Lab 1 Mystery Circuit

Deadlines & Grading

- **Prelab**: Monday, February 3, 2014 at 1:00 PM – **to be done individually**
- **In-Lab Exercises**: Monday, February 3 / Tuesday, February 4 – **in groups of 2**
- **Lab Report**: *none*

Section I: Overview

As this will be the first lab in electrical engineering for most of you, this exercise will cover some of the basic skills necessary for building and analyzing circuits. You will be required to build a mystery circuit in lab. The only thing you know about the circuit is how it is to be wired together, and what its *truth table* is. You will first put this circuit together on your breadboard, and then reverse engineer the circuit to discover which *logic gates* are inside the circuit. By the end of the lab session, you should be comfortable with handling *integrated circuits* (ICs) and *breadboards*.

Section II: Prelab

For this lab, the prelab will consist solely of having you read two tutorials, and then installing Quartus (a widely-used programmable circuit design application) on your personal computer. **Make sure you start early** – the Quartus installer is a very large download on the order of gigabytes, and those of you running Macintosh OS X will also need to download and install Windows 7 on your computer, which will involve a separate large download. While downloading can be done in the background, you still need to allot several hours for it to complete. Installation can take a long time too, especially if you need to install Windows.

ASSIGNMENT 1 Read *Tutorial A: Wiring and Testing Circuits* thoroughly.

ASSIGNMENT 2 Read and complete *Tutorial B: Installing Quartus II*.
1. Download the tutorial from Blackboard.
2. Download and install Quartus II and ModelSim-Altera (see tutorial).

While there are no deliverables for this lab, you must complete this activity before coming to your first lab session. You will be using Quartus for most of this semester, and will be required to do preparatory work using the software before lab sessions. Keep in mind that while the computers in Phillips 318 have Quartus installed, they use a slightly different version that may create some compatibility issues with the version that we use in class.

Section III: Lab Exercises

A. Circuit Assembly

Figure 1 shows how we need to wire our ICs (the chips) together. In your box of components, you will find chips with white labels on them, marked **A**, **B**, and **C**. Start by assembling this circuit on the breadboard.

Refer to *Tutorial A* to see how to properly wire the chips. Some things to keep in mind while working on this lab:

- Make sure all switches on the proto-board are set to **TTL** or **+5** (which is our value of $\mathbf{V_{CC}}$).
- Above the breadboard, only use the very top (**+5**) or very bottom (**GND**) horizontal rails for your power sources. Using the middle rails can damage the chips!
- Always make sure to hook up **GND** (pin 7) and $\mathbf{V_{CC}}$ (pin 14) to the chips properly. For this lab, do not connect any other pins to either **GND** or $\mathbf{V_{CC}}$.
- Make sure all of the notches on the chips face up.
- Remember to straddle all chips across the U-channel of the breadboard, to prevent pin shorts.
- Once the pins are aligned with the breadboard holes, make sure you press them so they snap into place.
- It is strongly recommended that you add wires one chip at a time, in order to reduce confusion.

As a refresher from *Tutorial A*, remember that the pins on the chip are numbered from the top left down, and then going back up, in a counter-clockwise manner. Typically, in 7400 series chips, the bottom left pin is always **GND**, and the top right pin is always $\mathbf{V_{CC}}$. Note that the notch in the chip always faces up when determining the pin numbers.

