**Phy 440 Lab 4: Schmitt trigger inputs, Decoders**

TTL Switching

In this lab we study the switching of TTL devices. To do that we begin with a source that is unusual for logic circuits, an offset sine wave from an oscillator.

Experiment 1: *Setup* the function generator as in Figure 1 to make a sine signal that is offset positively, with a maximum output not greater than 5 volts. The goal is to obtain a voltage that swings from a value near zero to a positive value that will appear as a high state to TTL input (about 2 volts) as shown in Figure 2.

Figure 1: Sine Signal Generator
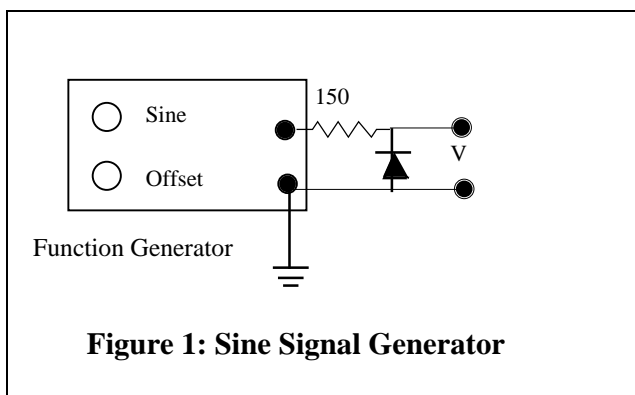
The diode is for protection of the TTL devices that will be connected to this source. It ensures that the input of the source does not go more negative than –0.7 volts.

An ideal diode would not permit any negative voltage. If the offset source would otherwise have some negative swing then the ideal diode would lead to an output that looks like Fig. 4. For a real diode the output, seen on the scope, looks like Fig. 3.

Figure 2: Sine Wave with offset.
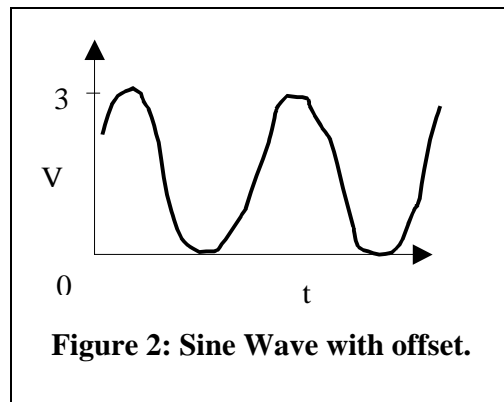
Experiment: Vary the level of the sine signal and the offset so that you see an output like Fig. 3. Then set the level and the offset so that the output resembles Fig. 2.
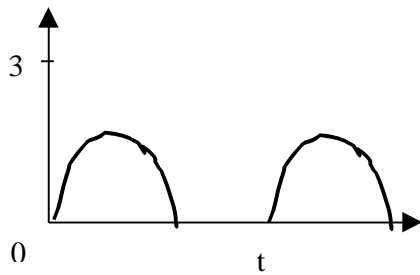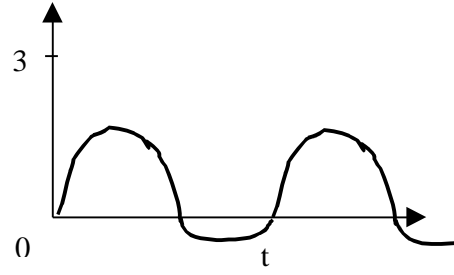
Figure 4: Sine Wave with Ideal Diode   **Figure 3: Sine Wave with Diode.**

Experiment 2: Connect the offset AC source to a TTL inverter made from a NAND gate on a 74LS00 as shown in Figure 5. [Don't forget the +5 volt supply to pin 14 and the ground to pin 7.]
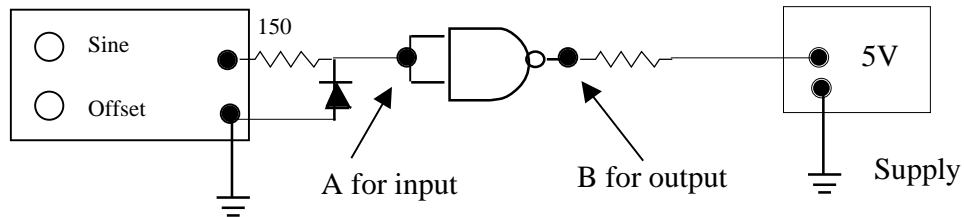

Figure 5: Sine inverter circuit.

You should observe the output go low when the input sine goes above the switching voltage. You should observe the output go high when the input sine goes below the switching voltage.

