Exercise 4.1: Familiarization with Lab Box Contents & Reference Books

4.1.1 CMOS Cookbook (In the bookcase in the Brainstorming Room)

An excellent resource for looking up the function and pinout of CMOS 74HC00 and 4000B series logic integrated circuits (and others). Many project examples are shown that may be interest to you.

4.1.2 Integrated circuit removal tool.
Remember to use this tool when attempting to remove an IC from a breadboard.

4.1.3 IC Pin Straightening Tool
When inserting an IC into a breadboard, it is necessary to slightly squeeze the leads first so that the IC can be pushed in with minimal force and without crimping. Eyeball the chip from one end and be sure the leads are perpendicular. Use the IC Pin Straightening tool to make the pins perpendicular:
Exercise 4.2: The 74HC00 NAND Gate & 2N3904 for LED Driving

Objective: Demonstrate the logic table of a CMOS 74HC00 NAND logic gate and drive an LED using a 2N3904 NPN transistor.

4.2.1 Breadboard the following circuit and test all possible switch states. For switches, use two positions of the DIP quad SPST switch. You may probe with your multimeter the various points noted in the diagram. You must also provide 5 VDC (Vcc pin 14) and ground (pin 7) to the 74HC00N chip, as well as the rest of the circuit as shown. (X2, X3 & X4 below are simply Multisim test points - ignore.)

Truth table above confirmed: _______ (yes or no)

The CMOS output can drive other CMOS chip inputs directly, but generally requires the use a transistor to handle the higher current requirement of the LED.

Image courtesy of Fairchild Semiconductor
Exercise 4.3: Four Bit Binary Counter with Buffer Drivers

Objective: To demonstrate asynchronous counting with CMOS flip flops, and driving LEDS with a CMOS hex buffer, the 4049.

Breadboard the following circuit and observe the LED binary counter. Set the function generator for a 5 volt square wave and amplitude offset of 2.5 volts (so that the voltage swing is 0 to 5 volts and not -2.5 to 2.5 volts). Set the frequency initially a 2 Hz, and once working, step up to 20 Hz. (See the photos below.) Remember to also power the ICs. V_{CC} and V_{DD} (diagrams below) go to the plus 5 volt rail, and GND and V_{SS} to the ground rail.

Does the circuit count the pulses correctly? ________ (yes or no)

Connection Diagram
Exercise 4.4: One-and-only One Synchronized Pulse

Objective: This exercise introduces the concept of synchronized or clock driven circuitry. Using a clock allows multiple chips to carry out their operation in tandem, independent of the time it might take for information to propagate along a chain of integrated circuits. This eliminates “settling time” and improves the chances of relevant data being present at the input of a chip when called for. This exercise also demonstrates a method for debouncing a pushbutton, eliminating noise generated by its mechanical contacts.

4.4.1 Study the circuit below closely. A logic analyzer has been incorporated so that the timing of the clock, debounced pushbutton and synchronized pulse (the “one and only one”) can be visualized. You can accomplish this with your oscilloscopes, but only two channels at a time. This timing relationship is shown in the display that follows the circuit. This circuit uses a 74HC14 Schmitt trigger for debouncing a push button and 74HC74 flip flops. When the button is pressed, you not only get a single pulse, but the pulse is synchronized to the clock, and lasts only one clock cycle.

Breadboard the following circuit except for the logic analyzer. We will instead use two channels of the oscilloscope and use the clock signal as our reference. First, connect the channel 2 probe to U1B pin 11 (the clock). Connect the channel 1 probe to U2A pin 2 (debounced pushbutton pulse). Remember to connect the function generator ground and power the ICs. Manually adjust the voltage per division and horizontal timing so that your display looks like the ones below. Momentarily press the pushbutton and you should see a pulse similar to the left-hand oscilloscope display below. Repeat this a few times.

Next connect the channel 1 probe to the final output – U1B pin 9. Press the button, and you see a pulse similar to the right-hand oscilloscope display below.
T74HC14 Hex Schmitt Trigger
Connect pin 14 to plus 5 volts, and pin 7 to ground. Lancaster, CMOS Cookbook.
4.4.2 Were you able to obtain the debounced pulse seen on the left-hand display above?

____________ (Yes or No)

4.4.3 Were you able to obtain the “one and only one” pulse seen on the right-hand display above?

____________ (Yes or No)
Exercise 4.5: Tri-State Logic and the Data Bus

Objective: To familiarize you with National Instruments Multisim and the use of tri-state logic. Rather than breadboarding this circuit, you will study it with Multisim.

