UNIVERSITY OF CALIFORNIA AT BERKELEY
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE105 Lab Experiments

Experiment 6: Biasing Circuitry

1 Objective

Setting up a biasing network for amplifiers often involves using transistors to build voltage and current sources to deliver the right amount of biasing goodness to the main amplifier components. In this lab, we will be exploring how to build these sources and adjust their components to exactly achieve the optimal biasing environment.

2 Materials

Component	Quantity
2N4401 NPN BJT	1
2N4403 PNP BJT	2
10 kΩ resistor	1
100 Ω resistor	1
100 kΩ resistor	1
10 kΩ potentiometer	1

Table 1: Components used in this lab

3 Procedure

3.1 Voltage Sources

In this part of the lab, we will use a BJT as a voltage source. In this case, we want to set up a voltage source to supply 650 mV, a typical common emitter base bias.

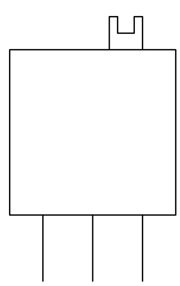

Figure 1: Potentiometer

1. Before setting up the circuit for this part of the lab, be sure to setup your potentiometer so that the leftmost two terminals in Figure 1 have the MAXIMUM resistance capable across them (should be at

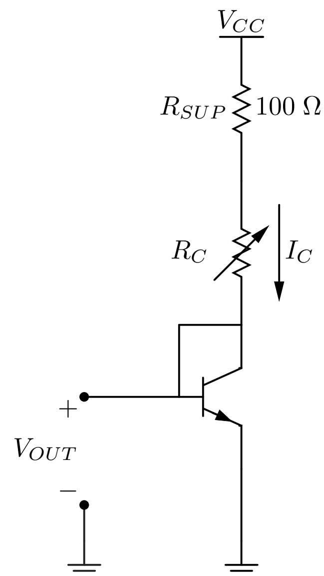

Figure 2: Voltage source using a transistor

least 10 kΩ). Be absolutely sure that you use these terminals as the initial resistance for your circuit, otherwise your transistor will **BLOW UP!**

2. Set up the circuit shown in Figure 2 using $V_{CC} = 5$ V.
3. Adjust the potentiometer until the output reaches 650 mV. What is R_C at this point?
4. Perform load-line analysis by plotting I_C vs. V_{OUT} for the transistor and for the resistor, showing the fixed point solution for V_{OUT}. How would we adjust the resistor to increase V_{OUT}?
5. Will the voltage source become better or worse (better defined as being closer to an ideal source) as the resistor decreases? Why?
6. Plot I_{OUT} vs. V_{OUT} using ICS to find the output impedance of the voltage source with the potentiometer resistance found in part 3.1.3. **Do not exceed** 700 mV **on your sweep of** V_{OUT}**!**
7. Now, suppose you want to make your voltage source output 1.3 V. Clearly, putting 1.3 V on V_{BE} of the diode connected BJT is not a good idea (please, don't even try). Draw a circuit topology to achieve this voltage without requiring a BJT to have an extremely high V_{BE}.

3.2 Current Sources

Voltages only get us so far! Current sources are also needed to bias transistors.

1. Set up the circuit shown in Figure 3 using $V_{CC} = 5$ V and $V_{BIAS} = 4.35$ V. As you bias, be sure to check that V_{BE} is less than 0.65 V, otherwise your transistor will **BLOW UP!** (*Warning: It is very easy to make a mistake and burn out a transistor. It is highly recommended that you set your V_{BIAS} and V_{CC}—and check their values with the multimeter or oscilloscope—**before** you connect the transistor.*)
2. Measure the short circuit output current.
3. In terms of the small-signal characteristics (g_m, r_o, β, etc.), what is the output resistance of this current source?
4. Sweep V_{OUT} from 0 V to 5 V and plot I_{OUT} using ICS. What happens to the output impedance as V_{OUT} nears 5 V? Why?

