Name_____

EET 1131 Lab #8
Comparators, Decoders, Encoders, MUXes, DEMUXes

Equipment and Components

> Safety glasses
> ETS-7000 Digital-Analog Training System
> Integrated Circuits: 7485, 74138, 74148
> Quartus II software and Altera DE2-115 board
> Multisim simulation software

Unused Pins

In the circuits that we build today and throughout the rest of this course, you will sometimes have unused input pins or unused output pins on a digital chip.

- For proper operation, **an unused input pin should be tied to its inactive level.** Tie the pin low if it is active-high. Tie the pin high if it is active-low.
- But an **unused output pin should be left disconnected, and should never be tied high or low**—tying output pins high or low can burn out the chip.
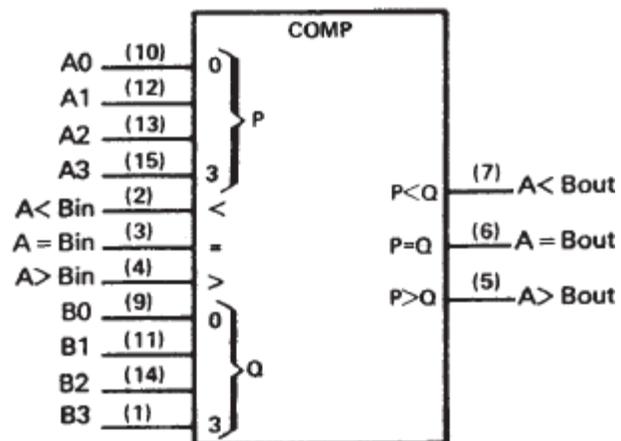
Part 1. Comparators

1. Shown below are the 7485 magnitude comparator's pin diagram and logic symbol.

<center>7485 pin diagram   7485 logic symbol</center>
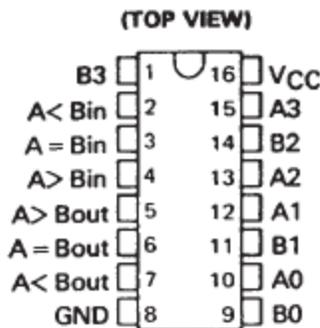
2. Use the 7485's logic symbol to answer the following questions:

   How many **input** pins does a 7485 have? _____

   How many **output** pins does a 7485 have? _____

3. Wire a 7485 chip on the breadboard. Make the following connections:
   - Tie A<Bin to the ground bus to make it permanently LOW.
   - Tie A=Bin to the power bus to make it permanently HIGH.
   - Tie A>Bin to the ground bus to make it permanently LOW.

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- Connect the chip's A inputs to the trainer's data switches SW7 through SW4, with SW7 as the most significant bit (MSB) and SW4 the least significant bit (LSB).
- Connect the chip's B inputs to the trainer's data switches SW3 through SW0, with SW3 as the MSB and SW0 the LSB.
- Connect A<Bout to LED 2.
- Connect A=Bout to LED 1.
- Connect A>Bout to LED 0.

4. Test the following combinations. Fill in the table's Output columns, and verify that the chip is producing the correct results.

Inputs								Outputs		
A3	A2	A1	A0	B3	B2	B1	B0	A<B	A=B	A>B
0	0	0	0	0	0	0	0			
0	1	0	1	1	0	0	0			
0	1	1	0	0	1	1	0			
1	0	0	1	0	1	1	1			
0	1	1	1	1	0	1	0			
0	0	0	1	0	0	0	1			
0	0	1	0	0	0	1	0			
1	1	1	0	0	0	1	0			

5. Now use the chip to compare the following pairs of decimal numbers. Fill in all input and output columns in the table:
- A = 2, B = 6
- A = 5, B = 1
- A = 8, B = 11
- A = 12, B = 12

Inputs								Outputs		
A3	A2	A1	A0	B3	B2	B1	B0	A<B	A=B	A>B

6. When you're finished, ask me to check your work.

Safety glasses? _____   Circuit works? _____   DIPs inserted correctly? _____
Using power/ground busses?_____   Wire colors? _____
Wire lengths? _____Wire ends trimmed? _____   DIPs accessible? _____

Part 2. Decoders

1. The glossary on pages 369-370 of your textbook defines the word **decoder**. Copy this definition below and make sure you understand what it means.

    A **decoder** is

74138 Decoder

2. At http://www.ti.com, find the datasheet for the 74138 (or 74LS138).
3. Using a straight edge, copy the 74138's pin diagram and logic symbol in the space below. **Be sure to include each pin's name and number.** Also be sure to include any markings that indicate active-low inputs or outputs.

