ECEN 240 Lab 2 – Logic Inverters

Name: Brodric Young

Purposes:

- Learn about the construction and characteristics of a CMOS inverter
- Measure and record the input and output characteristics of an inverter
- Find the threshold voltage of the inverter
- Gain experience using the 74HC04 and the 74HC05 inverter chips

Procedure:

Part 1 – Discrete CMOS Inverters

1. Construct the inverter shown in the schematic of Figure 1. Use the left side of the breadboard.

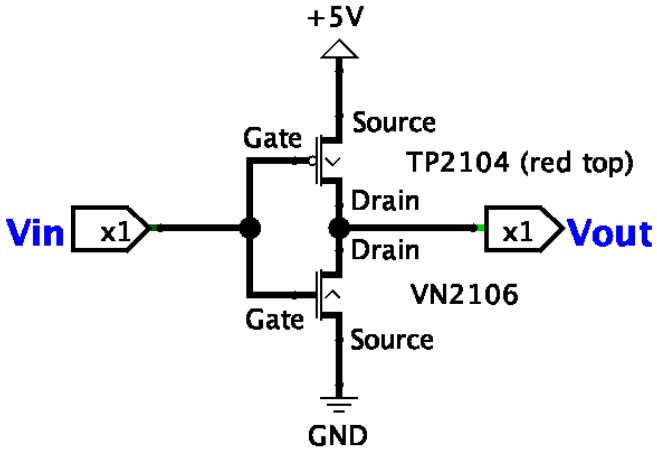

Figure 1 - CMOS Inverter

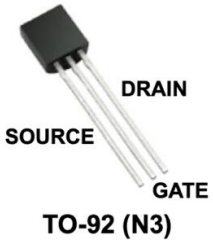

Figure 2 - Pin assignments of the TP2104 (PMOS) and VN2106 (NMOS) Transistors

2. Add the potentiometer circuit shown in Figure 3 (also used in Lab 1) and connect its middle pin to the input of the inverter.

