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Design and Implementation of BJT-Based NAND Gate Circuit with LED Indicators for Logic Operation Visualization

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Abstract: This paper presents the design and simulation of the two input and three input NAND gates using bipolar junction transistors (BJTs) with the aid of pretty light shows. This is quite a breakthrough since NAND gates are very importance, particularly in large-scale integration. This configuration presents two input connections wherein; eight independent n-p-n transistor are identified to connect each other. Input signals are supplied to the base terminals of the transistors whilst the output is taken from collectors of the second transistor. The output is low whenever there are two high inputs: the LED dims. Combinations of any other input values also give a high output, and the LED turns on. The only difference for NAND gate implemented with three inputs is that its structure is the same as for the two- input gate but has three input ports. In the output mode of operation, the LED mimics the NAND gate in every aspect except for the fact that it will only turn off when all three input bits are high. Detailed pathways of these circuits have elaborated in order to explain the functions of the NANDs while other symbolic moving lights are changed depending on the feedback received. This new strategy applies in the teaching of circuit design and avails the current use of BJTs in a vibrant area to the learners.

Keywords- **BJT (Bipolar Junction Transistor), NAND Gate, LED.**

Introduction: Further exploring the concept of electronics in this Information Technology era of electronic devices, probably it would not be wrong to begin with the assertion that, logic gates are the bare minimal of all operating electrical apparatus and networks. Among these gate circuit, NAND gate is one of them because majority of other gates can be built using NAND gates only. Therefore, this can be argued that NAND gates are essential from electron theoretical and electrical theoretical analysis approaches but for under graduate and any other professional depending on electronics computer science and electrical engineering. This work involves design and realization of 2-input and 3-input NAND gate circuits utilizing a Bipolar Junction Transistor; consideration of the semiconductor junction is accorded paramount importance. BJT technology has been applied in buildup of electronic circuits for many decades owing to their stability, versatility and ability to amplify or pass signals. Besides, the application of BJTs in making NAND gates assists in the basic functioning of a transistor besides assisting with the concept of real-life application within circuit designing, which is critical when designing more complicated circuits such as microprocessors and memory units. The NAND gate is the specification to build a desired model in which it produces true output at all times and where both operands are true. It is the and not gates that form it. Here in this case, this property makes the NAND gate one of the most important electronic devices whenever the circuits are designed for negation as well as conjunction. This specific project was to look into how these gates work with the use of BJTs and was expected to measure the result as there is an LED installed for confirmation. The NAND gate design presented in this work has less power dissipation, lower delay and about 2% better performance than standard known NAND gate designs. It also specifies efficiency concerning the time, effort and energy that is used within distinct operations. This is advantageous to the circuits of today's digital systems because this arrangement is essentially free of unwanted parasitic impedances and can easily be packaged into modular structures with capacities given by the requirements of the application [1]. A new design presents two input NAND gate to perform AND, OR, and XOR logic gates for digital circuit. It also means that the number of gates is the same as in the above approach to OR together with smooth transition between logic levels without enhancing the circuits' complexity. Higher work remains in the utilization of such designs employing NOR gates [2].

His work reviews the types of logic gates, their operations and uses for daily life and services, security systems and automatic devices. It shows how using basic gate operations they Boolean logic can so well model a complex such system [3]. Monte Carlo simulations of a design of NAND gates with single electron technology are also performed and these yield the desired behavior. Evaluation of the energy performance and stability shows the reliability and effectiveness of the functions throughout the gates of these single-electron NAND circuits and they can be incorporated into larger nano-electronic designs [4]. The work sets out a miniaturized circuit which implements four logic gates using two inputs six bipolar junction transistors (BJTs) Hence the circuit is trimmed down. This multifunctional design improves DSP and is suitable for employing in the contemporary integrated circuits application portrayed above [5]. Si/BN/SiC bipolar 2-input TTL NAND gate with high temperature capability operating up to 500°C. It has been established the desired output voltage swings is well stabilized over the tested voltage of 11V to 20V with significantly low power consumption. What doubles the potential of the design is that it is well suited for the absolutely aggressive conditions, characteristic for connections in the systems applied in venus exploration and industry [6].