<u>74138 pin diagram</u>   <u>74138 logic symbol</u>

4. Use the logic symbol to answer these questions:

    How many **input** pins does a 74138 have? _____

    Which one of the following statements is true?
    ___ All of the 74138's inputs are active-high.
    ___ All of the 74138's inputs are active-low.
    ___ Some of the 74138's inputs are active-high, and some are active-low.

    How many **output** pins does a 74138 have? _____

    Which one of the following statements is true?
    ___ All of the 74138's outputs are active-high.
    ___ All of the 74138's outputs are active-low.
    ___ Some of the 74138's outputs are active-high, and some are active-low.

Wire a 74138 chip on the breadboard, connecting data switches 7, 6, and 5 to the chip's C, B, and A input pins (in that order).

Also, connect an LED to each of the output pins. Be sure to match the numbers of the LEDs and the output pins. In other words, connect output Y0 to LED 0, and connect output Y1 to LED 1, and so on.

To enable the chip, connect its active-high enable input to +5 V, and connect its active-low enable inputs to ground.

Use the data switches and LEDs to fill in the following function table. Write **0** for LOW and **1** for HIGH. I've completed part of the table for you.

Inputs			Outputs							
C	**B**	**A**	**Y7**	**Y6**	**Y5**	**Y4**	**Y3**	**Y2**	**Y1**	**Y0**
0	0	0	1	1	1	1	1	1	1	0
0	0	1								
0	1	0								
0	1	1								
1	0	0								
1	0	1								
1	1	0								
1	1	1								

5. When you're finished, ask me to check your circuit.

Safety glasses? _____   Circuit works? _____   DIPs inserted correctly? _____
Using power/ground busses?_____   Wire colors? _____
Wire lengths? _____Wire ends trimmed? _____   DIPs accessible? _____

6. Next, to investigate the operation of the chip's enable inputs, connect its G1 pin to ground instead of +5 V. Use the data switches and LEDs to examine the outputs for all combinations of inputs A, B, and C. In one or two complete sentences, **describe** and **explain** what you observe.

7. Connect the G1 pin back to +5 V. Then connect the $\overline{G2A}$ pin to +5 V. Use the data switches and LEDs to examine the outputs for all combinations of inputs A, B, and C. In one or two complete sentences, **describe** and **explain** what you observe.

Part 3. More Practice with Quartus II's Library of Parameterized Modules: An LPM Comparator

In Lab 7 you learned how to use the adder/subtractor from Quartus II's library of parameterized modules (LPM). Our textbook has many examples and problems to teach you how to use other components from the LPM. Let's work through an example and an exercise that use an LPM comparator.

1. Use Quartus II's New Project Wizard to create a new project named **prob_c8_8**. Remember to use this same name for your project's working directory.

2. Work through Example 8-21 (**LPM Comparator**) on page 365 of the textbook. When you finish, call me over to check your simulation results.

   _____

3. After you've finished the example, modify your design according to the directions in Problem C8-8 on page 382 of the book. Be sure to read the problem's hint, which tells you the strategy to follow and also tells you how to pull a single bit from a multi-bit bus in Quartus II.

4. When you finish, call me over to check your simulation results.   _____

Part 4. Encoders

1. The glossary on pages 369-370 of your textbook defines the word **encoder**. Copy this definition below and make sure you understand what it means.

   An **encoder** is

74148 Priority Encoder

2. Using http://www.ti.com, find the datasheet for the 74148 (or 74LS148)..
3. Using a straight edge, copy the 74148's pin diagram in the space below. Include each pin's name and number. I've also given you the logic symbol from Multisim. **Write pin numbers on the logic symbol.** (The pin names on Multisim's logic symbol are slightly different from the names on your pin diagram, but you should be able to match them up.)

74148 pin diagram   74148 logic symbol

74148N
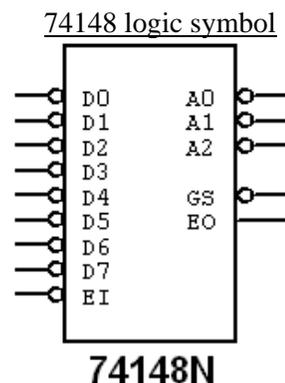
4. On a pin diagram like this one, it's important not to confuse a pin's **name** with its **number**. For example, notice that pin number 1 is named **4**.