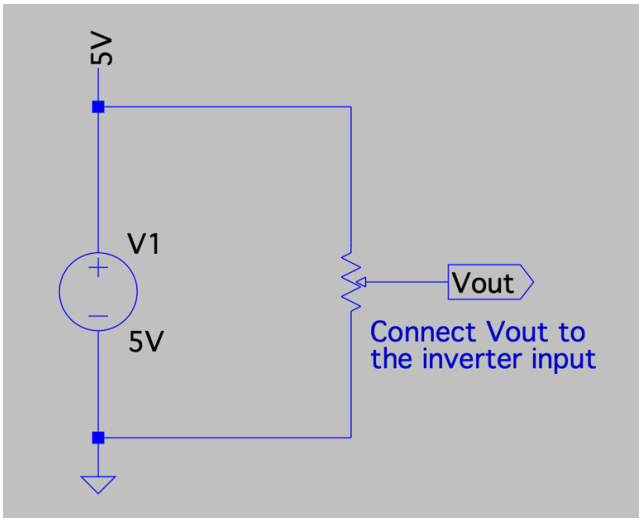

Figure 3 – Potentiometer circuit used for inverter input voltage

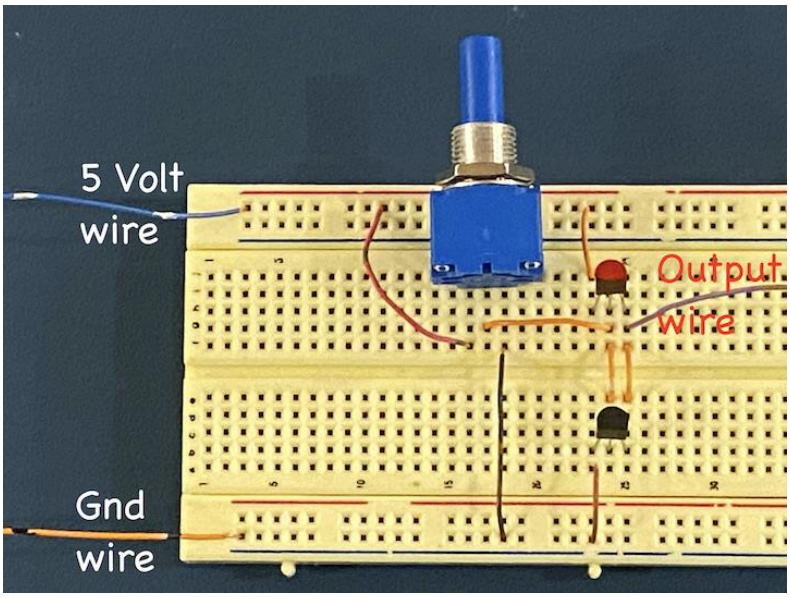

Figure 4 – Completed Inverter Circuit with a Potentiometer as the Input

3. Verify that the inverter circuit is working correctly by adjusting the knob of the potentiometer while monitoring the input and output with a voltmeter (if the input is near zero Volts, the output should be near 5 Volts and vice versa).

4. Make the necessary voltage measurements to complete Table 1. To do this:

- Connect the voltmeter to the input of the inverter and adjust the potentiometer knob until it is close to the target “Vin” value on the table.
- Without changing the potentiometer, connect the meter to the output of the inverter and record the “Vout” value.
- Repeat for the next input voltage until done

Inverter Vin (Volts)	Inverter Vout (Volts)
0	5.014V
1	5.008V
1.2	5.018V
1.4	5.001V
1.6	4.992V
1.8	4.935V
2	4.908V
2.1	4.863V
2.2	4.800V
2.3	4.735V
2.4	4.662V
2.5	4.368V
2.6	3.089V
2.7	0.728V
2.8	0.417V
2.9	0.327V
3	0.201V
3.2	0.135V
3.4	0.065V
3.6	0.023V
3.8	0.016V
4	0.023V
5	0.023V

Table 1 – Inverter Input vs Inverter Output

5. The threshold voltage is defined as the voltage where the input voltage is equal to the output voltage. From the table data determine the approximate threshold voltage:

Vthreshold = 2.6V

***** Take Lab 2 Quiz 1 *****

Part 2. Integrated Circuit Logic inverters.

1. Keeping the transistor inverter circuit on the left of the breadboard, build the circuit shown in the schematic diagram of Figure 5 on the right side of the breadboard. Refer to the data sheet of the 74HC04 and 74HC05 to understand the function of each pin on each chip

Notes: These two chips are integrated inverter chips with 6 inverters integrated into each chip.

- The 74HC04 inverters are built very much like your discrete transistor inverter of part 1.
- The 74HC05 does not have the top (PMOS) transistor. It can only pull down to GND and cannot pull up to 5V. It can drive more current, however, so it is ideal for driving LEDs.