For this exercise you will need to have Multisim running on your Windows computer (not Apple). This can be downloaded and run on a trial bases, and purchased for under $40 (as of this writing).

Recall that ordinarily logic gate outputs are not combined, but may drive the input of several other logic gates. With tri-state logic we may combine multiple outputs to a single line (“bus”), and electronically decide which device is presently “active” on the bus by “enabling” the device. While only one device can be enabled at a time on a single line, the bus may consist of several lines. For example, if a memory chip requires an 8-bit address input and has an 8-bit output of its memory contents, we might refer to them as the “address” and “data” bus (each with 8 lines). In a schematic, rather than drawing all 8 lines of the bus, we might simply draw a bold line and label it as “address bus”.

In the following circuit we see three signals of different frequency. We would like to pick one at a time electronically to send to the frequency counter. To do this we can use a 74HC126 quad state buffer, a tri-state logic device.

The rotary switch selects individual “C” inputs of the 74HC126 buffers to enable only one buffer at a time on the bus. You can find a 4 pole rotary switch under Multisim’s “Place/Component/Electro-Mechanical/All families”. Pressing the space bar moves the switch around.
The following is a diagram and truth table for the tri-state quad buffer 74HC126. This device requires the tri-state control input E to be brought low (here with a pull-down resistor) to put the output into the high impedance condition.

![74HC126 Diagram](image)

**TRUTH TABLE**

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>D</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>L</td>
<td>X</td>
</tr>
</tbody>
</table>

L = LOW Voltage Level  
H = HIGH Voltage Level  
X = Don’t Care  
(Z) = High Impedance (off)

There are three possible output states. The buffer can be high, low or high impedance (z). In the latter state it can co-exist with other tri-state devices with combined outputs. The caveat is that only one device can be enabled (“E” high) on the bus at a time. This is accomplished here with the rotary switch – but could be done with any digital “1” (high).

4.5.1 Run the simulation above, and using your keyboard space bar, move the rotary switch around to different positions.

Do you see the different frequencies on the meter? ____________ (yes or no)

Under “Tools” select the Capture Screen Area tool, and make a JPEG of your drawing for your lab workbook.
**4.6: Design a Circuit Board**

Objective: Convert a circuit drawn in Multisim into a circuit board using the Ultiboard software.

Open the Multisim file titled “Lab 4 – A 4-Bit Binary Counter Circuit Board.” (If this has not been previously distributed to you, request the file by email. You can purchase Multisim online from National Instruments for your personal computer at a low cost as a student from Studica. The left-hand computer in the Electronic Prototyping Lab has Multisim on it.)

The circuit is similar to the one you worked with earlier, but has been redrawn slightly to include a connector for inputting power and the frequency generator (below).

You can accept the circuit as is, or edit it to your own wishes. For example, you could replace the function generator input with a debounced pushbutton.

The resistors may initially have no manufacture’s footprint for placement on a circuit board. Double clicking on the part opens its feature dialog. Under the “Value” tab at the bottom, “Edit footprint” is selected, and a suitable footprint chosen from the list available. If you were producing this board, you would want to be sure that each footprint matched the actual part you plan to use. Take a moment to inspect a part’s features.
Next select “Transfer to Ultiboard” from the “Transfer menu.” A net list will appear as shown below:
Select “OK” and the circuit board layout workspace will appear. You may need to select “3D View” and “Spreadsheet” under “View” menu (and slide the window to the right).

All of the parts are first seen on the top. Inside the workspace (right-hand side) drag each part into position as shown (there is no special layout).
Select “Start autorouter” from the “Autorouter” menu. The software will automatically route each of the copper traces from pin to pin based on the netlist.

The board has now been populated and pins routed as specified in the netlist. You can use your mouse to rotate the board and visualize the traces underneath.

4.6.1 Create a JPEG (screen shot) of your circuit board in 3D and fully routed in the workspace as shown above. To do this, under “Tools” select the Capture Screen Area tool. Attach this to your Labs 4-8 Workbook Assignments.

Save your work and quit Ultiboard and Multisim.
To have this board manufactured you must export the file with relevant information concerning the physical properties of the copper clad board, silk screen layer, and even the holes through the board (vias). The export dialog is as follows: