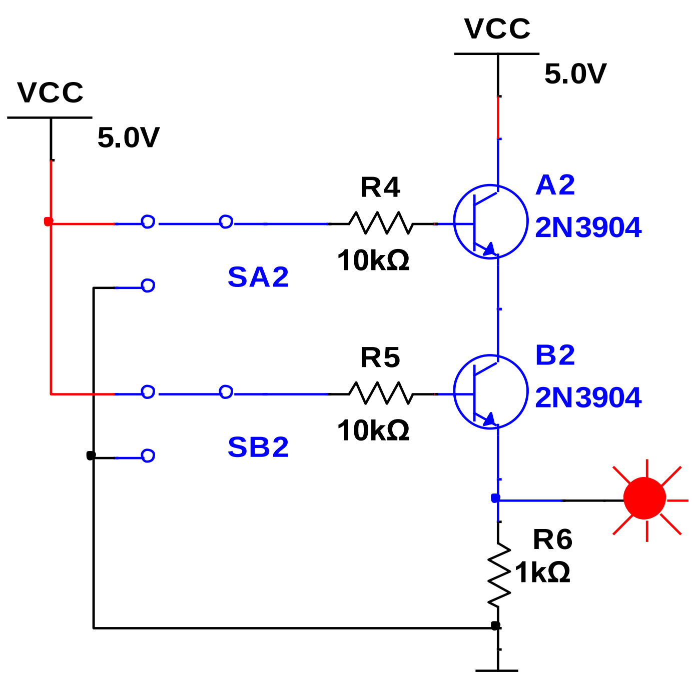


(Figure 5) LED is on when either switch is logic Low. (sw 7 & 8)

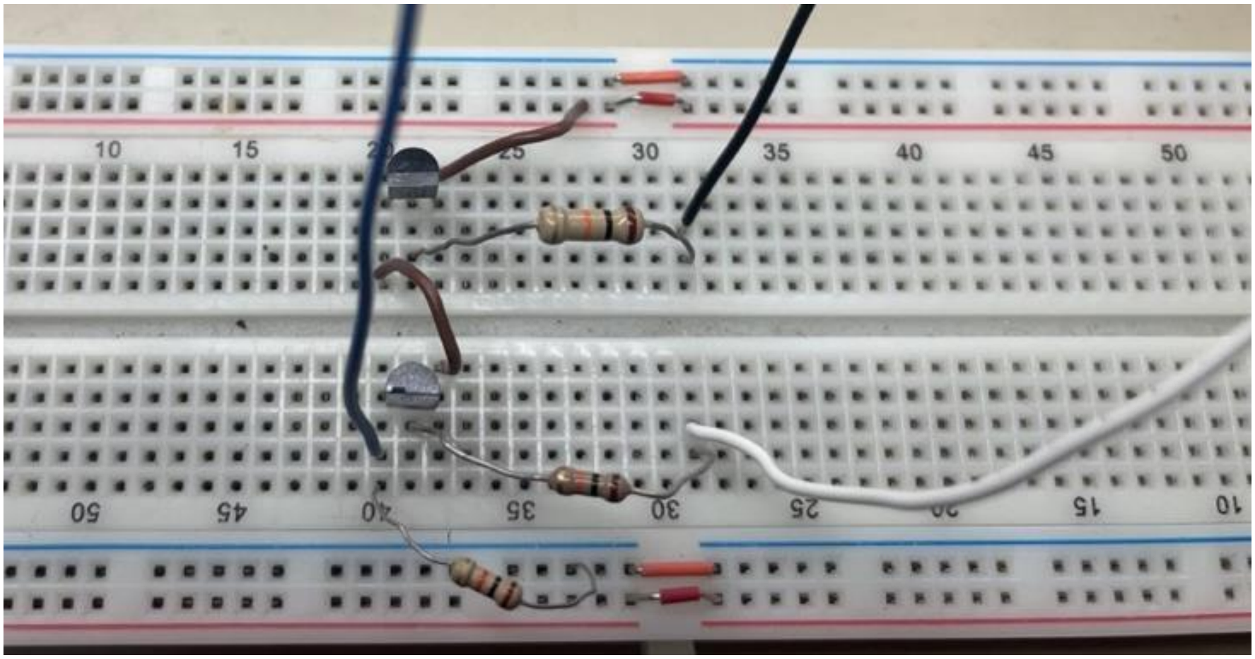
Table 1

Circuit 1 NAND gate		
A	*B*	*Output*
0	*0*	*1 @ 5.08V*
0	*1*	*1 @ 5.08V*
1	*0*	*1 @ 5.08V*
1	*1*	*0 @ 0.08V*

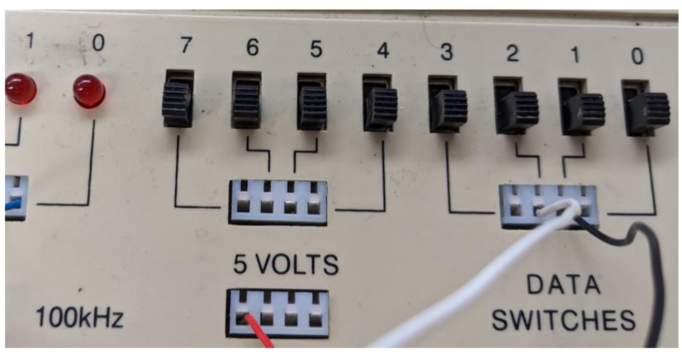
AND Gate: In the AND gate circuit, the results demonstrated that the output is high only when both inputs are high, which is characteristic of an AND gate. This is because the BJTs are arranged such that they both must be saturated (i.e., in the on state) for the current to flow through the load resistor to the output. If either transistor is not conducting, the path to the output is broken, resulting in a low output voltage. The experimental data followed this pattern, providing empirical support for the theoretical model of the AND logic gate.



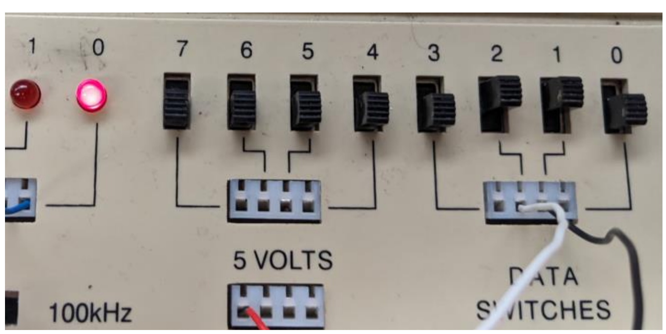
(Figure 6) AND gate using BJTs (Multisim)



(Figure 7) AND gate using BJTs on the Bench.



(Figure 8) Sw 2 & 3 are Low and LED is off.

