

Lab 6 Basic Digital Gates

Purpose:

Become familiar with the characteristics of digital logic gates and LEDs.

Equipment Required:

7400 Quad two-input NAND gate	Power Supply
Function generator	LED (Light Emitting Diode)
Decade Resistance Box (DRB)	Various resistors as needed

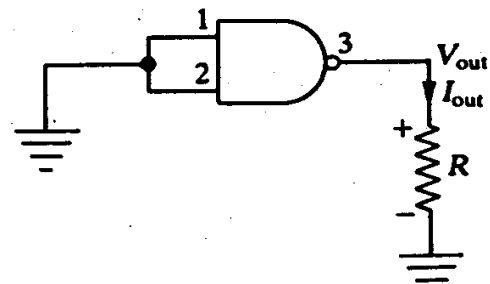
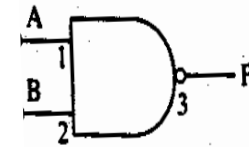
Pre-lab:

- 1) Read H&H 575-576 and 590-591.
- 2) Write a brief description (a sentence or a table or a drawing) demonstrating your understanding of the meanings of the following terms in the context of this lab: pull-up resistor, thresholds, hysteresis, TTL logic levels (guaranteed input HIGH and LOW voltages), Thevenin output voltage and resistance, and fan-out.
- 3) In your journal, write the truth tables for a NAND and NOR gate
- 4) From the datasheet on web site: What is the maximum HIGH input current rating, minimum input HIGH voltage, and maximum input LOW voltage of the 7400? Assuming the 7400 sinks the maximum input current (Use rating for $V_{CC} = \text{MAX}$, $V_{IN} = 7.0 \text{ V}$), what is the maximum resistance of a pull-up resistor tied to 5V to guarantee a valid HIGH input voltage?
- 5) What is the minimum resistance of a $\frac{1}{4} \text{ W}$ resistor so that it does not burn out when connecting from the TYPICAL output HIGH voltage of 7400 to ground? What is minimum resistance for a $\frac{1}{4} \text{ W}$ resistor connection from 5V to ground?

Procedure:

1. Characterize 7400 series logic gates.

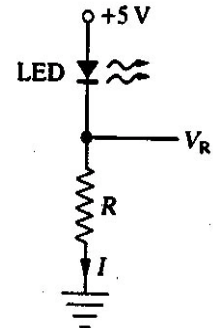
- a. Look up pinout of 7400 NAND gate (on web site). Connect +5V to V_{CC} (pin 14) and ground to pin 7. Put a pull up resistor (about half the maximum resistance calculated in pre-lab) on each input (A and B). Put a load of 10kOhms on "F". To get LOW inputs at A or B, use a wire directly connecting the input to ground. Verify that the NAND functions as claimed in this truth table. Measure the actual voltages at "F" for all possible combinations inputs to A and B. Also measure voltages across pull-up resistors when A and B are in the high state. Calculate input HIGH current for your 7400 and compare with maximum input HIGH current rating for the 7400.
- b. Thresholds: With "A" held high with pull up resistor, use a function generator to vary B with a 0V to 5V triangle wave (1kHz). Monitor input and output on scope. Determine the input HIGH and LOW thresholds of the 7400. Measure hysteresis (the difference between these thresholds). If hysteresis is close to 0V, determine an upper bound on the hysteresis.
- c. Fan Out: In this section you are to determine the output IV characteristics of your 7400.. "Fan out" is a measure of the number of devices that can be operated from a digital gate before the output voltage level becomes equivocal. Construct the circuit shown to the right. Use your DRB for the resistor R. Measure V_{out} as a function of I_{out} by varying R until V_{out} is 0.2V below a valid HIGH voltage. Don't use a resistance of DRB below the minimum calculated in pre-lab. Use fixed higher power resistors if needed.



- d. Low output voltage and current: Set both inputs high via pull-up resistors. Use DRB to measure V_{out} versus R starting at $R = 500$ ohms and decreasing R by 50 ohm steps to 100 ohms and then decreasing in 20 ohm steps until I_{out} reaches 10mA.

2. Light Emitting Diodes

An LED can be destroyed if it carries too much current. A common method of current-limiting an LED circuit is to include a series resistance. A loop equation ($V_S = i_D R + V_D$) allows you to size the resistor based on the source voltage, diode voltage drop, and the desired diode current. Your goal is to test the diode to failure (a.k.a. destructive testing). We will first use a current limit resistor (your DRB) as R while keeping resistance above the minimum calculated for 5V to ground in pre-lab. Start with 20kohm, 15kohm and 10kohm. Then decrease in 1kohm steps from 10kOhm to 1kohm, then decrease in 100 ohm steps while staying above minimum resistance. Then switch to using the constant current mode on your power supply to limit output current, starting at 10mA and raise current slowly in 10mA steps, pausing at each current. As you go through this procedure record both quantitative of voltages and resistance and qualitative observations of the brightness of the LED. Continue until brightness drops to zero (“burn out”). Record your observations about the failure of the LED, including voltage changes. Does LED light up again or does voltage change if you do back down in current? When finished throw your poor abused LED in the trash.



Data Analysis:

- a. Plot V_{out} versus I_{out} for you 7400. What is the maximum source current, I_{out} , for which V_{out} is a valid TTL high? What is the apparent Thevenin output voltage and impedance (R_{TH}) of your 7400 device? Plot V_{out} versus I_{out} for this equivalent Thevenin circuit.
- b. Make a table of v_D versus i_D for your LED along with your qualitative estimates of the “brightness” of the LED. Plot v_D versus i_D .

Conclusion:

- 1) Approximately how much current is necessary to make the LED appear bright in a lighted room? What is the approximate voltage drop across the LED when it is just sufficiently “bright” to be an indicator in a room with typical lighting? Is voltage v_D essentially constant as long as the LED is lit or does it vary? At what level of current did your LED fail? What was the diode voltage drop at failure?
- 2) Use the combined data you have taken in the lab to answer this question properly. The binary (on-off) nature of an LED indicator is a great match for creating “user-friendly” interfaces (MMI – man-machine interface) to logic circuits (see figure). While the current needed to drive an LED is small, it is not insignificant. Use the “Fan out” data you acquired for your 7400 and the LED current-voltage-brightness data to estimate how many LEDs could be driven in parallel by your 7400 chip with “sufficient” brightness to act as indicators while still maintaining the 7400’s minimum HIGH TTL output level. Draw a circuit similar to that above, but with the 7400 driving multiple LEDs. Include any and all resistors you would include in your circuit to maximize your fan-out (number of sufficiently bright LED indicators lit by one output of your 7400.). Make sure LEDs are off when 7400 is in LOW states. What resistor(s) values, if any, would you use in your circuit to get the maximum number of LEDs lit? Explain your reasoning.