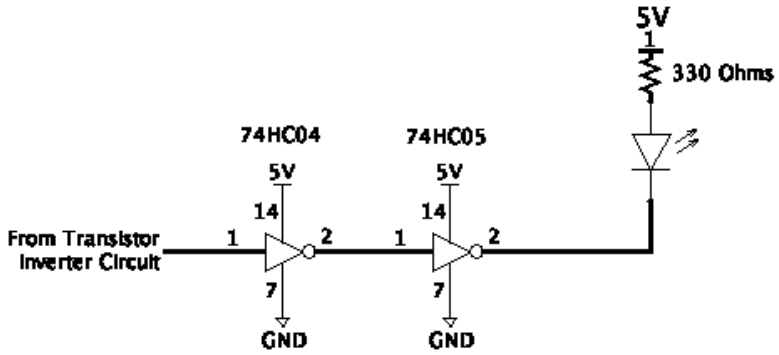

Figure 5 – Two Inverters and an LED

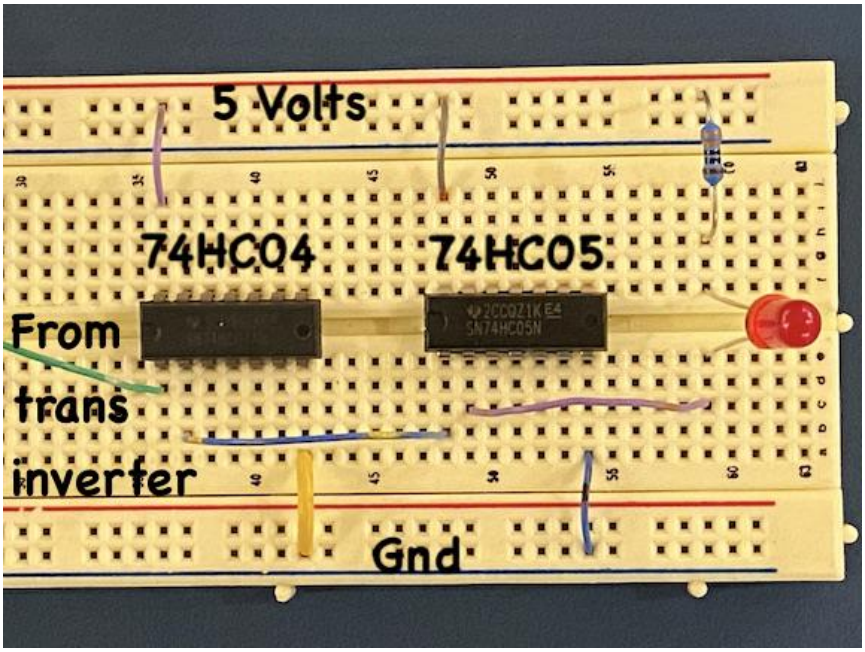

Figure 6 – Breadboarded Version of Figure 5

2. Create a 3 inverter chain by connecting the output of the discrete transistor inverter circuit to the input of the integrated inverter circuit shown in Figure 5. The complete circuit is shown in Figure 7.

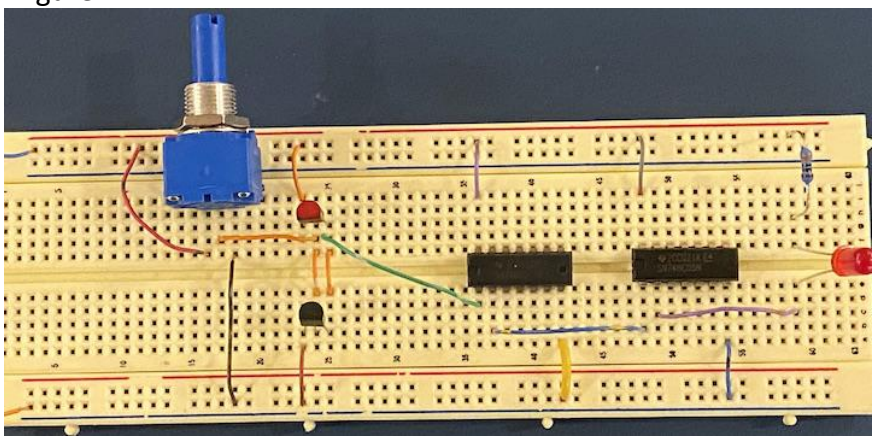

Figure 7 – Complete 3 inverter Circuit

3. Find the input threshold voltage of the discrete transistor by observing the voltage at which the LED changes from OFF to ON.

Vthreshold = 2.630V

Was this voltage similar to the threshold measurement in Part 1?

Yes it was

4. With the LED “on”, measure the output voltage of each inverter and repeat the measurements with the LED “off”.

	LED “on”	LED “off”
Inverter 1 Vout	0.025V	5.026V
Inverter 2 Vout	5.002V	0V
Inverter 3 Vout	0.329V	3.730V

***** Take Lab 2 Quiz 2 *****

Part 3. Conclusions statement.

Write a brief conclusions statement that discusses all of the original purposes of the lab. Please discuss your observations on all four bullets. Please use complete sentences and correct grammar as you express your thoughts (a lengthy report is not necessary):

Purposes (repeated):

- Learn about the construction and characteristics of a CMOS inverter
- Measure and record the input and output characteristics of an inverter
- Find the threshold voltage of the inverter
- Gain experience using the 74HC04 and the 74HC05 inverter chips

(The conclusions box will expand as you write)

Conclusions:

This lab gave us some trouble for the first hour until we figured out the issue was with the cables connecting the power source to the breadboard. But in the process of troubleshooting, we got to know how the circuit worked a lot better. I now know more about how the CMOS inverter works after putting the circuit together several times and running through what the output voltage should be. Once we got a proper connection, we were able to successfully measure what we knew the output voltages should be, and confirming the characteristics of the inverter. We found the threshold voltage of the inverter by finding where the biggest jump from going between 0V to 5V was. It gradually kept changing and then there was a big jump and gradual changes again until we got to 5V, just like how a non-ideal gate would act. We also gained experience using the inverter chips, which did the same thing we did with the two transistors, but more concise and has more gates than just one in the chip.

Conclusion Statement

Congratulations, you have completed Lab!
You may now submit this document.