1   You should find that the switching voltage is about 1.5 volts. Is this what you find?

2   Measure the rise time of the output.

The Schmitt Trigger Input

Read about the Schmitt Trigger (ST) on page 239 of the D&H text. Understand the roles of ON and OFF voltages.
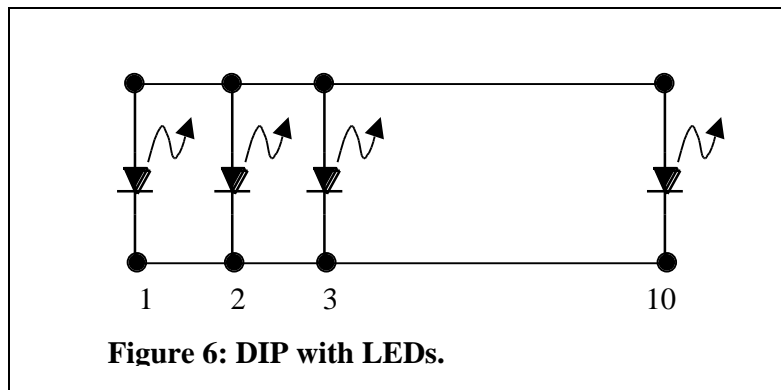
Experiment 3, ST Input:

The chip called the 74132 is a quad two-input NAND gate. It is the same as the 7400 (same pin-out too!) except that on the 74132 the inputs are all Schmitt triggers. The 74LS132 is a low-power Schottky version of the same.

Carefully pull the 74LS00 out of your circuit and replace it with the 74LS132. With the 74LS132 in place, you should observe the output go high when the input sine goes below the "OFF" switching voltage.

(a) What are the values of the ON and OFF voltages?

(b) Compare the rise time of the output with the rise time measured in Experiment 2.

LED Arrays

The next experiments in this lab use the light-emitting diode arrays. There are 10 LEDs in a single DIP connected as shown in Figure 6.

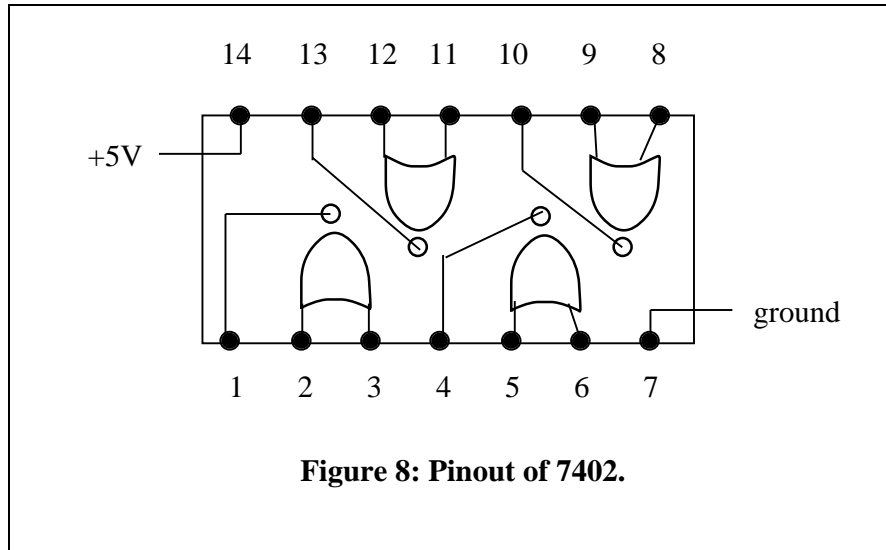**Figure 6: DIP with LEDs.**

The only problem is that you do not know which side of the package is which.

Experiment: Discover the answer by a test circuit like that shown in Figure 7.

Figure 7: Test Circuit.
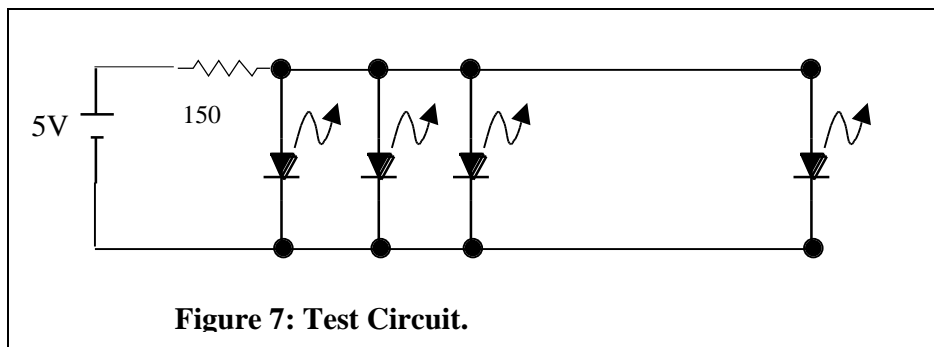
Remember the answer.

The quad two-input NOR gate:

The 7402 (or 74LS02) is a quad two-input NOR gate. The pin-out is shown in Figure 8:

Figure 8: Pinout of 7402.

Experiment: Verify the NOR truth table for one or two of the logic gates of a 74LS02: [This chip also needs a +5 volt supply at pin 14 and a ground at pin 7.]

Six NOR gates make a 2-to-4 Decoder

Suppose that we want to turn on any *one* of four circuits from some remote location. We could send control signals along four individual control lines. Alternatively, we could encode the data in a digital word and decode it downstream with a scheme like this:

Table 1: Two to Four Line Decoder

Code		Action Downstream
A	**B**	
0	0	Turn on circuit 0
0	1	Turn on circuit 1
1	0	Turn on circuit 2
1	1	Turn on circuit 3

The decoder at the downstream location is a 2-line to 4-line decoder. We can make it from six NOR gates as shown below in Figure 9.

