Parts List

- Resistors: 1 kΩ pull-up resistors, 10 kΩ variable resistor
- ICs: 7400, 7402, 7408, 7432, TIL311 (7-seg display)

1.1 General Lab Introduction

All relevant data, calculations, observations, and responses to questions in the lab handouts should be recorded in a lab notebook, which should be a hardcover composition notebook. Prelab writeups are not required, although reading through these instructions will be quite useful. All material to be turned in should be included in the lab notebook. Label your notebook entries with the corresponding section number from the handout. There should be one student per lab station, and it is expected that all students become familiar with electronics techniques. Students should feel free to compare notes and help each other during the lab sessions, however. It is a good idea to always have a prediction of what you expect to see for each lab task. If you don’t see what you expect, most likely there is a problem with your circuit. Check with your TA if you are not sure of your results!

1.2 Goals of this Lab

An introduction to basic concepts of binary numbers and logic, and familiarization with some lab tools. We will be working with integrated circuit chips (ICs). Here are a few rules to follow:

- Always turn off the power on your prototyping board before inserting any ICs.
- Be careful to avoid reversing power connections. Typically we only need +5 V and 0 V (ground) connections for digital circuits. Ask your T.A. for help with setting up power busses on your prototype board if in doubt. All ICs must be powered, you will get very strange and confusing results if you forget.
- We will primarily be using TTL circuitry. Do not connect TTL outputs directly together, as the resulting circuit will not work. Also, unconnected TTL inputs will usually “float” up to the high level. However, it is not good practice to count on this property, and “pull-up” resistors connected to +5 V should be used to maintain a high input.
- Get used to using a logic probe to check your connections. Make sure to power the logic probe as well.

1.3 Binary Generation and Translation

1.3.1 Generating a Binary Signal

As a simple exercise in binary generation, connect four of the DIP (dual in-line package) switches to four LED logic indicators on your prototype board. Make each connection as shown in Figure 1 (the schematic shows the connection to the LED for this part and for the IC in the next section). The DIP switches are set up to choose either ground or open (verify this with a multimeter—there may be integrated pull-up resistors in the newer, blue-box versions of the proto-boards). The pull-up resistor should be in the range ∼ 1 kΩ, but the exact value is not important. Check that the LEDs respond as expected to the switch positions. Verify that the four LEDs can be used to represent 16 digits numbered from decimal 0 to 15 in binary notation.

1.3.2 Hex Display

The four bits can be encoded and displayed as a hexadecimal digit using the TIL311 chip connected as shown in Figure 2. The TIL311 consists of an array of LEDs which form the digit (the “8” in the figure) and a logic-decoder chip (visible at the position of the small square in the figure below the LEDs). Be careful with the TIL311’s—they’re no longer manufactured, so they’re rare and none too cheap. Wire up your four DIP switch bits as the inputs (a0,a1,a2,a3) to the TIL311, as indicated in the figure, also retaining the connections to the previously used logic LEDs on the prototype board. In this way, you can observe both the binary LEDs and hexadecimal display.
Figure 1: One of four DIP switch to logic LED connections.

Figure 2: Pin diagram for the TIL311
Make a truth table as shown below. Cycle through all switch combinations and complete the table. What do you observe on the TIL display for binary inputs larger than 1001? Does it produce the hexadecimal digits A—F?

<table>
<thead>
<tr>
<th>Binary Number</th>
<th>Binary Display</th>
<th>Observed Hex Digit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>off-off-off</td>
<td>?</td>
</tr>
<tr>
<td>to 1111</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.4 Logic Gates

We will explore some standard logic gate ICs. Figure 3 indicates the pin assignments and function of a number of standard logic ICs. Note that all chips in this 74XX family have power and ground in the same place.

Detailed specifications can be found in the data books in the lab room, although it is not likely to be needed here. Recall that, for example, the designation 7408 is a generic label for ICs which could be marked 74LS08 (TTL), 74HC08 (CMOS), or 74HCT08 (TTL-compatible CMOS). We will typically use HCT, but all have identical pin assignments ("pinouts"). To determine orientation, the ICs usually include a cutout on the edge between pins 1 and 14, and may have a circular mark near pin 1 (viewed from above), as shown.
in the diagram below (a circular mark along the centerline of the chip does not count; a pin-1 circle will be distinctly in a corner).

Output states can be measured with a DVM, oscilloscope, or logic probe. Start by using a DVM or oscilloscope, but then verify your results with a logic probe. Don’t forget to power the probe! Logic probes are much more convenient to use in debugging digital logic than other devices.

1.5 Truth tables and thresholds

Apply \texttt{HIGH} and \texttt{LOW} inputs from your DIP bits to one of the AND gates of the 7408. You can either wire the output to an LED, or simply use the probe to observe the output. Measure the outputs for the 4 input combinations and make a truth table. Repeat these steps for one 7432 OR gate and for one 7400 NAND gate. Don’t forget to turn the power off when switching ICs.

1.5.1 Variable Input

Connect the ends of a 10 kΩ variable resistor (either on the prototype board or a separate one) to +5 V and ground. The voltage from the center tap can now be varied. Connect the variable voltage to the two inputs of a 7400 NAND gate (to form an inverter). Measure input and output voltages using a DVM. Compare how the chip behaves with the TTL standard voltages (0.8 V or lower is interpreted as \texttt{LOW}, 2.0 V or higher is interpreted as \texttt{HIGH}). Notice that near threshold, the output may be indeterminate.

1.6 Universal NORs and NANDs

1.6.1 OR gate

Using only NAND gates from the 7400, construct an OR gate. Verify its function by measuring the truth table.

1.6.2 AND gate

Using only NOR gates from the 7402, construct an AND gate. Measure the truth table.

1.7 Cleanup

It is important to clean up after yourselves. Please put all wire back into the trays and return the components to the drawers. You don’t need to take every single wire out of the breadboard (jumpers on the power rails can be left for example) but please leave each lab station as you would expect to find it when you first show up for lab.