American International University- Bangladesh
Faculty of Engineering (EEE)
Digital Electronics Laboratory

Experiment No: 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.

Fig 2.1: Bipolar junction transistor circuit symbols

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.

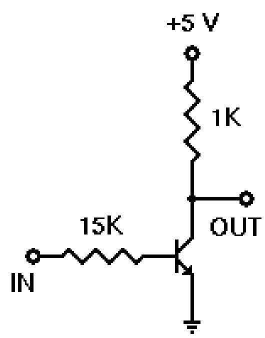


Fig.2.2: RTL Inverter

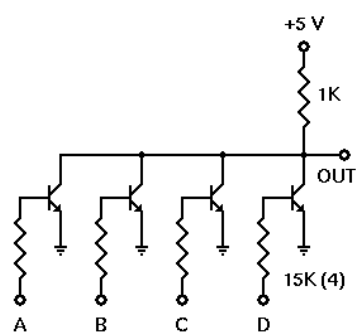


Fig 2.3: 4-input RTL Inverter

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.

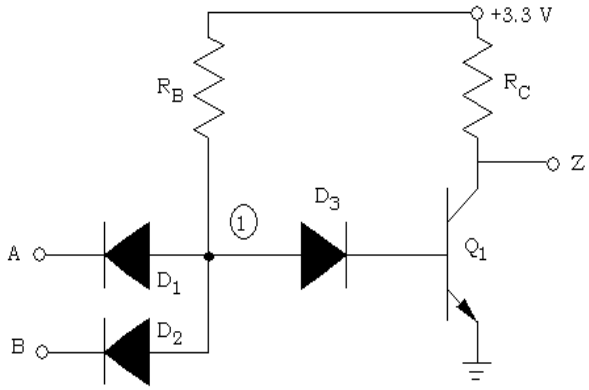


Fig 2.4: 2-input DTL NAND Gate

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.

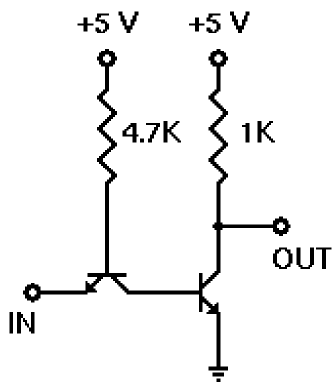


Fig 2.5: TTL Inverter

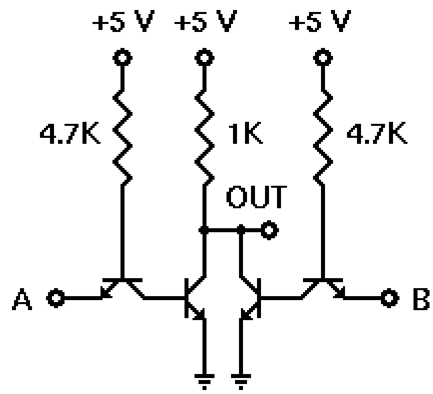
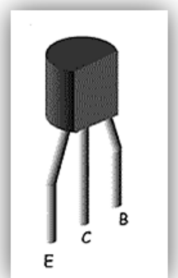


Fig 2.6: 2-input TTL NOR gate

BJT pin configuration:



Pre-Lab Homework:

Explain how n-p-n BJT transistors work?

Students must install PSpice/LTSpice/ Psim software and MUST present the simulation results using transistors to the instructor before the start of the experiment.

Apparatus:

1. 2N4124 NPN silicon transistor (or equivalent).
2. Resistors 15KΩ, 1KΩ, 4.7 KΩ
3. Connecting wires.
4. Trainer Board

Precautions:

Have your instructor check all your connections after you are done setting up the circuit and make sure that you apply only enough voltage (within V_{DD}) to turn on the transistors and/or chip, otherwise it may get damaged.

Experimental Procedure:

1. Set up the circuit for RTL inverter as shown in Fig.2.2.
2. For each input combination, find the output and place them in a Truth Table. The Truth Table should have two sets of outputs- one ideal and one experimental.
3. Repeat steps 1 and 2 for each circuit set-up from Fig.2.3 to Fig. 2.6.

Results and Discussion:

Students will summarize the experiment and discuss it as a whole. Interpret the data/findings and determine the extent to which the experiment was successful in complying with the goal that was initially set. Discuss any mistake you might have made while conducting the investigation and describe ways the study could have been improved.

Report:

1. For, each of the above set-ups, describe in words what the data means. Did your results match the expected ideal outputs? If not, explain why?
2. Design RTL and TTL 4-input OR gates.
3. Design 2-input TTL NAND and NOR gates.

Reference(s):

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