EE330 Lab 10
Basic Transistor Amplifiers

Sprig 2022

Contents

Objective

The objective of this lab is to become familiar with applications of MOS and Bipolar transistors as small-signal amplifiers. In this lab, MOS transistors will come from the EDU1000 MOSFET array. The BJT that will be used is the PN2222.

In this experiment, you will be measuring waveforms, operating points, and gains. All of these measurements should be made with the oscilloscope. The multimeter that is on the lab bench should not be used for any measurements.

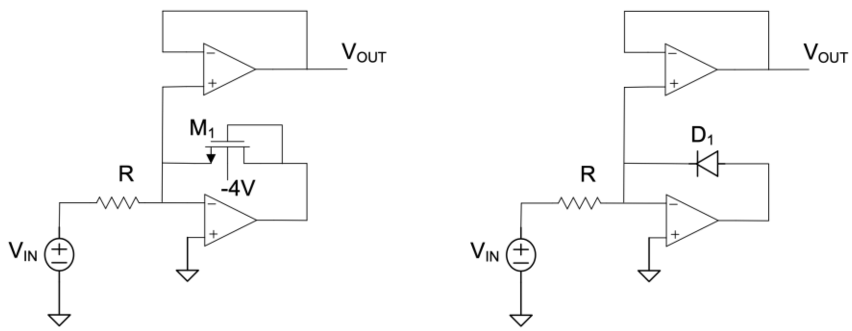
Checkpoints

1. Oscilloscope results showing V_{OUT} with a sinusoidal input when M_1 is used
2. Oscilloscope results showing the gain of the circuit in Part 3
3. Oscilloscope results showing the gain of the circuit in Part 4
4. Oscilloscope results showing the gain of the circuit in Part 5

Part 1: A Nonlinear Application

Two circuits are shown below. Analytically predict the relationship between V_{OUT} and V_{IN} for $-2V < V_{IN} < 2V$ and verify experimentally. Also predict the output if the input is a 1KHz sinusoidal waveform of 4V0-P and experimentally verify. Use a long-channel n-channel MOSFET from the EDU1000 array for M_1, a 1N4148 diode for D_1, and a LM324 for the op-amp. Let $R_1 = 2.2K\Omega$. Comment on what useful functions these circuits provide. Use $\pm 6V$ biasing for the op-amp.

Hint: The connection of gate to drain of a MOSFET to form a one-port circuit is often termed a "diode-connected" transistor.



Part 2: Common-Emitter Amplifiers

The amplifier shown below is one of the most basic and most useful amplifier structures. For reasons that will become apparent later, it is termed a common-emitter amplifier. The value of β for the PN2222 varies considerably from one device to another. In the data sheet that is linked on the class web page, the parameter β is designated as h_{FE}. The large variations in the values of this parameter should be apparent from the data sheet. You will need to measure the value of β for your transistor. Use the steps below to help guide you in the measurement process. The coupling capacitor should be large; in the $1\mu F$ range or larger. The polarity of the electrolytic coupling capacitor is critical and the orientation depends upon the voltage V_{SS}. If the voltage V_{SS} is larger than -0.6V, the polarity is as indicated with the "+" symbol. If the voltage V_{SS} is smaller than -0.6V, the orientation is reversed.

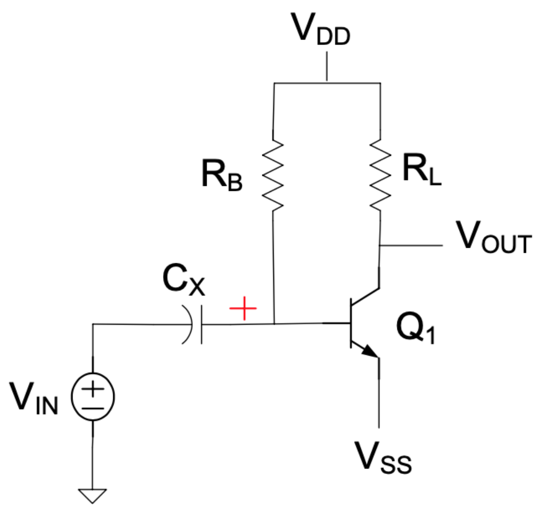


Figure 1: Capacitor-Coupled Common-Emitter Amplifier

a) Measure β of the transistor using the circuit of Fig. 2. In this measurement be sure that the transistor Q_1 is operation in the forward active region. When operating in the forward active region, $I_C = \beta I_B$ so β can be obtained by taking the ratio of the I_C to I_B. (Convenient values for the supply voltages are V_{DD}=12V and V_{SS}=0V). Since the measurements are to be made with the oscilloscope, the currents can be obtained by taking the difference of the two voltages across the appropriate resistors and dividing by the value of the resistor.