The paper involves the evaluation of the performance of a two-input NAND gate through different configurations: conventional CMOS, Stack, Sleep, and Sleepy Keeper technologies in 45 nm design style. From the evaluation of the result, it can be seen that the Sleepy Keeper technique generated the smallest value of static power dissipation as well as the static power delay product and therefore the proposed technique seems to be a good candidate for the implementation of low-power digital circuits in the advanced technologies [7].

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Methodology

In the circuit shown in Fig. 1, Q_1 has its Emitter(E) connect to ground, or GND if you will. Its collector wire is taken along with E of the Q_2 that is also connected with output of the LED. R_3 is linked between base and the input; the resistor has a 10 kΩ value. Apart from this, there is another 10 kΩ pull-down available to the ground only for stabilizing the circuit. Transistor Q_2 has its E connected to the collector of the Q_1 and C connected to the output and the LED. The B of Q_2 receives input through a 10 V source V_2 and a pull-down resistor, 10 kΩ to the ground. This anode of the LED indicator will be connected to the collector pin of Q_2 and the cathode of the LED will be connected to the ground and thus the LED could be deemed as an active indicator whenever a circuit exists.

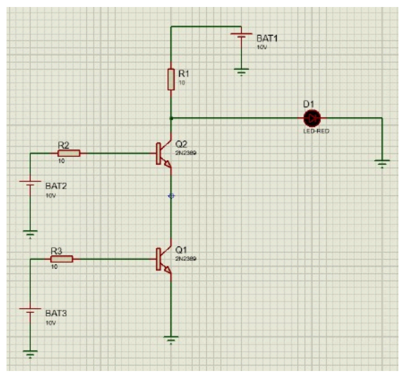

Figure 1: 2-Input BJT NAND Gate circuit

3-Input BJT NAND Gate circuit

Here in the circuit shown in Fig. 2, the collector of one transistor, Q_1 is connected to the emitter of second transistor Q_3 and its collector connected to the emitter of the third transistor Q_2. Q_1's base is connected with the input through R_3 of 10 kΩ, and there's also a pull-down from the input to ground using another 10 kΩ. Transistor Q_2 has its emitter terminal connected to collector of Q_1 and transistor Q_2 has its collector (C) connected to the circuit output/LED. The base of the trasistor (B) is connected to the input via 10 kΩ resistor, R_2, which is followed by another, 10 kΩ resistor connected to the ground. A zero volts is applied to the base of transistor Q_3 while collector of Q3 is connected with the emitter of Q_1. R_4 joins the base to 10 kΩ resistor. Anode of the LED indicator is connected to Collector of Q_2 and the cathode to Ground. Therefore, one will have this LED indicator showing the state of this circuit, whether it is active or not.

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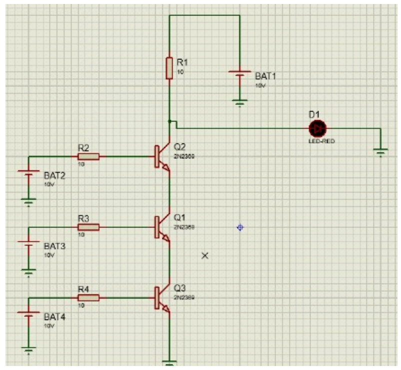

Figure 2: 3-Input BJT NAND Gate circuit

RESULT AND DISCUSSION

2-Input NAND GATE- This circuit includes varying values of resistors (R_1, R_2, and R_3) and input voltages (V_1, V_2, and V_3) to test the effects on whether the LED would turn on or remain off. Here in Result 1 shown in Fig. 3, the value of each resistor used was 10 ohms while all the input voltages were put to 10 volts. In these circumstances the LED was on. This proves that the current flow in the circuit as it is can be sufficient to light this LED. The above setup therefore shows that the impedance or the resistance as well as the voltage matched in this manner can make current to flow wherever it is needed within the NAND gate.

