Lab 10. Light Emitting Diodes and Digital Circuits I   (R1)

Tasks marked by an asterisk (*) should be carried out before coming to the lab.

The Light Emitting Diode:

The light emitting diode (LED) is used as a probe in the digital experiments below. We begin by studying the properties of the LED.

The LED is first of all a diode. It passes current in one direction, but not in the other.

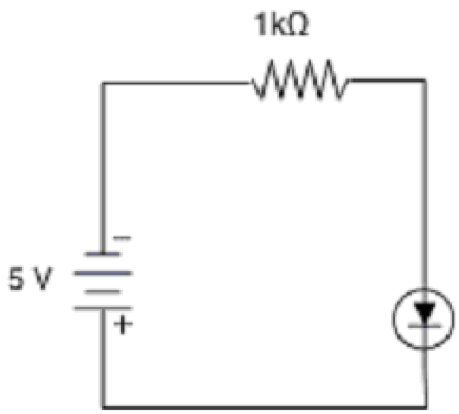


Figure 1: No current flowing.

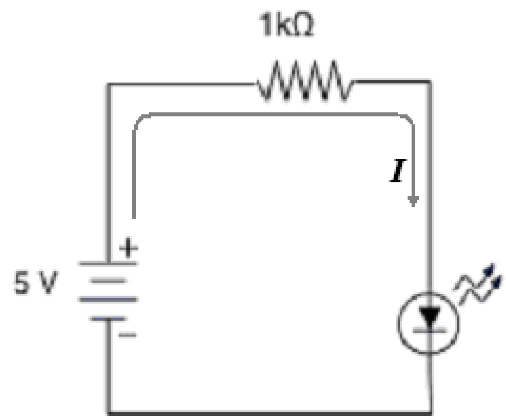
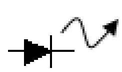
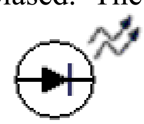


Figure 2: Current is flowing.

In Figure 1 the diode is biased in the backward direction or "reverse biased" and there is no current flowing through it whereas in Figure 2 the diode is "forward biased" and there is current flowing.

The LED gives off light when it is *forward* biased. The symbol for the LED is:

 or  .

The anode lead of an LED is typically longer. It is the left lead in the diagrams above.

Experiment 1:

Build the two circuits in Figs. 1 and 2 and observe that the LED glows in only one orientation. Use a variable voltage power supply and watch the LED intensity increase with increasing supply voltage.

Experiment 2:

Set up the forward-biased circuit in Fig. 3. You can study the operation of the LED by making two voltage measurements, one at the left side of the diode and the other at the right, as you change the supply voltage. Voltages should be measured with respect to the ground (negative terminal of the power supply). The difference between these voltages is

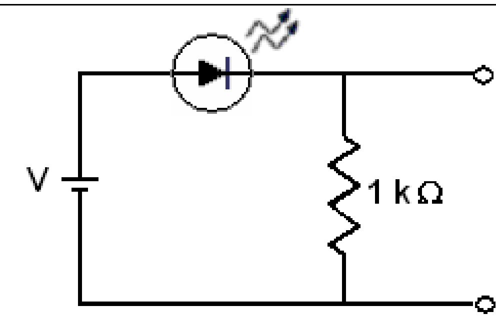


Figure 3: Measurement Circuit.

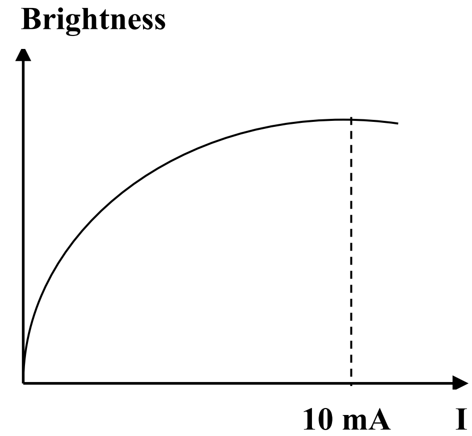


Figure 4: Brightness vs. current.

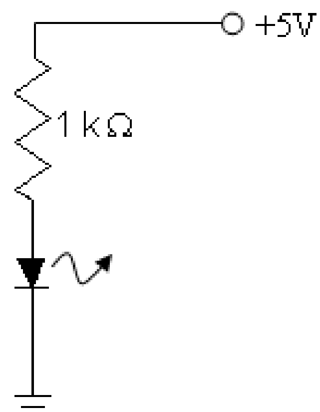


Figure 5: LED Circuit.

