Lab Number 6
EEE 108L – Electronics I - Laboratory

Common Emitter Biasing (One week)

Background

The factors affecting the DC bias of a common-emitter amplifier stage will be investigated here. The collector current is stabilized against variations in transistor parameters by the inclusion of an emitter resistor. After the stage is biased, the base voltage will be driven with an AC signal to illustrate principles of common-emitter amplifier operation.

Preliminary Calculations:

1. Consider the circuit of Figure 1. Assume that Q1 has $V_{BE} \approx 0.7$ V and $\beta = 150$. Neglect the Early effect; that is VA=∞. The default component values are R_C= 10k, R_{BB} = 22kΩ and R_E = 1kΩ. Use V_{CC} = 10V. Find the value of V_{BB} that will result in I_C = 0.5mA. Assume $I_C \approx I_E$, but do not neglect the voltage drop across R_{BB} due to base current. What is the voltage drop across R_{BB} at this bias?

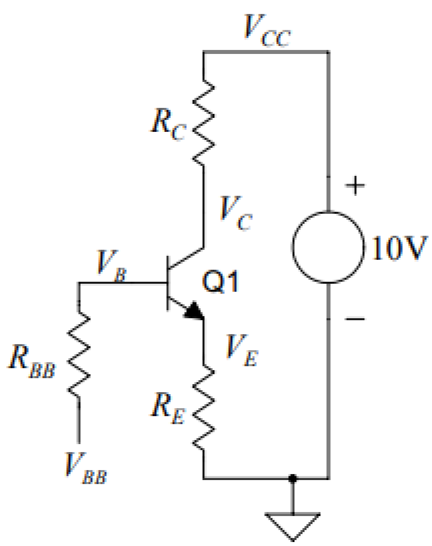


Figure 1

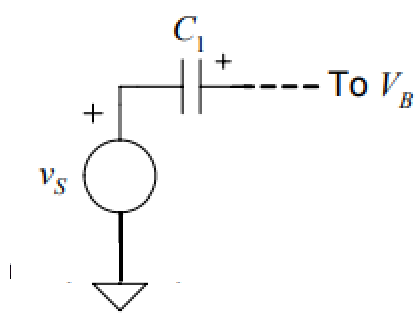
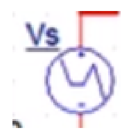


Figure 2

2. This step tests the sensitivity of I_C to variations in β. Let V_{BB} equal the value found before. If the value of β were to increase by 50% (i.e., to 225), by what percentage would the collector current increase? Assume that V_{BE} remains constant. (Hint: the voltage drop across R_{BB} changes.)
3. Let V_{BB} equal the value found before. Suppose that the temperature increases by 40°C, and that the temperature coefficient of V_{BE} is −2mV/ °C. Also, assume that β increases from its nominal value of 150 because of a (+1.25%)/ ºC temperature coefficient. What is the new collector current and by what percentage did it change?
4. Find an approximate expression for $\Delta V_C/\Delta V_B$ in terms of the circuit resistor values. Note that the denominator is ΔV_B, not ΔV_{BB}. Leave the resistor values as variables in your expression. (Hints: Assume that the transistor is biased in its forward active region and that V_{BE} is constant, so that $\Delta V_E=\Delta V_B$). Also note that $\Delta V_C=-\Delta I_C R_C$ and $I_C \approx V_E/R_E$. Evaluate this expression for this circuit by substituting the given component values.

SPICE Simulations:

1. Enter the circuit of Figure 1 into SPICE for simulation. Transistor Q1 should be a 2N3904. Set the DC value of the source V_{BB} equal to the value found before and run a bias point simulation. Enable the Bias Point Detail. Set V_S = 0,0 25u,0.1 75u, -0.1 100u,0



2. Record the values of V_B, V_E, V_C, I_C and I_B that correspond to this one value of V_{BB}.
3. Edit the SPICE model for the transistor by increasing the value of β by 50%. The parameter to edit is Bf, the ideal maximum value of β in the forward active region. Increasing this value of β by 50% should increase the computed value of β by about 50%.
4. Record the values of V_B, V_E, V_C, I_C and I_B that correspond to this one value of V_{BB}.
5. Return the SPICE model parameter Bf to its original value. Increase the temperature by 40ºC from its default value by using Analysis/Setup/Temperature.
6. Repeat the simulation and record the values of V_B, V_E, V_C, I_C and I_B that correspond to this one value of V_{BB}.
7. Set up the analysis to perform a DC sweep of V_{BB} from 0V to 5V. From the simulation results, obtain a plot showing V_C, V_B and V_E. Draw vertical lines on the plot to divide it into ranges for which the transistor appears to be in the cutoff, forward active, and saturation regions of operation. Label each region. (Note: Strictly speaking, operation in the cutoff region implies that both junctions are reverse biased and I_C=0.) On your plot, there is a region in which I_C=0, even though the base-emitter junction is slightly forward biased. Label this region "cutoff", because the transistor acts as if it is in cutoff.
8. For two values of V_{BB}, well within the forward active region, use the cursors to find corresponding values of V_B and V_C. Calculate $\Delta V_C/\Delta V_B$ and compare this value to that found in preliminary calculation.

Laboratory Measurements:

1. Construct the circuit of Figure 1. V_{BB} should be a variable voltage source.
2. Sweep V_{BB} from 0.5V to at least 4V. For different values of V_{BB}, record the resulting values of V_C, V_B and the corresponding I_C in a data table. It will be more accurate to use a DMM to measure these DC voltages. Take at least one data point for which I_C=0, and at least two data points in the saturation region. In the forward active region, take one data point at I_C=0.5mA (adjust V_{BB} until V_C has the value corresponding to I_C=0.5mA).
3. Using the same circuit, set V_{BB} to the value that causes I_C= 0.5mA.
4. Do not remove V_{BB} or R_{BB}, but add the components of Figure 2 to the circuit. The capacitor C_1 should be at least 1 µF, and should be installed observing the polarity indicated on the figure. Set source vs a 200mVpp triangle wave at 10kHz.
5. Observe the waveforms with an oscilloscope set to DC coupling. The DC bias voltages present will displace the centers of the AC waveforms vertically away from ground (zero volts). Record the following in a table:
   a) The DC voltage at the base, called V_B;
   b) the AC voltage at the base (in Vpp), called vb;
   c) the DC voltage at the collector, called V_C;
   d) the AC voltage at the collector called vc.
6. From this data, calculate the small-signal gain vc/vb. Is this value near the value of $\Delta V_C/\Delta V_B$ found in simulation analysis?
7. Increase the AC signal amplitude until V_C shows clipping at both peaks. Record maximum and minimum value of V_C.