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**DIGITAL LOGIC AND CIRCUITS LABORATORY**

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**LAB REPORT ON**

# Construction of Diode and Transistor Logic Gates

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## Part I: Construction of Diode Logic Gates Introduction:

A diode is a two-terminal electrical device that allows current to flow in one direction but not the other. It is like a pipe with an internal valve that allows water to flow freely in one direction but shuts down if the water tries to flow backward. The diode's two terminals are called the anode and cathode. In the diode symbol, the arrow points from the anode (flat part of triangle) toward the cathode (point of the triangle).

The device operates by allowing current to flow from anode to cathode, basically in the direction of the triangle. Recall that current is defined to flow from the more positive voltage toward the more negative voltage (electrons flow in the opposite direction). If the diode's anode is at a higher voltage than the cathode, the diode is said to be forward biased, its resistance is very low, and current flows. If the anode is at a lower voltage than the cathode, the diode is reverse-biased, its resistance is very high, and no current flows. The diode is not a perfect conductor, so there is a small voltage drop, approximately 0.7 V, across it.

In this group of experiments, we will implement some logic functions using the DL circuits and discover the potential benefits and problems of using the DL logic.

## Theory and Methodology:

***Diode Logic OR Gate:***

A Diode Logic OR gate consists of nothing more than diodes (one for each input signal) and a resistor. Here, the 10KΩ resistor (R) is added to provide a ground reference for the output signal. If there are no input signals connected to the diodes, the output will be ground, or logic 0. Thus, an open input is equivalent to a logic 0 input and will have no effect on the operation of the rest of the circuit.

It is possible to add any number of input diodes to this circuit, each with its separate input signal. However, two inputs are quite sufficient to demonstrate the operation of the circuit.

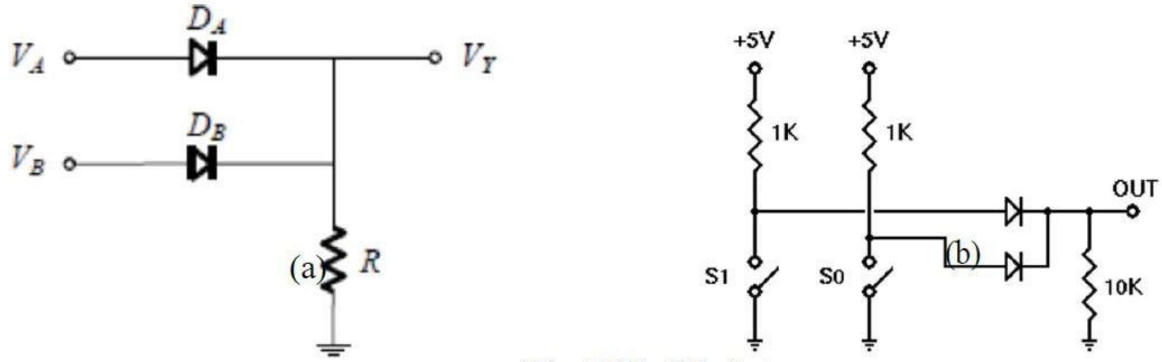



Fig.1 DL-OR Gate

Assuming the diodes are ideal, the voltage truth table as given in Table 1(a) is obtained. The corresponding logic truth table is given in Table 1(b):

| $V_A$ (volt) | $V_B$ (volt) | $V_Y$ (volt) |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 5 | 5 |
| 5 | 0 | 5 |
| 5 | 5 | 5 |

(a)

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

(b)

Table 1

***Diode Logic AND Gate:***

A Diode Logic AND gate consists of diodes (one for each input signal) and a resistor. As with the DL OR gate, the 10KΩ resistor (R) provides a reference connection. Unlike the OR gate, however, this is a reference to +5 volts, rather than to ground. If there are no input signals connected to the diodes, the output will be +5 volts, or logic 1. Thus, an open input will not affect the rest of the circuit, which will continue to operate normally.

As with DL-OR gates, it is possible to add any number of input diodes to this circuit, each with its separate input signal. However, two inputs are quite sufficient to demonstrate the operation of the circuit.