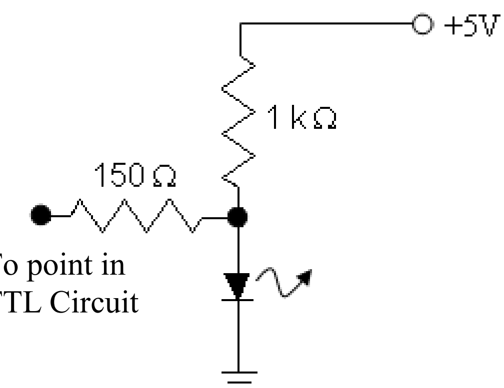


Figure 6: TTL Test Circuit.

the voltage across the diode. The voltage across the 1K resistor gives you the current through the diode. As you increase the supply voltage, find the diode voltage and current at which the LED starts to glow. Find the diode voltage and current where the brightness saturates. Find a few values of voltage and current in between these limits. You should find that, when the LED is glowing normally, the diode voltage is saturated at about 2 volts. The latter represents the typical forward voltage drop for an LED within the red-green color range. Blue and white LEDs are characterized by higher voltage drops.

Below, we use the circuit shown in Figure 6 to determine whether a point in a TTL circuit is logically high or logically low. If it is high then this point will not cause much voltage drop on the 1K resistor and the LED will glow. If the point is low then it will sink current, causing a voltage drop on the 1K resistor, and the LED will not glow.

7400 Quad Input NAND Gate

* Before doing this lab you should review the truth tables for the AND, NAND, OR and NOR gates in the textbook.

We consider a TTL (transistor-transistor logic) device called the 7400. It is part of the TTL family of digital logic devices whose names all begin with 74. All members of this family operate from a power supply of + 5V. The members are all compatible in that outputs from one can serve as inputs for another.

Most members of the family come in 14-pin DIPs (dual inline packages). Pin 14 is supposed to be connected to +5V and pin 7 is supposed to be connected to ground. These connections are so standard that we do not even bother to draw them for the circuits below.

The pin connections for the 7400 are shown in Fig. 7 below. Pin 1 is marked here and for other chips by a dimple on the case. Looking at the chip from the top, the pins are then numbered in a counterclockwise direction. In the following, you will use as few as one and as many as four individual gates of a quad chip.

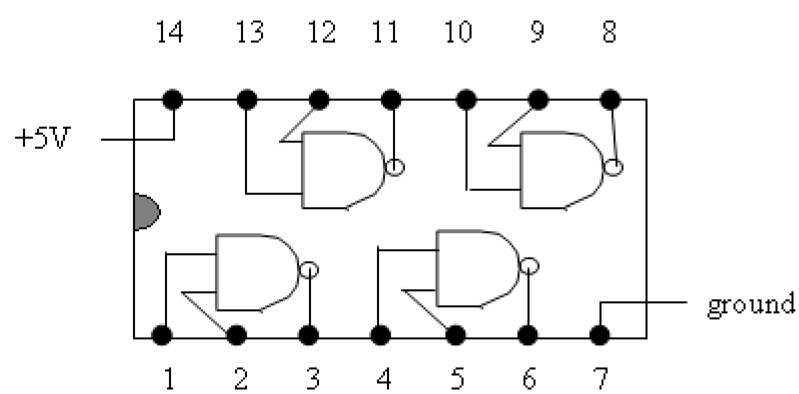


Figure 7: Pinout for the 7400 Quad NAND Chip

Figure 8 shows a circuit for demonstrating the principal operation of a two-input NAND gate. Note the LED indicator on the output.

The 3K resistors are known as “pull-up” resistors because they pull the two inputs to a high state. According to the NAND truth table, this is the only input configuration where the output is low and the LED is off. Points A and B may be grounded by means of a wire going to ground, to bring them to a low state. In this way you can create a zero on the input.

An open input pin on a logic circuit creates an uncertain state. With a pull-up resistor the state is certain, whether it be high or low. All the logic circuits in this lab use pull-up resistors.