On this chip, what is the name of pin number 3? _____

On this chip, what is the number of the pin whose name is **3**? _____

5. Use the 74148's logic symbol to answer these questions:

How many **input** pins does a 74148 have? _____

Which one of the following statements is true?
____ All of the 74148's inputs are active-high.
____ All of the 74148's inputs are active-low.
____ Some of the 74148's inputs are active-high, and some are active-low.

How many **output** pins does a 74148 have? _____

Which one of the following statements is true?
____ All of the 74148's outputs are active-high.
____ All of the 74148's outputs are active-low.
____ Some of the 74148's outputs are active-high, and some are active-low.

6. Wire a 74148 chip on the breadboard as follows:

- Connect data switches to the chip's data input pins (D0 through D7). Be sure to match the numbers of the switches and the input pins. For example, connect input pin D0 to switch SW0, and connect input pin D1 to switch SW1, and so on.
- Connect the A2, A1, A0 output pins to three LEDs, in order with the least significant bit on the right. We won't use the other outputs, so don't connect them to anything.
- **Enable the chip by connecting its enable input either to +5 V or to ground, depending on whether the enable input is active-high or active-low.**

7. Fill in the following function table for the input combinations I've listed below.

Inputs								Outputs		
D7	D6	D5	D4	D3	D2	D1	D0	A2	A1	A0
1	1	1	1	1	1	1	0			
1	1	1	1	1	1	0	1			
1	1	1	1	1	0	1	1			
1	1	1	1	0	1	1	1			
1	1	1	0	1	1	1	1			
1	1	0	1	1	1	1	1			
1	0	1	1	1	1	1	1			
0	1	1	1	1	1	1	1			

8. When you're finished, ask me to check your circuit.

Safety glasses? _____   Circuit works? _____   DIPs inserted correctly? _____

Using power/ground busses?_____   Wire colors? _____

Wire lengths? _____Wire ends trimmed? _____   DIPs accessible? _____

Based on the data in your table, and using complete sentences, briefly describe what the 74148 does. Include some discussion of whether the input pins and output pins are active-low or active-high, and what that means.

9. In each row of the table on the previous page, one switch was set LOW and all of the others were set HIGH. Now let's look at some cases where two or more switches are LOW at the same time. Try the settings in the table below, and record the output levels.

Inputs								Outputs		
D7	D6	D5	D4	D3	D2	D1	D0	A2	A1	A0
0	1	0	1	1	0	1	1			
1	1	0	1	1	0	1	1			
1	1	1	0	1	0	0	1			
0	0	0	0	0	0	0	0			

10. Based on the data in this table, what additional information can you give about the 74148 that you couldn't tell from the earlier table? Your answer should include discussion of the term "priority encoder." What does that term mean?

Part 5. Multiplexers and Demultiplexers

1. The glossary on pages 369-370 of your textbook defines the words **multiplexer** and **demultiplexer**. Copy these definitions below and make sure you understand what they mean.

    A **multiplexer** is

    A **demultiplexer** is

74151 Multiplexer

2. Using http://www.ti.com, find the datasheet for the 74151 (or 74LS151).
3. Using a straight edge, copy the 74151's pin diagram and logic symbol in the space below. Be sure to include each pin's name and number. Also be sure to include any markings that indicate active-low inputs or outputs.

<div style="text-align:center">74151 pin diagram   74151 logic symbol</div>

4. Use the 74151's logic symbol to answer the following questions:

    How many **input** pins does a 74151 have? _____

    Which one of the following statements is true?
    ___ All of the 74151's inputs are active-high.
    ___ All of the 74151's inputs are active-low.
    ___ Some of the 74151's inputs are active-high, and some are active-low.

    How many **output** pins does a 74151 have? _____

Which one of the following statements is true?

___ All of the 74151's outputs are active-high.

___ All of the 74151's outputs are active-low.

___ Some of the 74151's outputs are active-high, and some are active-low.

Mutliplexer/Demultiplexer Circuit

5. Study the schematic diagram on the following page. It shows a circuit containing three ICs:
    - a 7493 counter (which we'll study in a few weeks)
    - a 74151 multiplexer (MUX)
    - a 74138 demultiplexer (DEMUX)

    The circuit also contains:
    - a square wave generator
    - seven switches (three to control the MUX, and four to control the DEMUX)
    - eight LEDs.