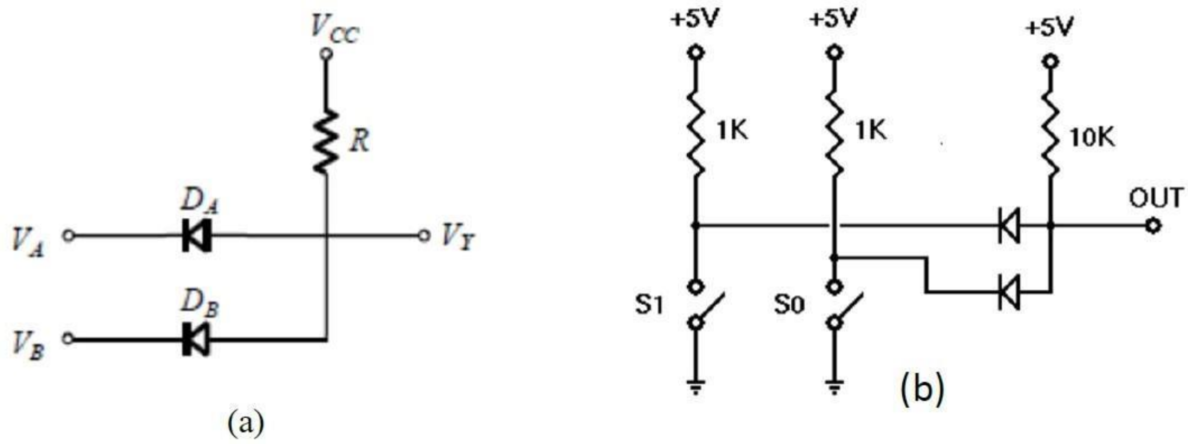



Fig.2 DL-AND Gate

Assuming the diodes are ideal, the voltage truth table of the above AND gate is as given in Table 2(a). The corresponding logic truth table is in Table 2(b).

| $V_A$ (volt) | $V_B$ (volt) | $V_Y$ (volt) |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 5 | 0 |
| 5 | 0 | 0 |
| 5 | 5 | 5 |

(a)

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

(b)

Table 2

***Two-Input DL AND –OR Gate:***

After looking at both the Diode Logic (DL) OR gate and AND gate and evaluating whether their operations were within acceptable parameters, the AND and OR gates will be cascaded. The OR gate will be used to combine the outputs of two AND gates and how well this combination works will be observed.