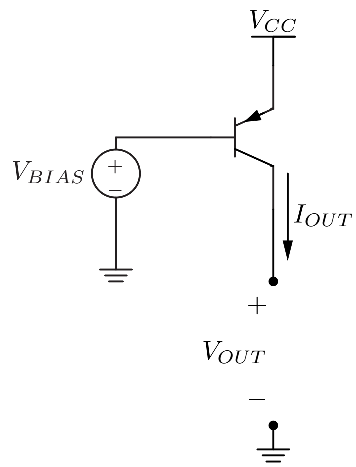

Figure 3: Transistor current source

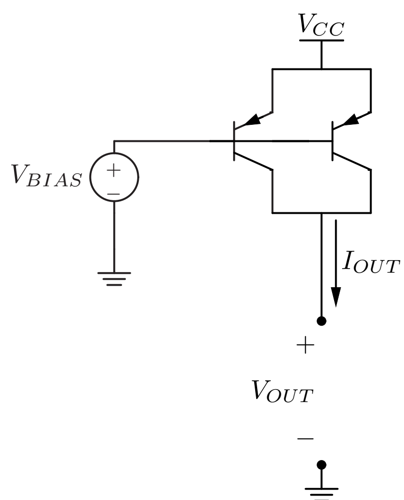

Figure 4: Current source using transistors in parallel

5. Find the output impedance at $V_{OUT} = 2.5$ V.
6. Now let's try putting transistors in parallel to increase current! Set up the circuit shown in Figure 4 using the same bias voltage as before ($V_{BIAS} = 4.35$ V).
7. What is the resulting short circuit output current?
8. Measure the output impedance using ICS. Explain the effect of the second transistor on the output impedance.

3.3 Current Mirror Bias of a Common Emitter Amplifier

A current mirror is nothing more than biasing a series of transistor current sources with a transistor voltage source, as shown in Figure 5. This setup is useful for injecting the same current in many places in your circuit, and also for automatically correcting itself with temperature. Referring to Figure 6, we will use a current mirror to bias a common emitter amplifier.

1. Set up the circuit in Figure 6 using $V_{CC} = 12$ V, $R_C = 10$ kΩ, and $R_E = 100$ Ω.
2. Sweep V_{IN} vs. V_{OUT} and determine the point of maximum gain. What is V_{IN} at this point?

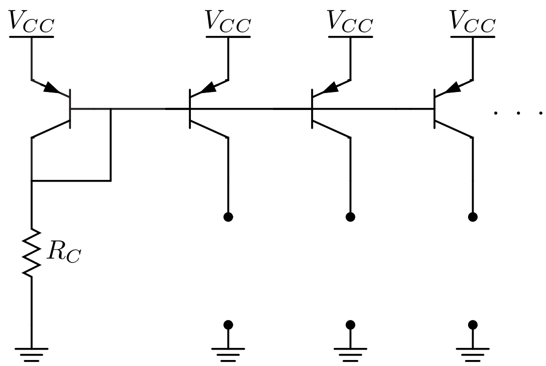

Figure 5: General PNP current mirror

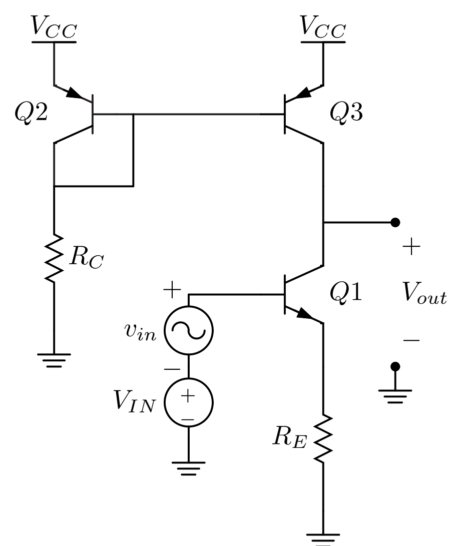

Figure 6: Biasing a CE amplifier with a current mirror

3. Measure the currents I_{C2} and I_{C3}. Do they match?
4. What is the gain at this point?
5. Bias V_{IN} for maximum gain and measure the input impedance of the amplifier.
6. Apply a 10 mV amplitude, 1 kHz sine wave at the input and plot the output on the oscilloscope. Because of the huge gain, the output waveform could be clipped. Attach a 100 kΩ load resistor at the output (which should make the output no longer clipped) and measure the peak-to-peak voltage across it. Using the gain you found from the sweep and the voltage across the load, find the output impedance.
7. How do the impedances and gain compare with a common emitter biased with a resistor instead?
8. Now let's check out the temperature effects.
   (a) Apply a small signal sine wave v_{in} of amplitude 10 mV at 1 kHz. View the output waveform on the oscilloscope.
   (b) (*CAUTION: First check that the transistors are not hot before doing this.*) Heat up only one of the transistors in the current mirror by putting your finger on the transistor. Observe the effect on the output waveform.

(c) Now put the other transistor in the current mirror between your other two fingers, thus heating both transistors up, and watch the effect on the output waveform.

(d) Explain your observations using what you know about BJT temperature effects. How may this be an advantage of BJT biasing over resistive biasing (as shown in the prelab)?