Lab 10
BJT Two-stage amplifiers

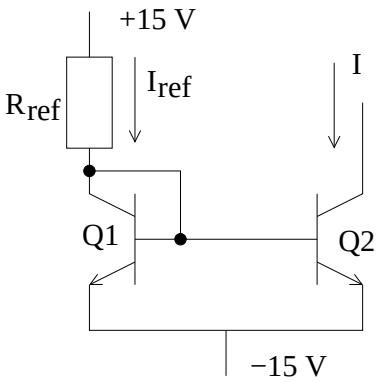
Pre-Lab

1. Determine R_{ref} in step 1.
2. Estimate the load resistance at which the current mirror breaks down, in step 2.
3. Design the circuit in step 3. Think about how the input and output resistances interact, and how R_1, R_2, and R_{E1} might affect the lower knee frequency of the amplifier.
4. Related to step 4, what is the output resistance of an ideal current mirror?
5. Estimate the input and output resistances in step 6.
6. Estimate the knee frequency in step 7. Which resistance should you use in $\omega_0 = \frac{1}{RC}$?

In this lab you will design a current mirror and use it to bias a two-stage amplifier.

BJT current mirror

In this section you will build a BJT current mirror.



1. Build a 1 mA current mirror from two NPN BJT transistors. Use ±15 V power supplies. Adjust the reference resistor such that you get 1 mA through a 10 kΩ load resistor. Normally a current mirror is built from matched components on the same semiconductor die which ensures that it will operate at the current expected. Since the transistors you will use are not matched you will likely need to adjust the resistor to get the output current to be what you want. If you have difficulty you can also add a small resistance to the emitter of Q_2 and perhaps Q_1 (If you expect to run out of 3904s, then use 2222s for the current mirror).

2. Attach a large range of load resistors to the input (the collector of Q_2) including resistances beyond the failure point of the current mirror. Plot the current versus the load resistance, possibly on a logarithmic resistance scale. Is the current more or less constant as a function of load resistance in the regulation region? What causes the (hopefully small) variation of current with load resistance? What is the output resistance of the current mirror? Compare the measured failure point to what you expect from theory.

   NOTE: since the two BJTs are not exactly matched it takes a little effort to match the currents, something which happens automatically on a single silicon die. Can you think of another way to create a current source, with just one BJT? Hint: it is a different use of a familiar circuit. If we fail at making a useful current source from two BJTs we will revert to this circuit. What would be the disadvantage of a single-BJT current source on a silicon die?

BJT two-stage amplifier

In this section you will use the current mirror to bias one of the amplifiers in a two-stage amplifier.

3. Build a two-stage amplifier consisting of the cascade of two common-emitter with emitter resistance stages, and total gain 25 distributed evenly between the two stages. Use $\pm 15\,\mathrm{V}$ power supplies. The first stage should be built from a NPN transistor and biased by the current source built above. The second stage should be built from a PNP transistor and biased with resistors. The base of the second stage is biased by the collector of the first stage. The input and output of the amplifier should both be biased at $0\,\mathrm{V}$. That means that the output should be at ground when no input is attached and when the input is attached to ground. Here are some hints:

   (a) Begin by selecting the bias current for the second stage, then the collector resistor to produce the desired output voltage, then the emitter resistor to give the desired gain. This will set the input bias voltage for the second stage.

   (b) The first stage is biased by the current mirror, so select a collector resistor to set the output bias voltage. Select a emitter resistor to get the desired gain. Bypass the current source with a large capacitor. Select base bias resistors (usually called R_1 and R_2) to set the desired base voltage.

   (c) Verify that input and output resistances are appropriate and result in at most small gain loss. If that is not the case modify the circuit.

4. Measure the small-signal gain (at a few frequency in the 1 kHz-10 kHz range to make sure you are not on the attenuation slope of the HP filter) and compare with a theoretical calculation based on your design.

5. Plot the input-output characteristic in XY mode including saturation levels. Does the amplifier saturate where you expect it?

6. Measure input and output resistances and compare with a theoretical prediction.

7. This amplifier will function as a high-pass filter. Why? Measure the knee-frequency and compare it to a theoretical prediction. (If you picked C too large in step 3, you may reduce it here to make it easier). The knee-frequency is where the gain is reduced by a factor of $\frac{1}{\sqrt{2}}$.