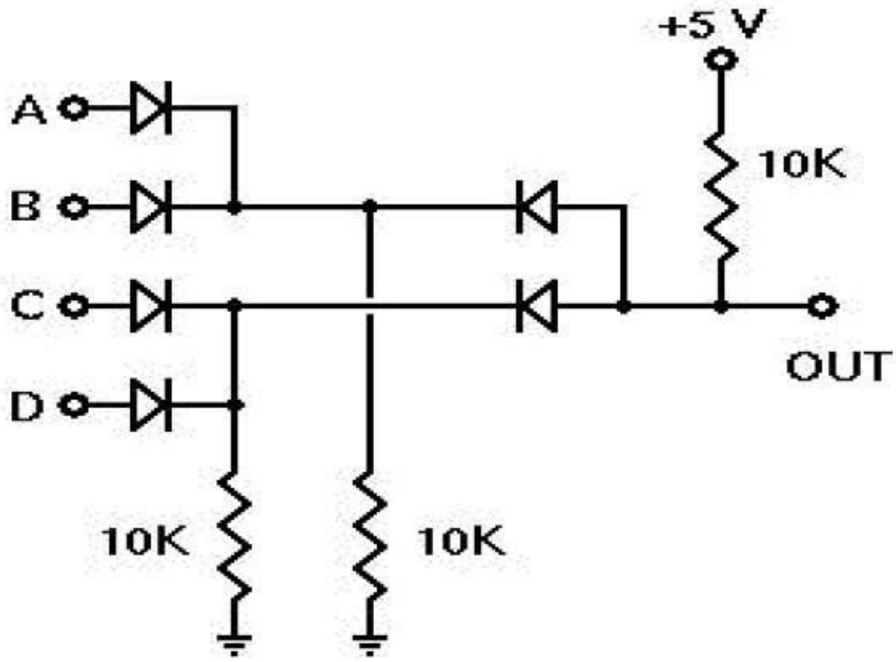



Fig.3 DL-AND-OR Gate

**Diode polarity:**

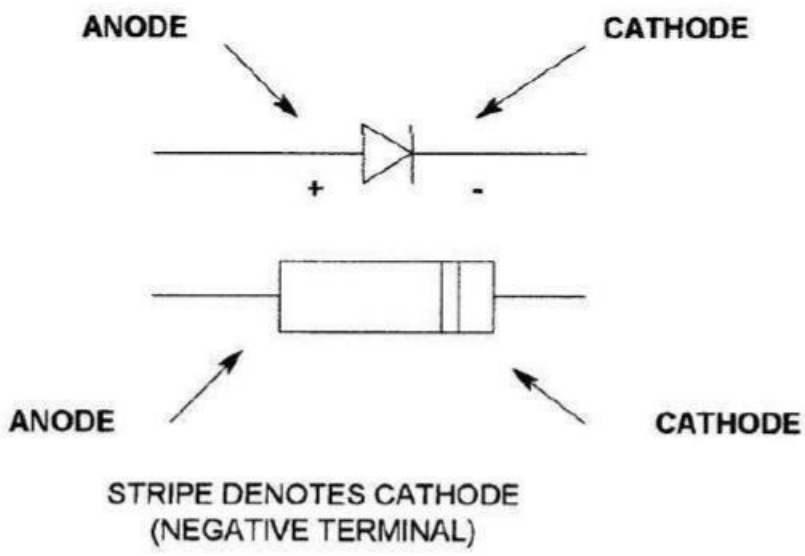
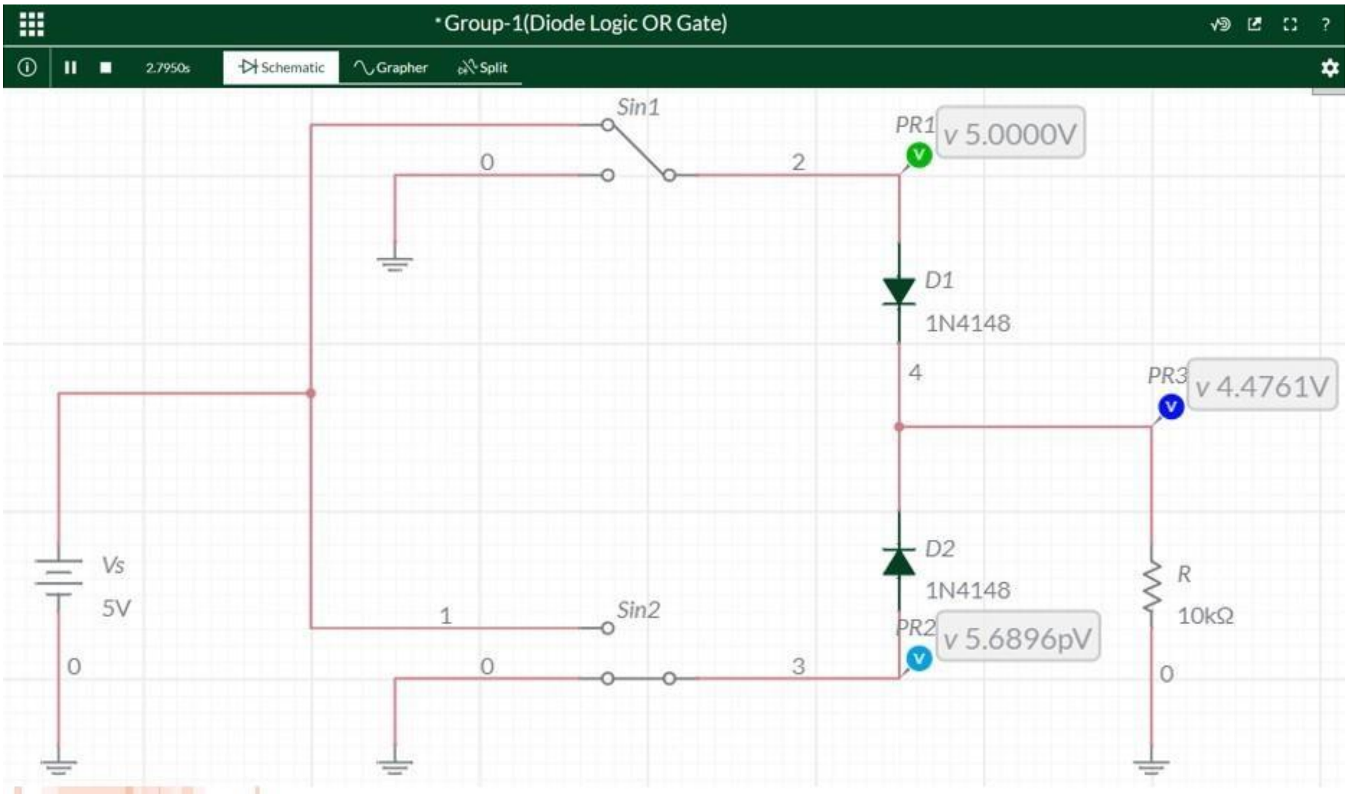