Figure 9: Two to four line decoder.
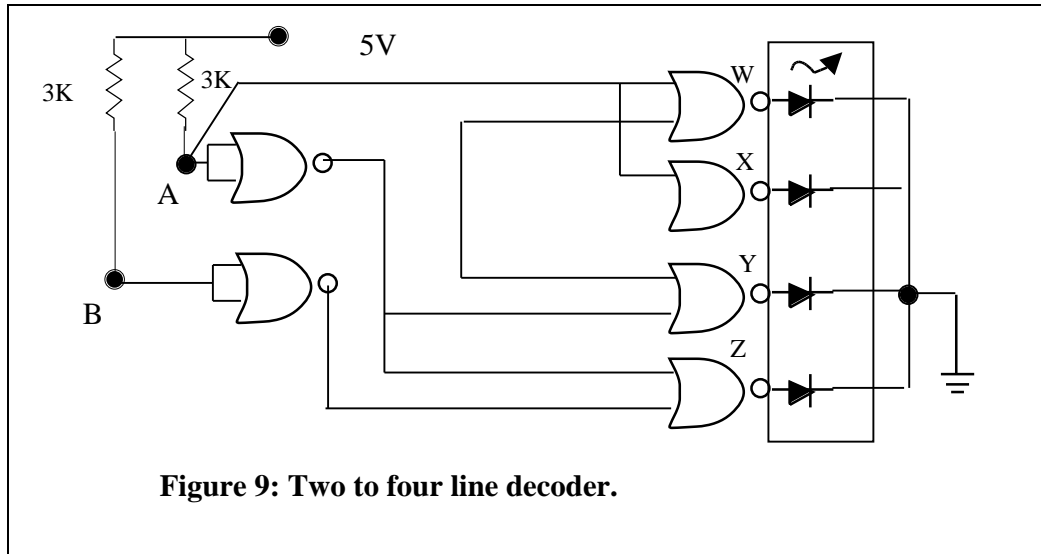
Calculation: Complete the truth table for the four outputs w, x, y, and z, given the four possible inputs from lines A and B.

Experiment: Build the circuit as shown in Figure 9 using the diode array for indicators. Note that an LS NOR gate is not capable of sourcing enough current to burn out an LED. Therefore, we do not need current limiting resistors. We can hook the LEDs of the array directly to the outputs of the NOR gates.

Verify that with the four control codes you can turn on any one of the four LEDs.

Three-to-eight Decoder

If we want to get really serious about this matter of coding and decoding we can use a chip that is especially designed to decode three data lines and give eight output lines.

Question: Why eight?

A copy of the 74138 decoder's data page is available in the Supplementary Document area of the course web page. Print out a copy for your use. If you look at the table of outputs Y0 through Y7 you will see that these are "active low." That means that when an output is turned on the corresponding pin goes low. Therefore, to use this decoder to light the LEDs of the array we let the decoder sink current, as shown in Figure 10 below.

Figure 10: Three-to-eight Decoder.
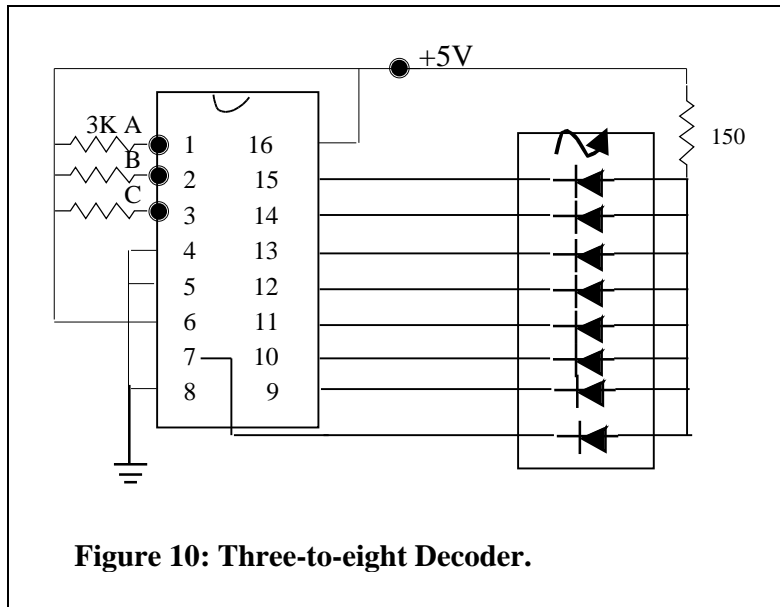
A TTL chip can sink quite a lot of current. Therefore, we need a current limiting resistor to keep from burning out the LEDs with too much current.

Question: Why don't we need a resistor on each LED of the array?

Experiment: Build the decoder shown in the figure above and verify its operation.

Table 2: Three-to-eight decoder.

C	B	A	Output Value
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	