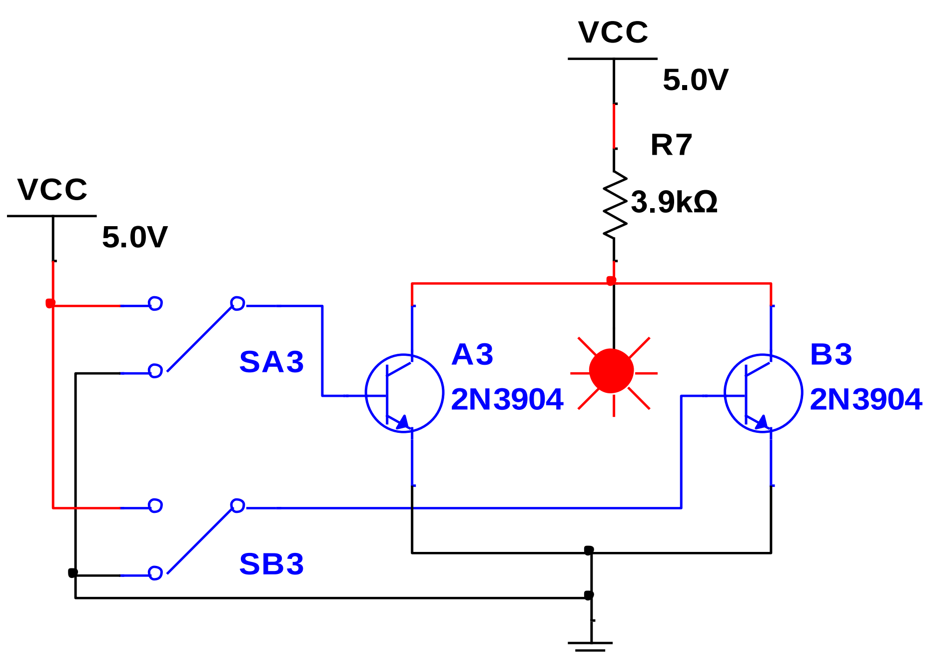


(Figure 9) Sw 2 & 3 are High and LED is on.

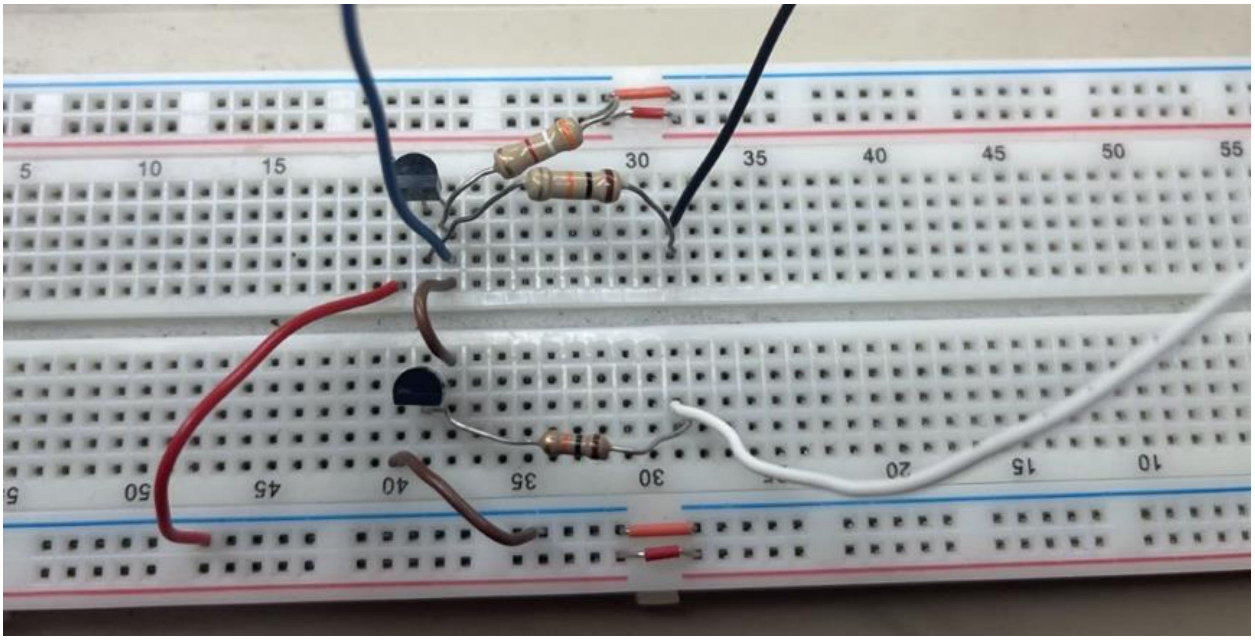
Table 2

Circuit 2 *AND gate*		
A	*B*	*Output*
0	*0*	*0 @ 0V*
0	*1*	*0 @ 2.2V*
1	*0*	*0 @ 0V*
1	*1*	*1 @ 4.32V*