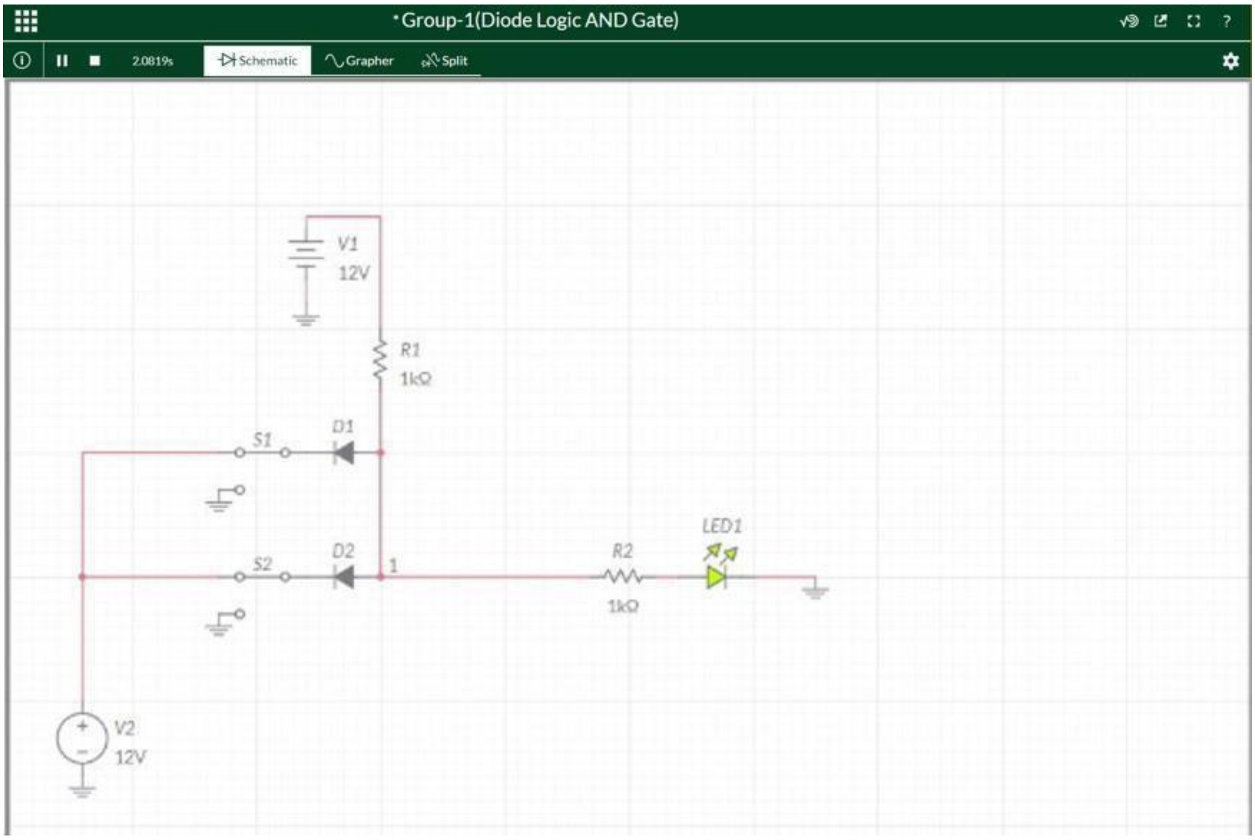

Fig.4 Diode polarity

## Simulation: Diode

### Logic OR Gate:




### Diode Logic AND Gate:




## Discussion:

If one or both inputs are at logic “1” (12 volts), the current will flow through one or both diodes. This current passes through the resistor and causes the appearance of a voltage across its terminals, thereby obtaining logic “1” on the output. We only get logic “0” (0 volts) on the output when both inputs are in logic “0”. In this case, the diodes do not conduct, there is no current through the resistor R and there is no voltage across its terminals. As a result, the voltage at V1 is the same as ground (0 volts). When both inputs are at logic “1″, the two diodes are reverse biased and there is no current flowing to ground. Therefore, the output is logic “1” because there is no voltage drop across the resistor R. If one of the inputs is logic “0”, the current will flow through the corresponding diode and through the resistor. Thus, the diode anode (the output) will be logic “0”. This method works fine when the circuits are simple, but there are problems when you have to make interconnections with such gates.

**Part 2: Construction of Bipolar Transistor Logic Gate Introduction:**

A bipolar transistor is a three-terminal semiconductor device. Under the control of one of the terminals, called the base, current can flow selectively from the collector terminal to the emitter terminal.

In this experiment we examine how to build logic gates from bipolar transistors using the RTL, DTL and TTL design.

## Theory and Methodology:

***Resistor-Transistor Logic (RTL):***

Resistor-Transistor Logic (RTL) is a large step beyond Diode Logic (DL). Basically, RTL replaces the diode switch with a transistor switch. If a +5v signal (logic 1) is applied to the base of the transistor (through an appropriate resistor to limit base-emitter forward voltage and current), the transistor turns fully on and grounds the output signal. If the input is grounded (logic 0), the transistor is off and the output signal is allowed to rise to +5 volts. In this way, the transistor not only inverts the logic sense of the signal, but it also ensures that the output voltage will always be a valid logic level under all circumstances. Because of this, RTL circuits can be cascaded indefinitely, where DL circuits cannot be cascaded reliably at all.