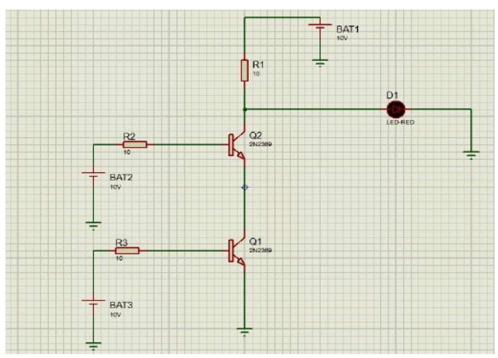

Figure 3: LED status (OFF) for 2-input NAND gate circuit

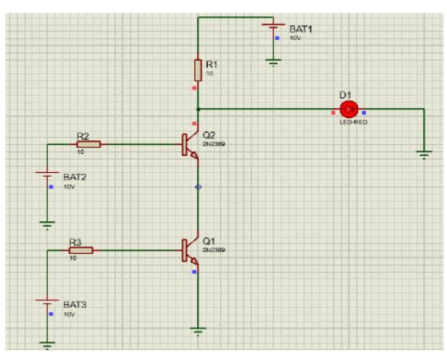

Figure 4: LED status (ON) for 2-input NAND gate circuit

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In Result 2 shown in Fig. 3, the resistance of R_1 remained 1000 **Ω** and R_2 and R_3 remained 10 ohms; all the voltages also remained 10 volts. In this experiment, the LED was off. This means that the extra load of R_1 is too much to allow much current to the LED in the circuit.
Result 3 as shown in Fig. 4, was to bring down the value of V_1 to 1 volt more while V_2 and V_3 still stands at 10 volts for all the resistors dignity 10 ohms. In such conditions also the LED did not turn on at all. That is why a circuit would not get to the required voltage where Low V_1 was, to power the NAND gate's output. This would suggest that each input voltage must be high enough to turn the LED on using this configuration.
Actually, the fourth result is similar to the last 3rd result, where R_1 still measures 1 ohm, and R_2 along with R_3 measuring 10 **Ω**, with all voltages of V_1, V_2 and V_3 at 10 volts. From this result, the decrease in the value of the resistance R_1 enables the passage of full current flow and hence provide enough power to light an LED which we found to be on. This therefore would suggest that a lower R_1 resistance will lead to activation of the led as indicated in the last two results.

Result 5 shown in Fig. 5, also indicated that, on conditions where R_2 and R_3 are set to a value of 1-ohm resistance. For R_1 at 10 ohms, and each voltage at a rate of 10 volts, the LED activates the circuit. The resultant finding of this result illustrates the low resistance of R_2 and R_3 to guarantee the necessary current in the given powers to light up an LED. Therefore, this proves once more how resistance operates to determine circuit outgoings.
Finally, Result 6 shown in Fig. 6, checked reducing only V_2 and V_3 to 1 V while V_1 sticks at the 10 V levels and the resistors at 10 ohms. For one more cycle, the LED is turned on; therefore, it is considered that the values of V_1 are high enough to compensate for the V_2 and V_3 low value so that the LED remains energized. Thus, it is proved that though some of the input voltages can be very, very low yet if one of them is high it will light up the LED. From the analysis performed here, it is concluded that the state of the LED is managed by either high or low resistor values as well as either high or low input voltages in this BJT NAND gate circuit. Having high resistances will restrict the amount of current that pass through, enough input voltages will guarantee that the required power to activate the LED gets to the gate. Each pair stresses the interaction of the resistance and voltage in the circuit regarding the ultimate state of the LED.

