Name: _____

Hands-on Introduction to Electrical Engineering
Assignment 2: Diode, MOSFET, Digital logic

1 Topics

In this assignment, you will review the following topics:

- Nonlinear iv-curve of a light-emitting diode
- MOSFET inverter
- NAND-gate from MOSFETs
- Digital logic
- MOSFET amplifier (Demo only)

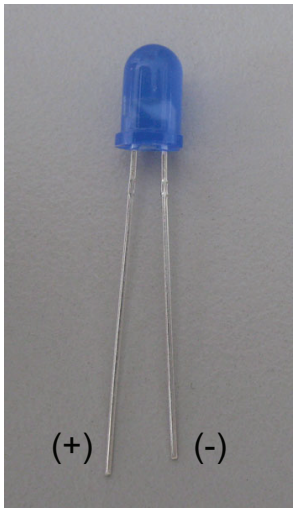
Please make sure that you are familiar with these topics prior to the lab session.

2 iv-curve of a LED diode

2.1 Variable voltage circuit

In this assignment, the supply voltage will be $V_S = 5$ Volts.

Use a 1 kΩ potentiometer to create a resistive divider, with an output voltage that ranges between 0 and 5 V. Connect the output of the potentiometer to the positive terminal of the LED. Draw the circuit below.



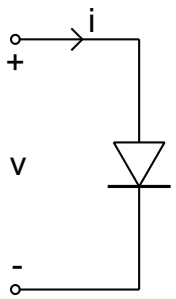
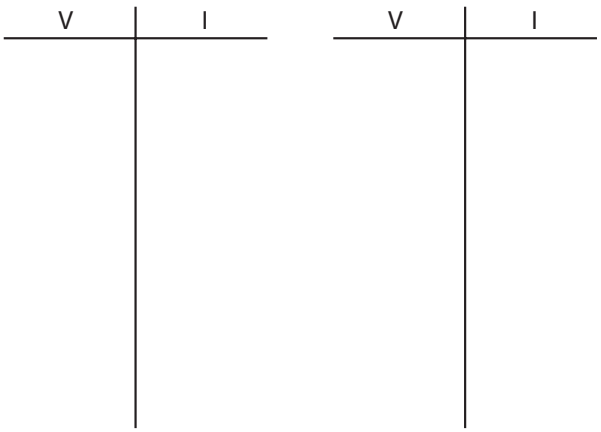


Figure 1: A photograph and schematic view of a light-emitting diode (LED). The lengths of the two leads indicate the positive and negative terminals of the diode.

2.2 Measurement of i vs. v

Measure the voltage and current through the diode, as indicated in Fig. 1. You will need two multimeters for this exercise (one to measure i and the other to measure v).

Start measuring from $v = 0$ V and slowly increase the voltage. Do not exceed $i = 40$ mA.



Use an extra sheet for the measurements if needed.

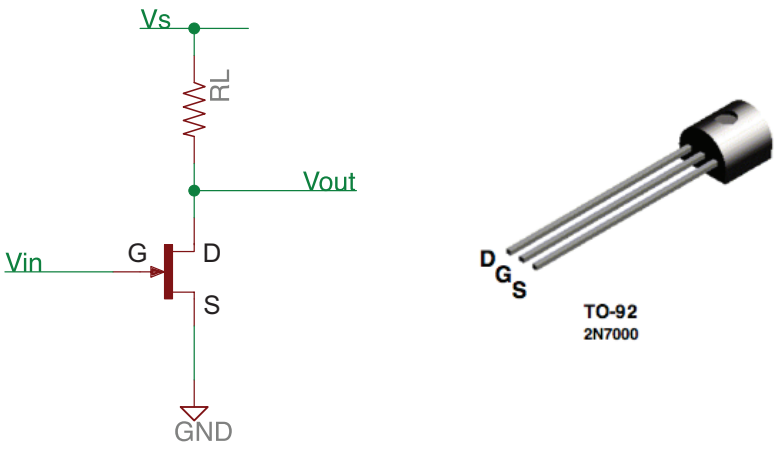


Figure 2: Basic MOSFET inverter circuit using the 2N-7000 transistor.

2.3 Determination of parameters

The diode equation is

$$i = I_0 \cdot (\exp(v/V_T) - 1)$$

for some parameters I_0 and V_T. Based on your measurements, estimate V_T and I_0. Hint: recall the technique for parameter estimation in MITx Lab 4.

$V_T =$

$I_0 =$

3 MOSFET inverter

3.1 Variable voltage circuit

As before, use a potentiometer (any value) to yield an output node whose voltage varies between 0–5 Volts.

3.2 MOSFET inverter

Build the MOSFET inverter circuit as shown in Fig. 2. Use a load resistor $R_L = 100\ \Omega$. Measure v_{in} vs. v_{out}. Use increments of 0.2 V for v_{in}. Use an extra sheet if needed.

Vin	Vout	Vin	Vout

3.3 Static discipline

Suppose we choose $V_{\text{IL}} = 1$ V and $V_{\text{IH}} = 4$ V. Based on your measurements, what are V_{OL}, V_{OH}, and NM_{L}, NM_{H}?

$V_{\text{OL}} =$

$V_{\text{OH}} =$

$NM_{\text{L}} =$

$NM_{\text{H}} =$

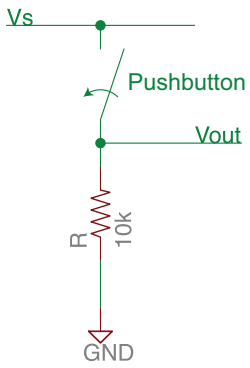


Figure 3: A simple push-button circuit.

4 NAND gate from MOSFETs

4.1 Digital button

A momentary push button is a short-circuit when pressed, but an open-circuit when not pressed. In the switch circuit of Fig. 3, what is V_{out} when the button is pressed/un-pressed?

V_{out} (Pressed) =	V_{out} (Unpressed) =

4.2 NAND from MOSFETs

Draw the 2-input NAND gate using two MOSFET transistors.

Build the circuit with the two inputs being taken from two push-button outputs, and verify that the output voltage behaves as expected.

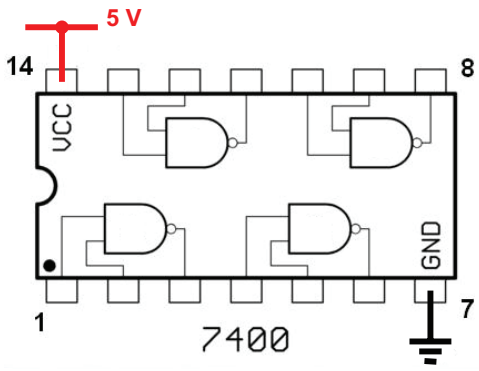


Figure 4: Pinout of the 74HC00, an integrated circuit version of the NAND gate.

4.3 NAND in an integrated circuit (IC)

Rather than using discrete transistors to implement digital logic, one can make use of **integrated circuits** (IC) that provide the same functionality in a more convenient package. Fig. 4 shows the **pinout** of a common NAND integrated circuit: 74HC00.

Verify that the 74HC00 performs as expected.

5 Digital logic – Three-input majority circuit

We wish to build a three-input **majority circuit**. Given digital inputs A, B and C, the output Z will be 1 if the majority of the inputs are 1, *i.e.* when $A = B = 1$, $A = C = 1$ or $B = C = 1$.

5.1 Truth table

Fill out the truth table for Z.

A	B	C	Z

5.2 Boolean expression

Give the logical (Boolean) expression for Z.

$$Z =$$

5.3 Logic circuit

Design the logical circuit.

Finally, please implement the three-input majority circuit using IC digital logic. The following information can be helpful:

- 74HC00: NAND
- 74HC02: NOR
- 74HC08: AND
- 74HC32: OR

You can easily find the pinout of these ICs by searching the Internet for their **datasheet**.