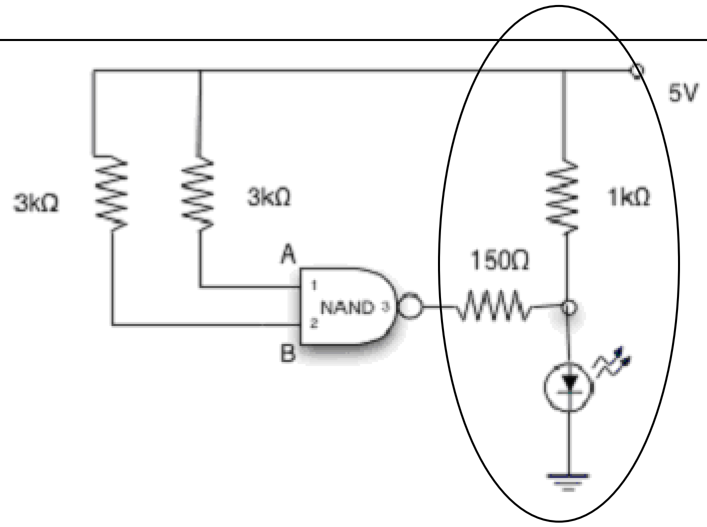


Figure 8: NAND Gate with LED Indicator

Experiment 3:

Build the NAND circuit in Figure 8 and verify its operation for all choices of the inputs A and B. Draw the circuit in your lab notebook.

A	B	AND(A,B)
0	0	0
0	1	0
1	0	0
1	1	1

Inverter Turns NAND into AND

You can make a logical inverter (turns 1's into 0's and 0's into 1's) by connecting the two inputs of a NAND together.

*First prove the above fact logically (i.e. on paper) by verifying the truth table for the inverter.

Experiment 4:

Convert your NAND circuit into an AND, as shown in Figure 9, and verify its proper operation.

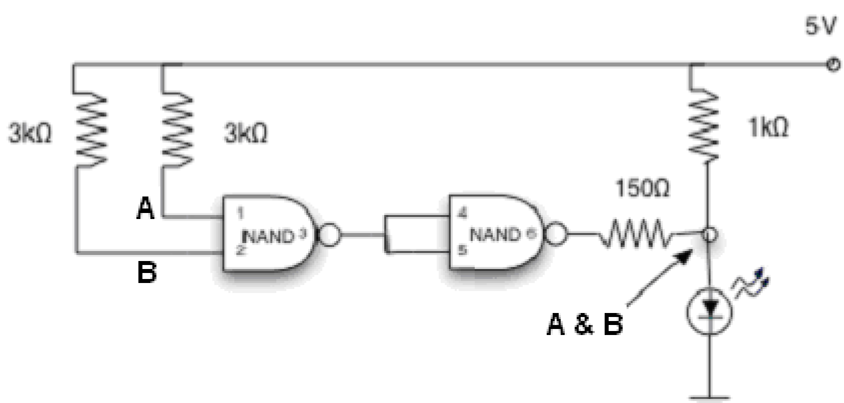


Figure 9: The AND circuit.

Three NANDs can make an OR

The circuit in Figure 10 inverts the two inputs to convert a NAND into an OR, in accordance with a DeMorgan theorem.

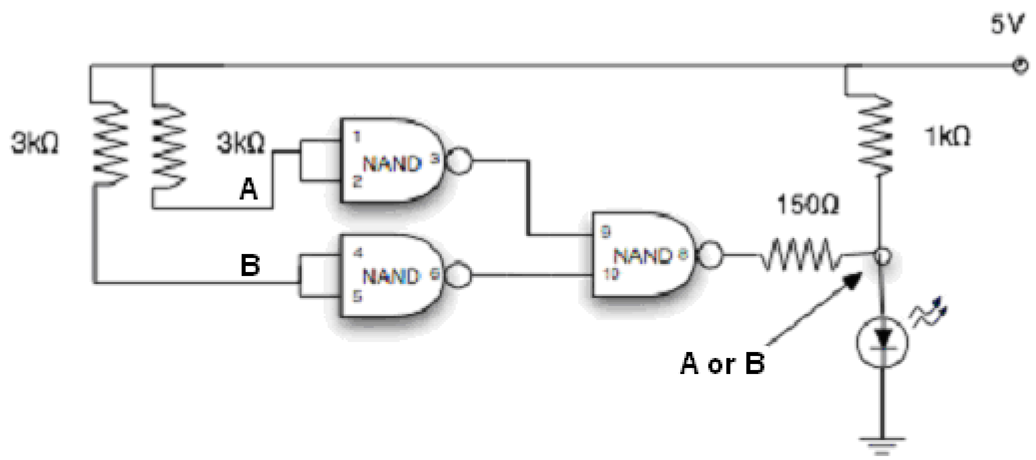


Figure 10: The OR Circuit.

Experiment 5:

Make the OR as shown and verify its proper operation according to the truth table.

A	B	OR(A,B)
0	0	0
1	0	1
0	1	1
1	1	1

Four NANDs can make a NOR

The circuit in Figure 11 inverts the output to convert an OR into a NOR. A much simpler way of getting a NOR circuit is by using a 7402, which is, in fact, a quad two-input NOR gate.