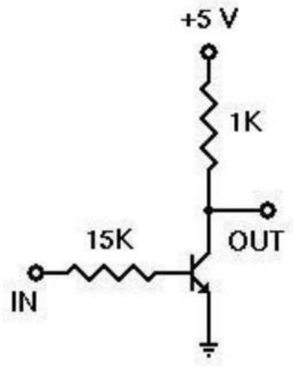



Fig.6: RTL Inverter

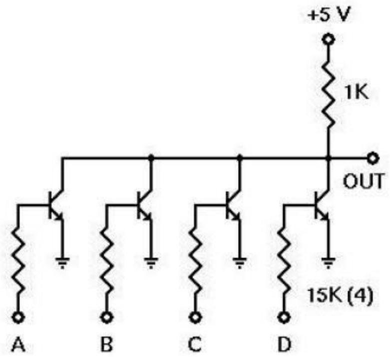



Fig .7: 4-input RTL Inverter

***Diode-Transistor Logic:***

Diode–Transistor Logic (DTL) is a class of digital circuits built from bipolar junction transistors (BJT), diodes and resistors; it is the direct ancestor of transistor–transistor logic (TTL).

DTL offers better noise margins and greater fan-outs than RTL but suffers from low speed (especially in comparison to TTL).

RTL allows the construction of NOR gates easily, but NAND gates are relatively more difficult to get from RTL. DTL, however, allows the construction of simple NAND gates from a single transistor, with the help of several diodes and resistors.

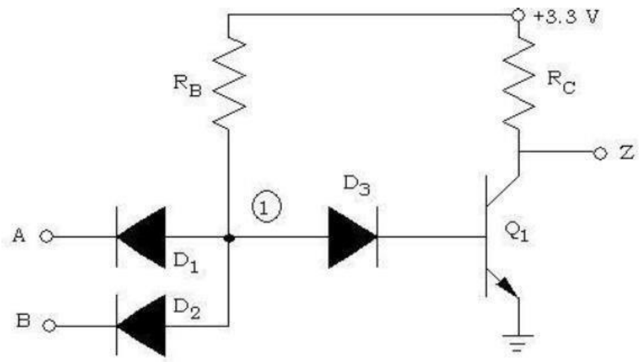



Fig 8: 2-input DTL NAND Gate

***Transistor-Transistor Logic:***

We can think of a bipolar transistor as two diodes placed very close together, with the point between the diodes being the transistor base. Thus, we can use transistors in place of diodes to obtain logic gates that can be implemented with transistors and resistors only; this is called transistor-transistor logic (TTL).

One problem that DTL doesn't solve is its low speed, especially when the transistor is being turned off. Turning off a saturated transistor in a DTL gate requires it to first pass through the active region before going into cut-off. Cut-off, however, will not be reached until the stored charge in its base has been removed. The dissipation of the base charge takes time if there is no available path from the base to ground. This is why some DTL circuits have a base resistor that's tied to ground, but even this requires some trade-offs. Another problem with turning off the DTL output transistor is the fact that the effective capacitance of the output needs to charge up through Rc before the output voltage rises to the final logic '1' level, which also consumes a relatively large amount of time. TTL, however, solves the speed problem of DTL elegantly.