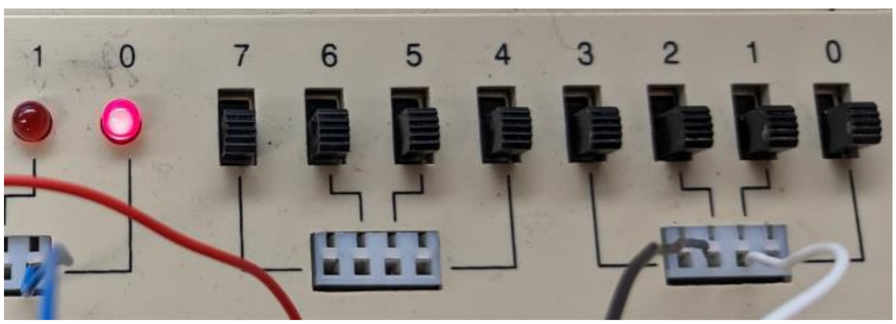
NOR Gate: For the NOR gate, the data shows that the output is low if any input is high, which is consistent with the NOR logic function — the inverse of the OR function. In this setup, the BJTs are configured so that if either is conducting, it will pull the output low. The only condition for a high output is when both transistors are off, which happens only when both inputs are low. Observing this in the collected data validates the concept that a NOR gate is an OR gate combined with a NOT gate, reinforcing the theoretical principles of digital logic design with BJTs.



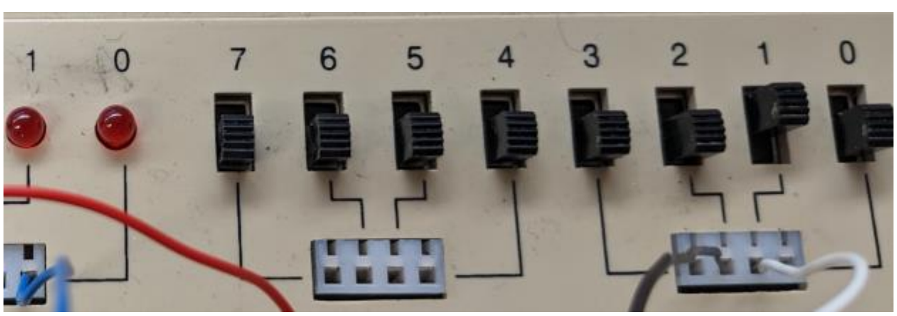
(Figure 10) NOR gate using BJTs Multisim.



(Figure 11) NOR gate using BJTs Bench.



(Figure 12) LED is on when both SW1 & 2 are Low.



(Figure 13) LED is off when SW1 & 2 are in any other combination.

Table 3

Circuit 3 *NOR gate*		
A	*B*	*Output*
0	*0*	*1 @ 5.8V*
0	*1*	*0 @ 0.5V*
1	*0*	*0 @ 0.4V*
1	*1*	*0 @ 0.4V*

Experiment 5

Bipolar Junction Transistors

Basic Logic Circuits

In digital systems courses you studied the characteristics, function, and application of the three basic logic gates AND, OR, and NOT gates. In previous experiments you observed that a high enough voltage (>0.7V) at the base of the transistor will cause electrical current to flow from the collector to the emitter and a low voltage (<0.7V) the flow of current stops. Under these conditions transistor acts as a switch. Therefore the collector voltage changes from V_{CC} when the transistor is switched off to almost zero when the transistor is switched on.

Objective: To examine the operation of basic logic gates using Bipolar Junction Transistors.

Materials

- power supply, DMM
- Two BJT Transistor (2N3904)
- One 3.9kΩ, one 1kΩ, and two 10kΩ Resistors

Input: DC voltage
Output: DMM

Procedure

1- Build the circuit diagram shown in circuit 1.
2- Apply 5 volt as V_{CC} input.
3- Connect input A to SW2 and input B to SW1 of the breadboard.
4- Determine the output voltage for the input conditions shown in table 1.
5- In the space below comment on your observation and name the logic gate the circuit in circuit 1 represents.