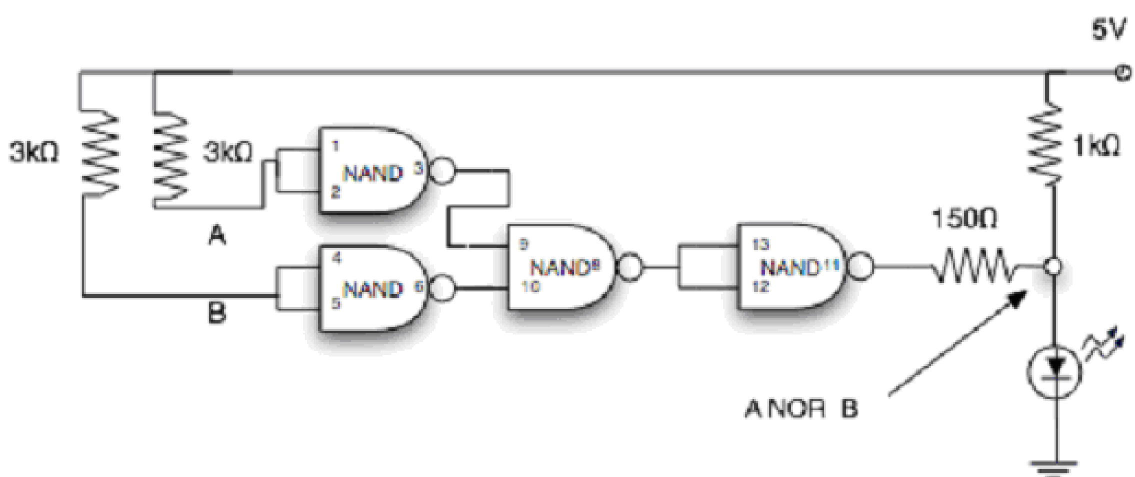


Figure 11: The NOR Circuit.

Experiment 6:

Construct the NOR circuit in Figure 11 and verify its operation relative to the desired truth table. Draw the circuit in your lab notebook. Demonstrate its operation to your instructor who will initial your drawing.

A	B	NOR(A,B)
0	0	1
0	1	0
1	0	0
1	1	0

The Flip-flop

The circuit in Figure 12 is a flip-flop made from two NAND gates. It has two stable states. By momentarily grounding input A you make output X go high and output Y go low. By momentarily grounding input B you make output Y go high and output X go low.

Experiment 7:

*Explain why the flip-flop states are stable. That is, explain why the states remain unchanged after the momentary ground is removed.

Build the flip-flop and test its operation. Draw the circuit in your lab notebook. Demonstrate its operation to your instructor who will initial your drawing.

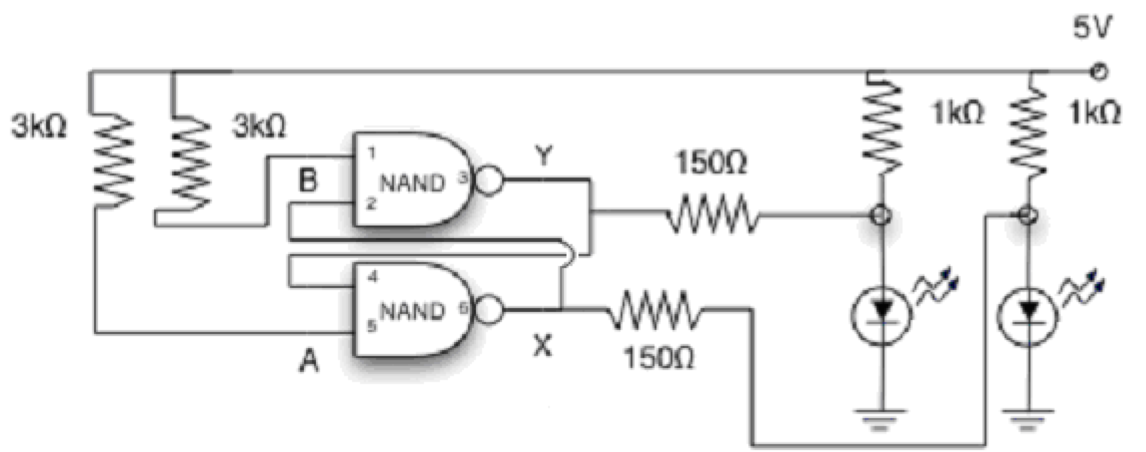


Figure 12: The Flip-Flop.