LAB 7 –ECE 230L LABORATORY

Device Non-Idealities

1. Objectives of this Laboratory

The objectives of this laboratory session are as follows:

- To gain understanding of some of the less than ideal behavior of devices and circuits explored in previous laboratories. These non-idealities include the following:
- To explore methods for measuring these non-idealities in a less structured lab environment using the tools presented during the course of the semester.
- To work with a group in the course to explore these methods.
- To present group findings to fellow students in the course in a lab presentation.

2. Experimental Exploration Format

- This lab will be conducted in *groups* of two or three.
- Each group will be assigned an exploration
- Complete the exploration and form a brief presentation to share with the lab section—you have *one hour*
- Each group will present their findings to the entire lab

Experimental Exploration 1: Thermal Effects on PN junction diode & MOSFET[1]
Group of 2 or 3

PN Junction diode

i. Construct the following circuit on a breadboard:

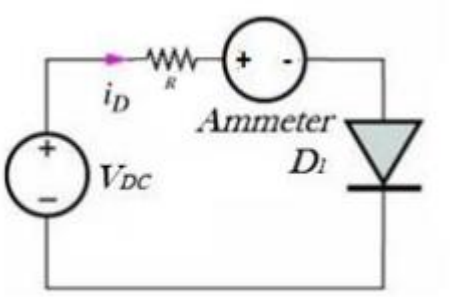


Figure 1: PN-Junction diode test circuit

ii. Run the LabVIEW singleloop.vi script. Run from 0 to 6 V with 100 steps. This produces $I_D(V_d)$
iii. Repeat the above, but with a voltmeter over the diode, to measure V_{PN}. Combine the results to produce the graph $I_D(V_{PN})$.
iv. Now, obtain thermal paste from your TA and apply it to the diode. Obtain a soldering iron and heat it to its lowest setting. Apply the soldering iron to the diode to allow it to heat it.
v. Repeat steps i-iii, and compare the results.

Next, you will explore the thermal effects on a MOSFET…

[1] Sze, S. M., Semiconductor Devices: Physics and Technology, New York: John Wiley & Sons,: 1985, pp. 96

MOSFET

i. Construct the following circuit on a breadboard:

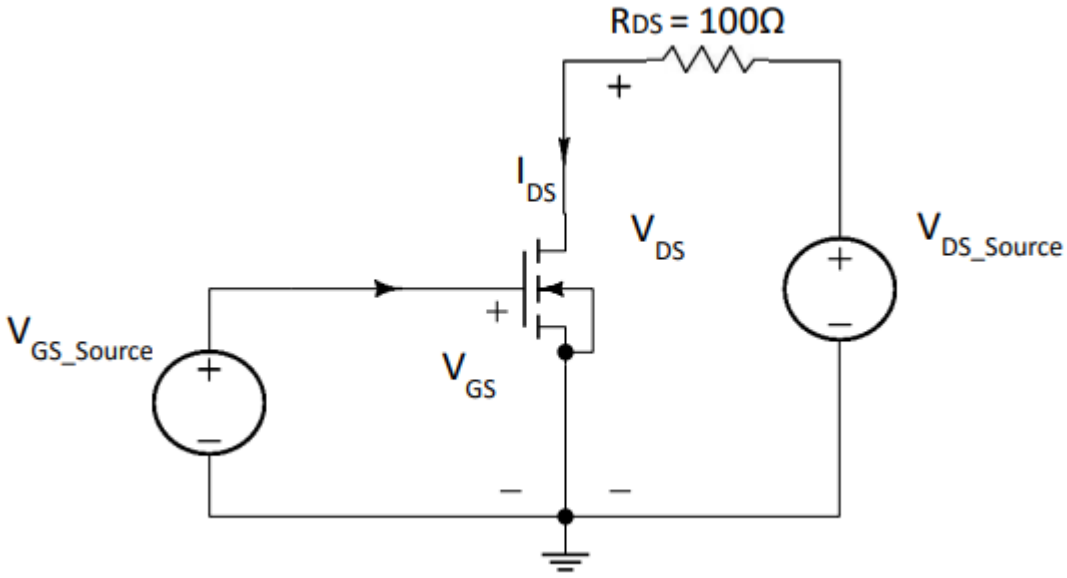


Figure 2: Circuit used to characterize an NMOSFET.

ii. Open doubleloop.vi on LabVIEW. Set the inner voltage $V_{DS,Source}$ to run from 0 to 6.0 V with 50 steps, and set the outer-voltage ($V_{GS,Source}$) to run from 2.0 to 3.0 V with 5 steps. Obtain the I_D vs V_{DS_Source}.

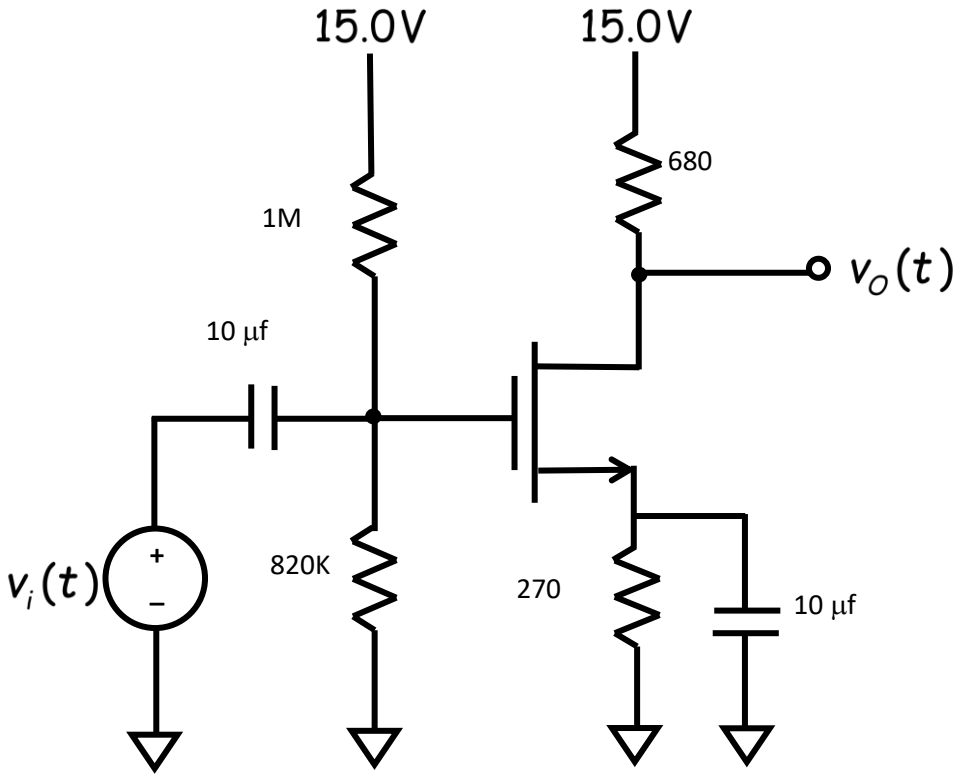
iii. Obtain thermal paste from your TA and apply to the face of the NMOSFET. Heat the NMOSFET with a soldering iron on its lowest heat setting. Then, repeat step ii.

iv. Analyze the results.

Present your findings for both the PN junction diode and the MOSFET under temperature to the class

Experimental Exploration 2: MOSFET Amplifier Gain and Load Limits[2]
Group of 2 or 3

i. Construct the following circuit on a breadboard.

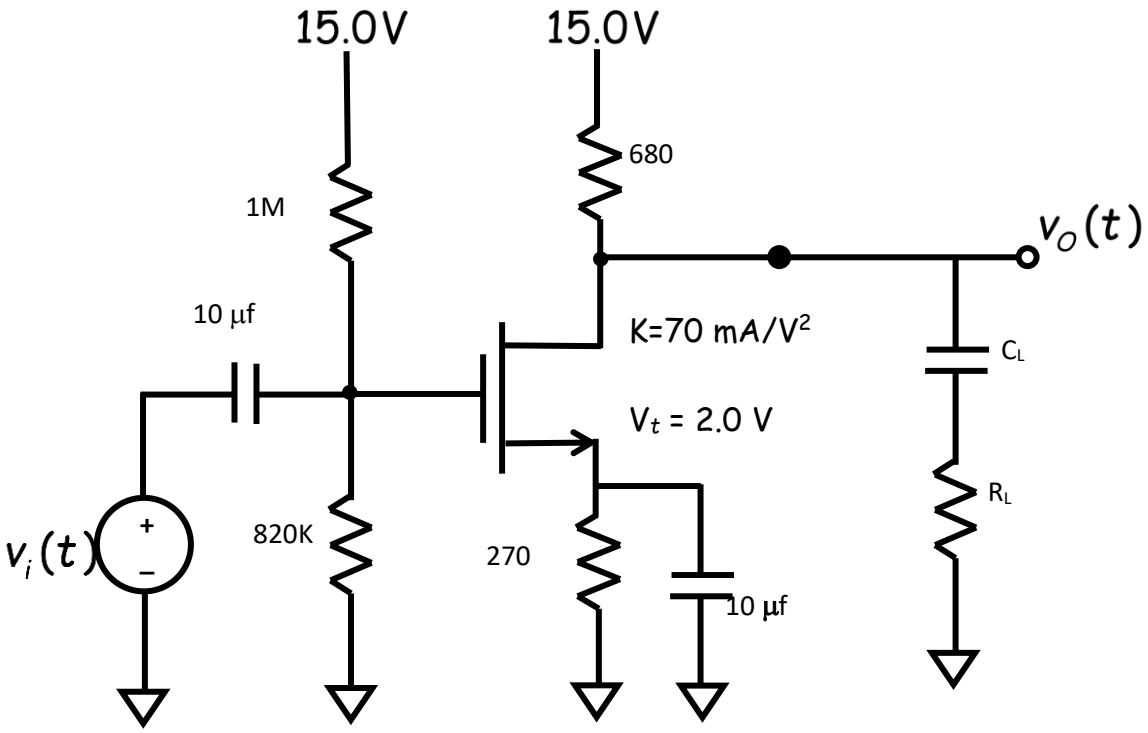


ii. Set $v_i(t)$ to be a 100 mV pp, 50-kHz sinusoid. Carefully measure and record $v_O(t)$ (both AC and DC components).

iii. Based on this measurement only, determine the AC voltage gain of this amplifier.

[2] Inspiration for this laboratory experiment came from one developed by Jim Stiles, EECS, University of Kansas, EECS 412 Laboratory #7: MOSFET 1.

iv. Now attach the following load to the amplifier output. Carefully measure and record the total output voltage v_{out}.



v. Now attach the following load to the amplifier output. In the first instance, C_L and R_L equals 1 µF and 100 Ω. Carefully measure and record the total output voltage v_{out}.

vi. Based on this measurement only, determine the voltage gain Vout/Vin with this output load applied.

vii. Now increase the magnitude of input Vin until Vout is severely distorted (i.e. both the top and bottom of the sinewave are clipped). Carefully measure and record the output Vout (both AC and DC components).

viii. Repeat iv-vii for C_L and R_L equals 10 µF and 680 Ω, and for C_L and R_L equals 47 µF and 10k Ω.

At what voltage values did the output signal clip, and why?

Comment on the effect of a capacitive load on this circuit.

Comment on the effect of increasing the magnitude of the input voltage on the circuit.

Comment on the effect of increasing the capacitive load values.

Present your findings to the class.

Experimental Exploration 3: MOSFET Input and Output Resistance
Group of 2

The Inverter circuit from Lab 6 is often referred to as a Buffer circuit. One of the benefits of using a MOSFET between stages of a system is that the MOSFET has a very high input resistance and a very low output resistance. A high input resistance means that not much current enters into the device; a high output resistance means that the device does not affect the loading of the system it is attached to. A MOSFET Buffer, as in Lab 6, has both of these advantages. Hence, in a system, it can "buffer" the stages from one other so that the stages acts more or less independently of one another.

i. For the MOSFET Inverter from Lab 6, devise a way to determine the input resistance and the output resistance of the circuit (note that the input and output resistances can be modeled as the Thévenin equivalent resistances at the input and output terminals, respectively).
ii. Conduct your experiment by measuring input and output voltages and currents, respectively. (Hint: Apply Ohm's Law to determine resistance from current and voltage measurements.)

    What is the input resistance of the MOSFET buffer?

    What is the output resistance?

iii. Now, explore what might change the input and output resistance values the most in this MOSFET Inverter circuit. What you explore as a group is up to you. As suggestions, the source resistor value might be changed, or the voltage supplied to the Inverter circuit could be changed, perhaps what effect adding a load resistor from source to ground has on the input and output.
iv. Repeat i-iii in PSpice.

Present your findings to the class

Experimental Exploration 4: MOSFET Inverter maximum clock frequency with external capacitive load

Group of 2 or 3

Build the inverter circuit from Lab 6 with a BS170 MOSFET and 240 kΩ resistor. The purpose of this experiment is to determine the effect of capacitance at the output on the maximum achievable inverter clock frequency.

i. Input a slow 100 Hz, 2 V_{pp} square wave at the Gate of the MOSFET and observe the output. It should look square and should be inverted from the input waveform.
ii. Increase the input square wave frequency until the output waveform is degraded. (Justify how you define a degraded square wave output. Consider whether a digital switching circuit could use the output waveform as a reliable input source.)
iii. Add a small capacitance (10 nF) to the inverter output from Drain to Ground.
iv. Repeat step ii., above
v. Now, continue to replace capacitors at the output and repeat step ii., above. Repeat with 0.1 µF, 1 µF, 10 µF, & 47 µF.
vi. Plot the frequency of the input waveform where the output was considered to be degraded (this is the maximum output frequency f_{max}) vs. capacitance.

What can you conclude from your plot?

How does maximum clock frequency relate to load capacitance?

Why might this be important in applications?

Present your results to the class.

Experimental Exploration 5: Zener diode (Reverse breakdown)
Group of 2

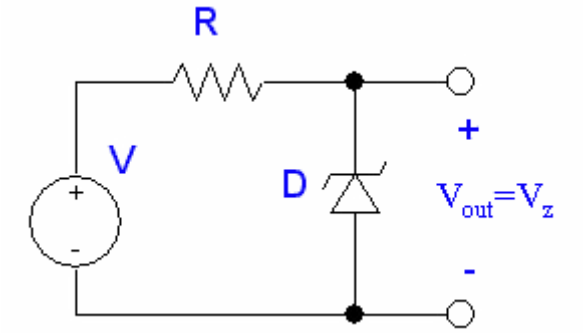
Purpose: To showcase the use of Reverse breakdown in a practical circuit and to show a circuit using the Zener diode to demonstrated voltage clamping

One of the parameters that was not measured for the diode in Lab 2 was the reverse breakdown voltage of the device. This is because most diodes have very large reverse bias breakdown voltages, on the order of 100's of Volts. However, some diodes are specifically manufacturer to be used in the reverse bias breakdown region. These diodes are called Zener diodes.

Warning: Diodes can get hot when supplying a forward bias to them.

Procedure:

1. Simulate the following circuit in PSpice using a 5.5 V Zener diode found in the standard PSpice parts library, a 6V DC source, and a 100 Ω resistor.



2. Verify in simulation that the output voltage, V_{out} is 5.5V.

   Where is the remaining 0.5 V voltage drop going?

3. Verify the current, *I* through the resistor in PSpice. Is this value what you expect? Why?
4. Build the Zener diode circuit shown. Use the Zener diode in the laboratory and R = 100 Ω.
5. Attach the 6V DC output to the source to the circuit, output 0V and measure the output
6. Now, increase the DC voltage up to the maximum supplied by the power supply: 6V
7. Measure the output voltage again.
8. Repeat steps 2-4, but measure current.

   What can you conclude about the Zener diode? How might this be of practical use in an application?

9. Now, using the LabVIEW program singleloop.vi from Lab 2, create a plot of the Zener diode V-I curve. Be sure to take both forward biased and negative biased measurements of the Zener diode to show turn-on voltage, V-I characteristics, and reverse breakdown.

   What differences do you notice about the Zener diode as compared to the PN junction diode observed in Lab 2?

Present your findings to the class.