Since the output is only high when both switches are low, this has the characteristics of a NAND gate.

Inputs		Output	
SW2(A)	SW1(B)		
0	0	1	5.08V
0	1	1	5.8V
1	0	1	5.8V
1	1	0	.08V

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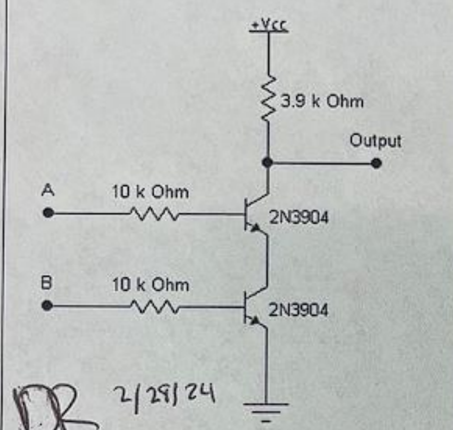
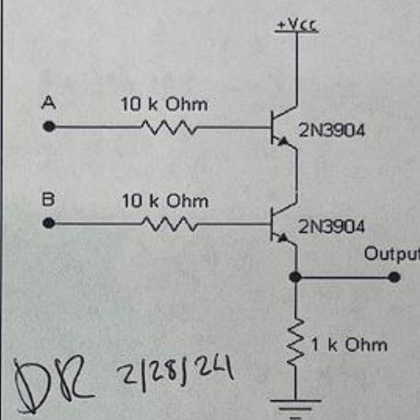
6- Repeat steps 3 through 4 for the circuits shown in circuits 2 and 3.
7- Provide the truth table for the circuit diagram 2 and 3.
8- Identify the logic gate the circuit diagram 2 and 3 represent.



DR 2/28/24

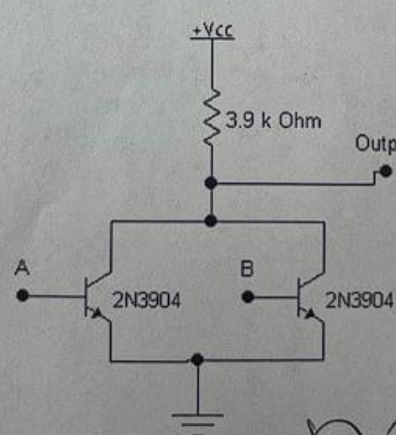
Circuit 1



DR 2/28/24

Circuit 2

A	B	X
0	0	0-.0v
0	1	0-2.2v
1	0	0-0v
1	1	1-4.32v



Circuit 3

DR 2/28/24

A	B	X
0	0	1 - 5.8V
0	1	0 - .05V
1	0	0 - .04V
1	1	0 - .04V

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Conclusion:

The primary objective of this lab was to explore the operation of basic logic gates using Bipolar Junction Transistors (BJTs). We specifically aimed to construct and analyze NAND, AND, and NOR gates, and understand how BJTs control the flow of current in these digital circuits. This lab successfully met its objectives, as we were able to not only build the circuits as per the schematic diagrams but also observe the expected logical behavior through the output voltage measurements. For instance, the NAND gate output was high except when both inputs were high, which is in perfect agreement with the truth table for a NAND gate.

Through this lab, I gained a practical understanding of how transistors function as switches within logic gates, a concept that was previously abstract to me. I learned the importance of pull-up resistors in establishing a default high state when the transistors are in the off state. Furthermore, the hands-on experience solidified my comprehension of how current flows through the circuit and the role of each component in influencing this flow. This lab has not only reinforced my theoretical knowledge but also enhanced my confidence in building and troubleshooting digital circuits.