PHYS 344 Experimental Techniques  
Laboratory #8  
INTRODUCTION TO DIGITAL CIRCUITS  
Due January 14

Equipment

Solderless breadboard, 5-v power supply, LED’s, resistors, ICs, a 350-Ω potentiometer, oscilloscope, DVM, and hook-up wire (#22, not larger).

Preliminary

Draw the pin-out diagrams for the following integrated circuits, using either a data book or a web source such as http://www.embeddedlinks.com/chipdir/.

7400 Quad 2-input NAND
7402 Quad 2-input NOR
7404 Hex inverter

NOTE: the pinout is the same for all varieties of each chip type. For example, the pinout for the 7400, 74F00, 74HC00, 74S00, and 74LS00 does not vary.

1 Digital Gates

1.1 Good TTL logic highs and lows

Using a 7400 quad NAND, assemble the following circuit. It is implied that the power connections of the chip (pins 7 and 14) are connected! Adjust the power supply to 5.0 v using a voltmeter.

The output should be high when the input is low, and vice-versa. While observing the output on the scope, vary the input voltage from 0 to +5 v using the potentiometer. Graph the output versus input voltage (a small graph using your ruled notebook paper will do). The x-axis should go from 0 to 5 v. Generally, a good TTL high is >2.0 v, and a good TTL low is <0.8 v. Do your results conform to this?

1.2 Floating (unconnected) inputs

Modify your circuit above to look like those below, monitoring the output with the scope. In each case, record what the output is, high or low. Therefore, what is input B acting like: a low (0) or a high (1)? So, a floating TTL input acts like what logic level?

Note: Never try to define a high on an input by leaving it floating! Either ground it or connect it to +V_{CC} through a 1K resistor. If the gate is not being used, then for TTL you may leave the inputs unconnected. However, with CMOS you must define every input on the entire chip. This is worth repeating:

With TTL, define a high with a 1 K resistor between +5 v and the input. For a low, just ground the input.
2 Light-emitting diodes

We will sometimes use these as indicators of digital outputs. Hook up the circuit below. If the LED does not light, then you have the polarity wrong – reverse the diode. If it still does not light, the LED may be burnt out (someone put too much current through it). Try another diode.

\[
+5 \text{ V} \quad \text{330 ohm} \quad \text{LED}
\]

Measure the voltage across the 330-Ω resistor and calculate the current through the diode. Now try three other resistors: 220 Ω, 470 Ω, and 1 K. In each case measure the resistor’s voltage drop and calculate the current. How much current (roughly) is necessary for good visibility of the LED? We will use the 330-Ω value in most cases. (By the way, would you ever hook an ordinary diode from Vcc to ground? Well, don’t do it to an LED either — it may explode.)

Comments on LED use. (1) You can often hook the LED either way: anode grounded or cathode grounded. (Recall: the anode is the side where the current goes in: it is the P-doped side.) If you ground the cathode, and hook the anode to the gate output through a resistor, then a HIGH will light the diode. Hooking it the other way, a LOW will light the resistor. It is very common to ground the anode, especially in displays employing LEDs. The reason is that logic gates can often sink more current than they can source. It then makes sense to light the LEDs with a logical LOW.

(2) You now know how to use discrete LEDs to indicate logic levels, but you will not often do it in lab. Instead, just use the LED indicators available on our digital training units. We have two types: the “Wish-Maker II” and the “Global Specialties Proto Board.” On either one, the LEDs light red for high and green for low. The difference is that the Wish-Maker uses two-color LEDs and the Proto-Boards use separate red and green LEDs. You don’t need to use a series 330-Ω resistor with these; just hook wires directly to the outputs.

3 Some digital circuits

3.1 A one-chip circuit

Using a 7400 quad NAND, assemble the following circuit.

To establish LOW and HIGH levels, use the switches provided on the prototyping units. (You do not have to use a 1K resistor when defining a HIGH with these.) The switches make it very easy to try the four different input combinations available. Power up the circuit and determine the truth table experimentally, by applying combinations of high and low signals to the inputs. Does it function as you would predict?

Determine the Boolean expression for the output, in terms of A and B. What is this circuit called?

3.2 Another circuit

Using 3 ICs, wire the following circuit. Determine its truth table experimentally and from this, describe its function. Use Boolean algebra to show that its output is described by a Boolean expression familiar to you by now.
3.3 Decoders

A single-output decoder is a circuit which looks at its inputs and makes the output go high only when there is a particular combination of 1’s and 0’s on the inputs. (Alternatively, of course, the output could go low and be high for all other conditions). A four-bit decoder may be represented:

![Decoder Diagram]

A decoder for $ABCD = 1110$ is illustrated below.

![Decoder Diagram]

Your job is to design a 4-bit decoder for which the output is high for either $ABCD = 1010$ OR $ABCD = 0110$, but low for any other combination $ABCD$. Use only 2-input gates. In your notebook, make it clear how you obtained the solution; give your reasoning and show the Boolean algebra.