    Here's how the circuit works:
    - The square wave generator produces a 12 Hz square wave that drives the counter.
    - The counter then produces:
        - a 6 Hz square wave at its QA output
        - a 3 Hz square wave at its QB output
        - a 1.5 Hz square wave at its QC output
        - a 0.75 Hz square wave at its QD output.
    - The five square waves of different frequencies become the MUX's data inputs. Switches SW 3, SW 2, and SW 1 then select one of these five square waves, which is passed through the MUX to its output pin and sent to the DEMUX.
    - Switch SW 7 enables or disables the DEMUX.
    - If the DEMUX is enabled, then Switches SW 6, SW 5, and SW 4 select one of the DEMUX's outputs, sending the square wave to one of the LEDs.

    For example, suppose switches SW 3, SW 2, and SW 1 are all switched OFF. Then the MUX will select the 12 Hz waveform and send it to the DEMUX. Suppose also that switches SW 7, SW 6, SW 5, and SW 4 are all switched OFF. Then the DEMUX is enabled and sends the waveform to LED 0, which will blink at a rate of 12 Hz. The other LEDs will stay lit constantly.

6. To test your understanding of the circuit, fill in the blanks below.   Suppose the switches are set as follows:

    SW 3: OFF   SW 2: ON   SW 1: ON
    SW 7: OFF   SW 6: ON   SW 5: OFF   SW 4: ON
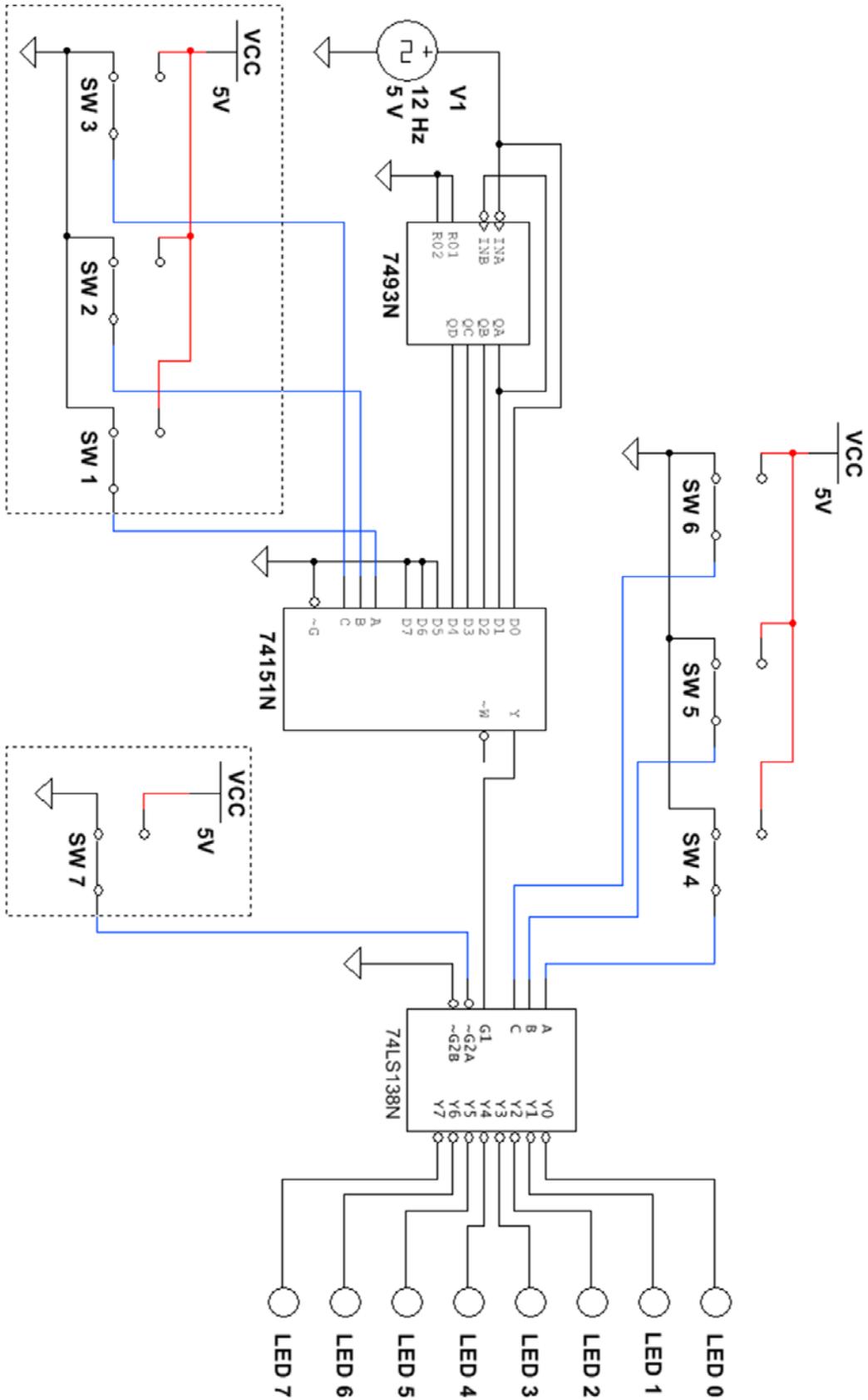
    Then LED _____ will blink at a rate of _____ Hz.