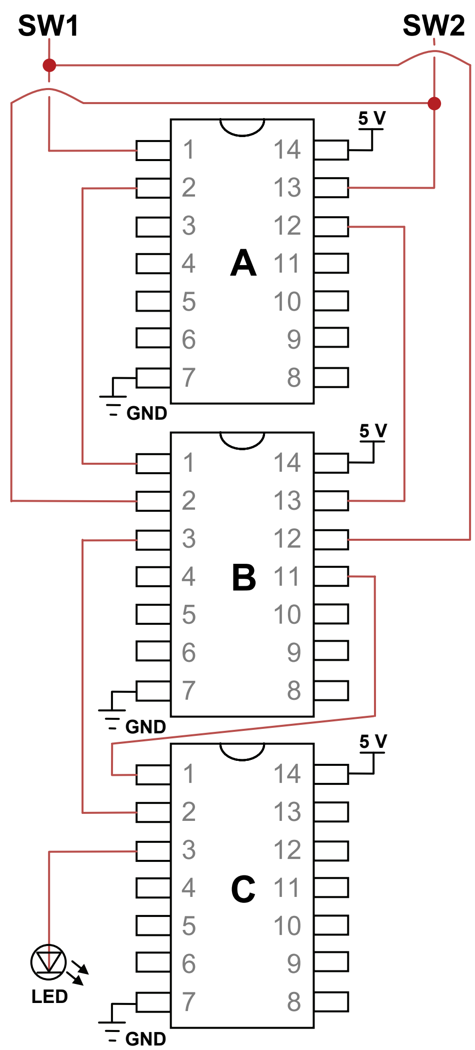

Figure 1. Pin diagram for mystery circuit.

> **NOTE 1** Make sure that you properly hook up both $\mathbf{V_{CC}}$ and **GND**, and that you straddle all of the chips across the U-channel of the breadboard. **Failure to do so will cause an electrical short, which will burn out the chip.**

Truth tables are an exhaustive way of representing the logical output of a circuit. These truth tables can have any arbitrary output on the right-hand side, depending on what circuit we want to implement. We have provided a truth table (see Table I) for the expected output of the mystery circuit in Figure 1.

SW1	SW2	LED
OFF	OFF	LOW
OFF	ON	HIGH
ON	OFF	HIGH
ON	ON	??

Table I. Partial truth table.

You should verify your circuit's output against that of the truth table to ensure that you have correctly assembled the circuit. We have left out one of the entries in Table I; **you must successfully discover the correct output for the fourth entry as part of your check off.** When a switch is off, or the low (red) LED on the protoboard lights up, the output is at ground (**GND**), which we refer to as outputting a **0**. When the switch is on, or the high (green) LED on the protoboard lights up, the output is at **+5V** (**V_{CC}**), which we refer to as outputting a **1**.

Once you are sure that your circuit is indeed working as expected, have a TA check you off.

B. Reverse Engineering the Circuit

Now that you have a fully working circuit, you will now try to use only the output signals to determine what the logic gates are that make up this circuit. In order to do this, you must systematically walk through the circuit, tracing where the inputs (which in our case are the input switches **SW1** and **SW2**) go into.

On each chip, pins can either be an *input* or an *output*. You need to be careful with this terminology, because a wire between two chips connects the output of one chip to the input of another chip. Therefore, **it is best that we classify pins, and NOT wires, as inputs or outputs**. For our mystery circuit, any wires that connect chip **A** and chip **B** together are actually connected to output pins on chip **A**, and input pins on chip **B**. Likewise, any wires connecting chips **B** and **C** together are actually connected to output pins on chip **B**, and input pins on chip **C**.

First, find out which pins are inputs and which pins are outputs. **You should never connect an output pin directly to +5V or to GND.** Once you have done this for each pin, you can start figuring out what the actual logic gates are, one gate at a time. Remember – each logic gate consists of a few inputs (in our case, only one or two inputs) and a single output, and each chip contains several logic gates. Start by figuring out what the first gates (the ones connected to **SW1** and **SW2**) are.

In order to find out what the logic gate is, you should connect the output of the logic gate to the LED. Then, you should toggle **SW1** and **SW2** so that the inputs going into the gate are exhaustively tested for every input combination. (You can verify the input values by connecting the input pins to LEDs on the protoboard as well – as long as some wire is coming into the input pin, you can observe its voltage using an LED.) When you do this, make a truth table for the gate that you are currently testing, and fill it in. Using this truth table, you can determine what the gate is, as it should match a Boolean function that you have already seen in lecture.

Once you have figured out all of the logic gates, you should draw a diagram of the mystery circuit using Boolean logic gates. When you have completed this, have a TA check you off.

Before leaving the lab:

- Make sure that you have had a TA check off all parts of your lab, including parts that aren't fully working if time is up.
- Turn off the proto-board, using the large switch at the top left.

- If you have used the computer, make sure to **save all files remotely** and then log off. Upon logging off, the computer automatically deletes any files that you created, so be careful!
- Clean your bench.
    - Place all wires in the plastic box at the front of class. Return any borrowed cutters and screwdrivers.
    - Use a small flat-head screwdriver to gently pop all chips out of the protoboard.
    - Return all ICs to their correct slot in the box, and return the box to a TA.
    - Throw out any stripped insulation or other garbage.