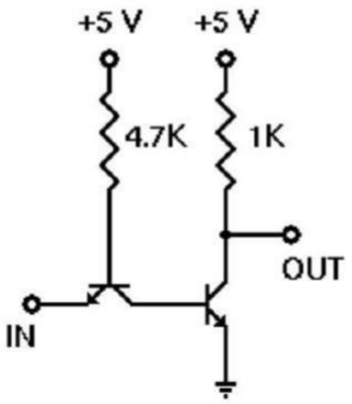



Fig 9: TTL Inverter

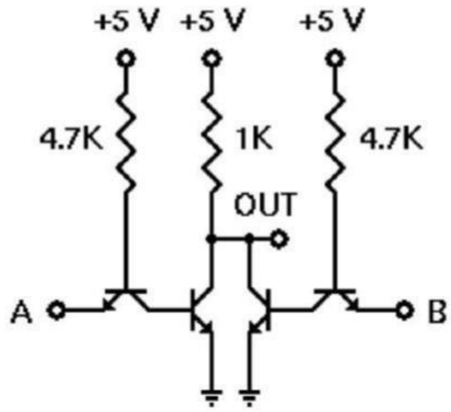
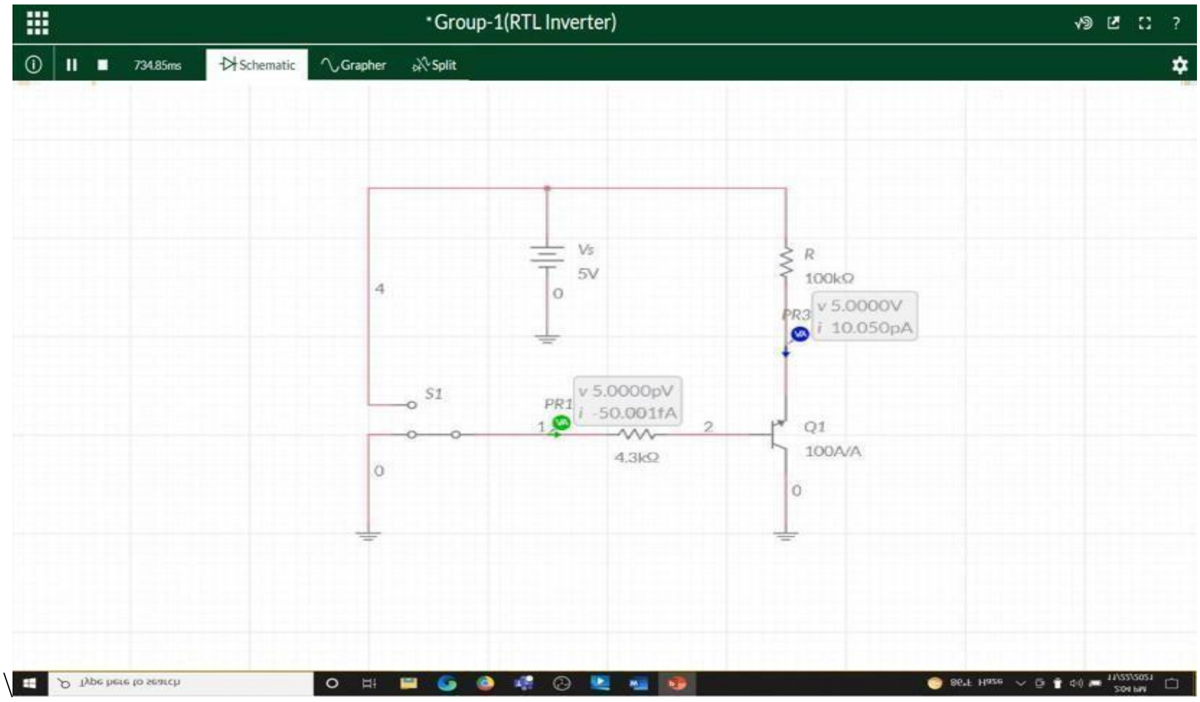



Fig 10: 2-input TTL NOR gate

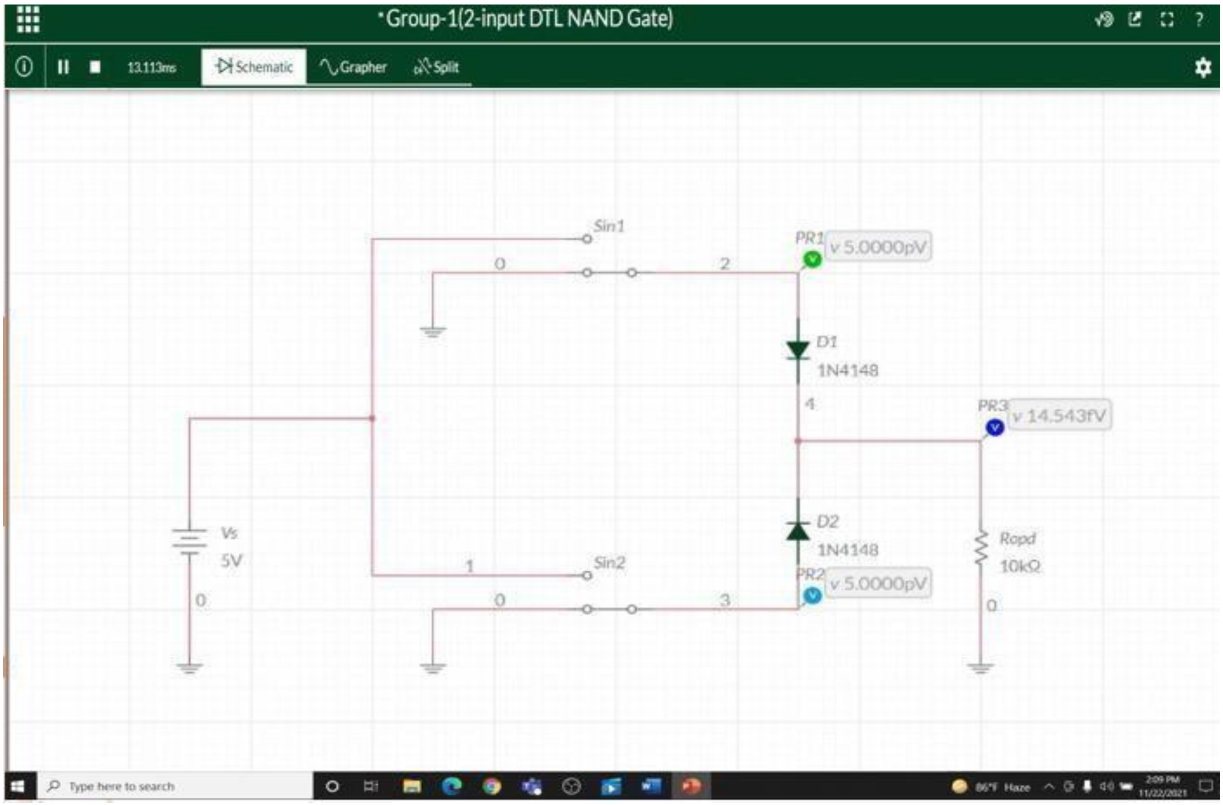
## Simulation:

### RTL Inverter



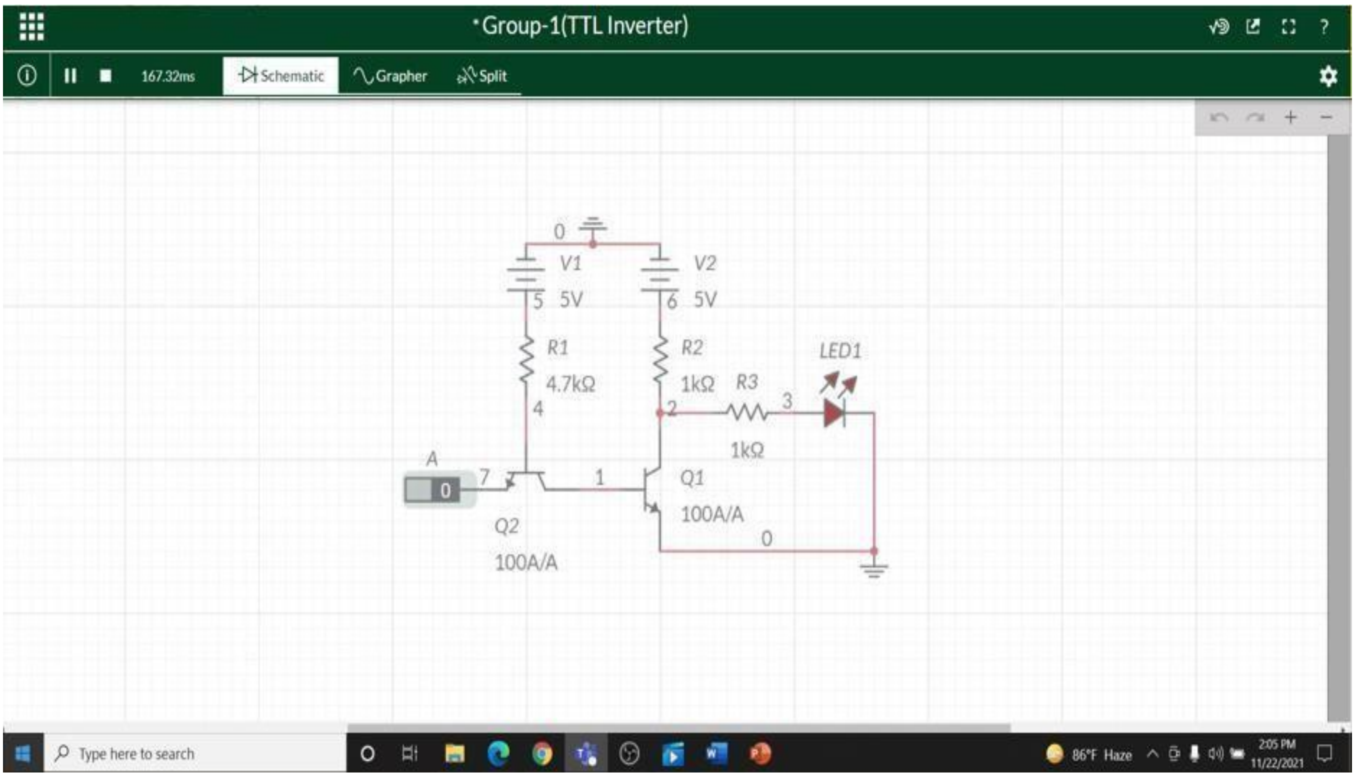
**Diode-Transistor Logic:**

**2-input DTL NAND Gate**

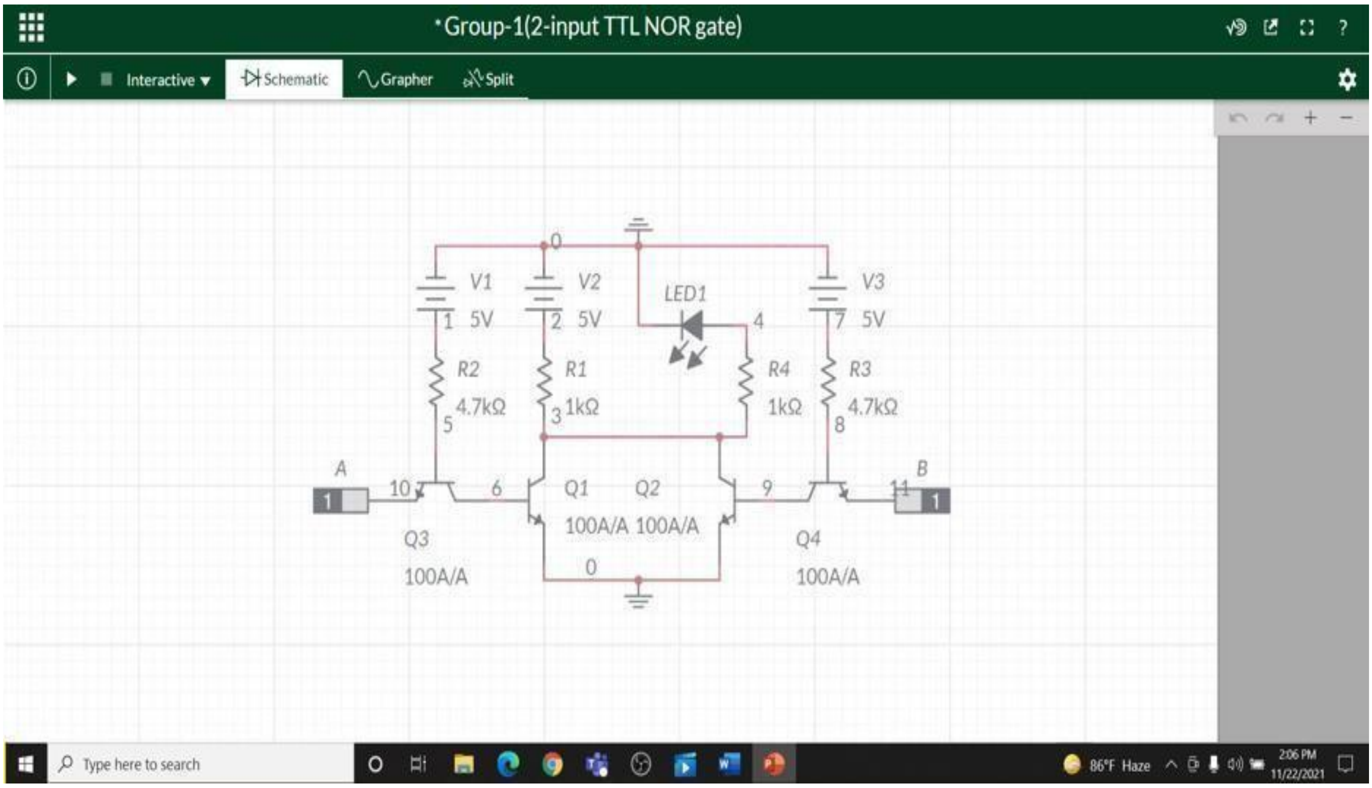



**Transistor-Transistor Logic:**

**TTL**



**2-input TTL NOR gate**




## Discussion:

Transistor-transistor logic (TTL) is a class of digital circuits built from bipolar junction transistors (BJT) and resistors. It is called transistor-transistor logic because both the logic gating function (e.g., AND) and the amplifying function are performed by transistors (contrast this with RTL and DTL).

TTL is notable for being a widespread integrated circuit (IC) family used in many applications such as computers, industrial controls, test equipment and instrumentation, consumer electronics, synthesizers, etc. The designation TTL is sometimes used to mean TTL-compatible logic levels, even when not associated directly with TTL integrated circuits, for example as a label on the inputs and outputs of electronic instruments.

## Reference(s):


1. Thomas L. Floyd, *Digital Fundamentals*, 9th Edition, 2006, Prentice Hall.