3-INPUT NAND GATE: This analysis is based on construction of a 3-input BJT NAND gate circuit and varying the values of the different resistors (R_1, R_2, R_3, R_4) and input voltages (V_1, V_2, V_3, V_4) and observing the effect on the LED. In the first test when R_1=R_2=R_3=R_4=R_5=10 ohms and V_1=V_2=V_3=V_4=V_5=10 volts the LED comes on hence this circuitry can supply the LED with enough current power. In the second test I make V_1 to be 1 V with other inputs being 10 V in this configuration all the resistor remains at 10 ohms and the LED does not light up. This means that one way of guaranteeing that the circuit never gets to the V_1 level that will make the LED turn on is by keeping on V_1 low. In the third case, let the new value of R_1 is 1000 Ω the other resistance R_2, R_3, R_4 and R_5 are 10 Ω and all the input voltage V_1, V_2, V_3, V_4, and V_5 are 10 V. LED turns on here, so it is seen that even though the value of R_1 is high it does not mean that the circuit does

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not supply current and thus light up the led. For the fourth test, R_2, R_3, and R_4 are shorted to 1 ohm, R_1 at 10 ohms, and all input voltages at 10 volts. The LED lights up, meaning that lower value of R_2, R_3 and R_4 values enables enough current power to drive the LED well.

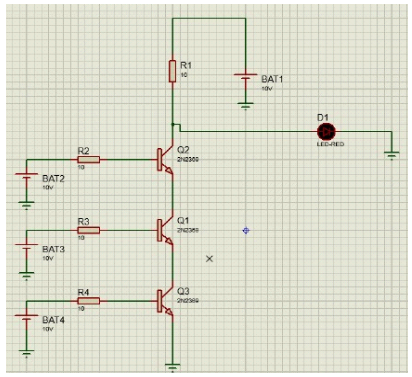

Figure 5: LED status (OFF) for 3-input NAND gate circuit

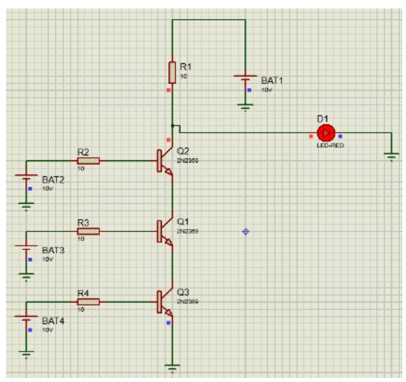

Figure 6: LED status (ON) for 3-input NAND gate circuit

In the fifth test, all components are unchanged with V_2, V_3 and V_4 set to 1 volt each, and V_1 is 10 volts, and all resistors are 10 ohms. Here, there is some current path and the LED is on which means that even single high input (V_1) will help in providing power to the LED while V_2, V_3 and V_4 are low. Finally, in the last scenario, in R_2, R_3 and R_4 components each is set to 1000 ohms while R_1 being set to 10 ohms and all the input voltages set to 10 volts. The LED turns on to indicate that though at high resistance, the circuit allows current flow through R_2, R_3 and R_4. That is why the obtained results show that not only resistor values but also input voltages affect the state of the LED – it is either on or off. High resistances prevent a large amount of current from being supplied and only if one input gives high enough voltage then the LED remains on. Changing these values affects the present location in the circuit and, in turn, toggle the state of the LED.

CONCLUSION

This work demonstrates the use of BJTs to create NAND gate circuits with two and three inputs together with the incorporation of LEDs to display the output. Present findings suggest that the

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current produced by the LEDs depends with the resistor value and the input voltage. A higher value of resistance will give less current path therefore the LED turns off while a lower value will be more permitting of current flow that turns on the led. But there could be some low input voltages a high one would make certain the LED does not go off this is a quite flexible for a NAND gate. The results observed here, therefore, show how BJTs can be used to construct simple NAND gate circuits using iodine output indicator and provide a reliable general solution for easier digital logic problems. This approach therefore provides useful information on how BJTs are utilized in such circuits and how their output responds to electrical signals. Such results formulated certain foundation of employing BJT based NAND gates in certain complicated systems where lesser counts of component and well-defined output signals are required.

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