# ECEN 240 Lab 2 – Logic Inverters

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# 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.

Diagram, schematic

Description automatically generated

Figure 1 - CMOS Inverter

Diagram

Description automatically generated

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.

Diagram, schematic

Description automatically generated

Figure 3 – Potentiometer circuit used for inverter input voltage

A picture containing diagram

Description automatically generated

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 | 5.046 |
| 1 | 5.046 |
| 1.2 | 5.046 |
| 1.4 | 5.046 |
| 1.6 | 5.046 |
| 1.8 | 5.034 |
| 2 | 4.985 |
| 2.1 | 4.904 |
| 2.2 | 4.820 |
| 2.3 | 4.671 |
| 2.4 | 4.475 |
| 2.5 | 3.826 |
| 2.6 | 0.571 |
| 2.7 | 0.373 |
| 2.8 | 0.272 |
| 2.9 | 0.214 |
| 3 | 0.143 |
| 3.2 | 0.086 |
| 3.4 | 0.036 |
| 3.6 | 0.011 |
| 3.8 | 0.001 |
| 4 | 0.000 |
| 5 | 0.000 |

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 = 2.503

\*\*\*\*\* 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.

Diagram, schematic

Description automatically generated

Figure 5 – Two Inverters and an LED

A screenshot of a computer

Description automatically generated with medium confidence

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.

A close - up of a ruler

Description automatically generated with low confidence

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 = 2.565

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

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 | 0.489 | 4.370 |
| Inverter 2 Vout | 5.047 | 0.000 |
| Inverter 3 Vout | 0.166 | 3.767 |

\*\*\*\*\* 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):

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* Measure and record the input and output characteristics of an inverter
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(The conclusions box will expand as you write)

|  |
| --- |
| Conclusions:A CMOS inverter will output a high voltage when a low voltage is inputted, and vice-versa. To make it, we connect two transistors, a PMOS and an NMOS. Their power sources are different, one connected to 5V (PMOS) and the other to ground (NMOS). The outputs of both are connected to produce the output of the inverter. The gates of the transistors are both connected to the potentiometer to allow us to control the input voltage.For an inverter, when the input is low then the output is high. When the input is high then output is low. There is a middle point, the threshold, when the voltage starts to vary before being inverted.The threshold of the inverter is about 2.5V for a 5V input.The 74HC04 and 74HC05 both have built-in inverters. They take their inputs in pin 7 and outputs the result in pin 8. |

## Conclusion Statement

## Congratulations, you have completed Lab!

## You may now submit this document.