7. Now suppose you want to make LED 1 flash at a rate of 6 Hz. How should you set the switches? (For each switch, write ON or OFF)

    SW 3: _____   SW 2: _____   SW 1: _____

    SW 7: _____   SW 6: _____   SW 5: _____   SW 4: _____

8. **Build the circuit in Multisim**. Then test it by checking all possible switch combinations. When you're sure that it works correctly, ask me to check it.

    _____

Note: The dotted boxes around the switches indicate that the power/ground connections are internal to the Altera board. When you build this circuit in Quartus, replace each switch with an input pin.

9. In Quartus II, create a new project named **Lab8MuxDemux**. Create a block diagram/schematic file that implements the circuit shown above, with the following changes:

    a. Replace each of the LEDs shown above with an output pin in Quartus. Name these output pins **LED0**, **LED1**, and so on.

    b. Replace each of the switches shown above with an input pin in Quartus (and in Quartus you won't need the VCC's and grounds that you connected to the switches in Multisim). Name these input pins **SW1**, **SW2**, and so on.

    c. Replace the 12 Hz Clock Voltage shown above (and the ground connected to it) with an input pin and six frequency dividers, wired together as in the project named Lab4BlinkingLED in Lab #4. But for the last frequency divider, instead of using the divide-by-16 output (named DV 16), use the output that will give you an output frequency close to 12 Hz if the input pin is connected to a 50 MHz source. Name the input pin **Clock**.

10. Perform analysis and synthesis, and then assign input and output pin numbers so that:
    a. The output pins named LED0, LED1, and so on are connected to LEDs on the DE2-115 board.

    b. The input pins named SW1, SW2, and so on are connected to switches on the DE2-115 board.

    c. The input pin named Clock is connected to the Cyclone chip's 50 MHz clock source, as in your Lab #4 project named Lab4BlinkingLED.

11. Compile your design and download it to the Cyclone FPGA on the DE2-115 board.

12. Test your circuit by checking all possible switch combinations. When you're sure that it works correctly, ask me to check it.

                                     Circuit works? _____

13. Close your Quartus II project.

Questions
    1. On the 74151 chip, why is pin 7 tied to ground?

    2. On the 74151 chip, why are pins 12, 13, and 14 tied to ground?

    3. On the 74138 chip, why is pin 5 tied to ground?

Part 6. Review Questions
Match each type of chip with its function by filling in each blank with the correct number.

1. Decoder
2. Demultiplexer
3. Encoder
4. Multiplexer

_____ Accepts an active level on one of its inputs representing a digit and converts it to a coded output.

_____ Allows information from several sources to be routed onto a single line for transmission over that line to a common destination.

_____ Detects the presence of a specified combination of bits on its inputs and indicates the presence of that combination by a specified output level.

_____ Takes digital information from one line and distributes it to a given number of output lines.

Match each chip number with its description by filling in each blank with the correct letter.

A. 74150
B. 74138
C. 74LS280
D. 74283
E. 74139
F. 7485
G. 74154
H. 74147
I. 74153
J. 7442
K. 74151
L. 74157
M. 74148

_____ 8-line to 1-line data selector/multiplexer

_____ 4-line to 16-line decoder/demultiplexer

_____ 4-bit magnitude comparator

_____ 16-line to 1-line data selector/multiplexer

_____ 8-line to 3-line priority encoder

_____ Dual 2-line to 4-line decoder/demultiplexer

_____ 9-bit odd/even parity generator/checker

_____ Dual 4-line to 1-line data selector/multiplexer

_____ 4-line BCD to 10-line decimal decoder

_____ 4-bit binary full adder with fast carry

_____ 10-line to 4-line priority encoder

_____ Quad 2-line to 1-line data selector/multiplexer

_____ 3-line to 8-line decoder/demultiplexer