b) After β is measured, bias this circuit (by choosing the appropriate value of R_B) to operate a quiescent collector current of $1mA$ when $V_{DD} = 12V$, $V_{SS} = 0V$, and $R_L = 4.7k\Omega$.

c) Derive an expression for the small-signal voltage gain of this circuit in terms of the device model parameters and the quiescent operating point.

d) Measurement the small-signal voltage gain of this circuit when biased to operate with a quiescent collector current of 1mA. In this measurement, use a $1KHz$ sinusoidal input signal with the input amplitude adjusted so that the output signal swing is $4V_{PP}$. Compare the measured gain with the theoretical gain calculated in part c).

e) Gradually increase the amplitude of the input until clipping distortion is observed on the output. How big can the output signal be without clipping?

f) Return the output signal swing to $4V_{PP}$. Utilize the DFT function on the oscilloscope, observe the frequency spectrum of your output signal. Now, increase your input signal until your output clips again. Observe how the frequency spectrum of your output signal changes with the amount of signal clipping. What changes?

Part 3: Common-Source Amplifier

Two widely used single-transistor MOS amplifiers are shown below. For reasons that will become apparent later, these are termed common-source amplifiers. The one on the left uses the resistors

R_{B1}, R_{B2}, the capacitor C_X, and the voltage source V_{DD} for biasing. The one on the right uses the two voltage sources V_{DD} and V_{SS} for biasing.

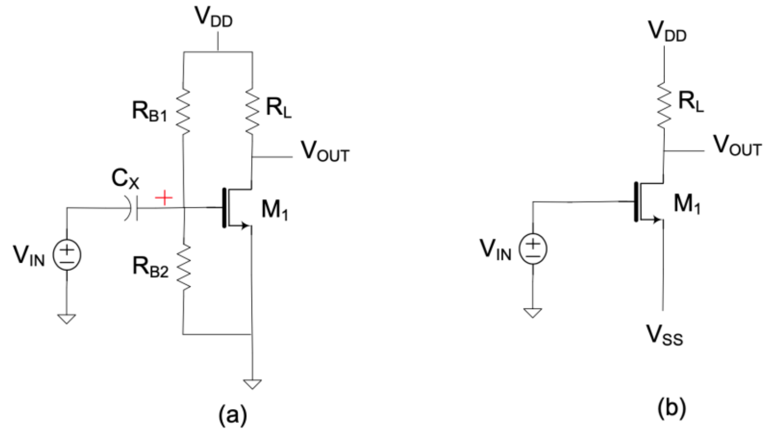


Figure 2: Common-Source Amplifiers

The MOSFET model parameters (V_{TH}, μC_{OX}, λ) for the transistor were measured in a previous experiment. Since you will not be using the same EDU 1000 device, in this part of the experiment, use the values of the model parameters given in the EDU 1000 datasheet.

- **a)** Derive an expression for the voltage gain of these two amplifiers in the small-signal parameter domain.
- **b)** Express the voltage gain of these two amplifiers in terms of the model parameters and the excess bias voltage as the Q-point, $V_{EB} = V_{GSQ}-V_{TH}$. Assume you will be using the Long-Channel transistor in the EDU1000 that has W/L=60μm/3μm.
- **c)** Design one of these two amplifier circuits using the long-channel transistor in the EDU 1000 for a voltage gain of -5 with V_{DD}=5V and R_L=10KΩ.
- **d)** Test the circuit you designed in part c) with a sinusoidal input of 100mVp-p and frequency 1KHz. Compare the gain you measure with the design value of -5.

Part 4: Amplifier Design

Build and test a small-signal voltage amplifier using the NMOS transistor as the active device that has a small-signal gain of -10 that can drive a $5K\Omega$ load resistor. You have a single 5V supply voltage available for this design and any number of resistors and capacitors in addition to the Long-Channel NMOS transistor that is available in the EDU 1000.