Experiment 7: The Common Emitter Amplifier

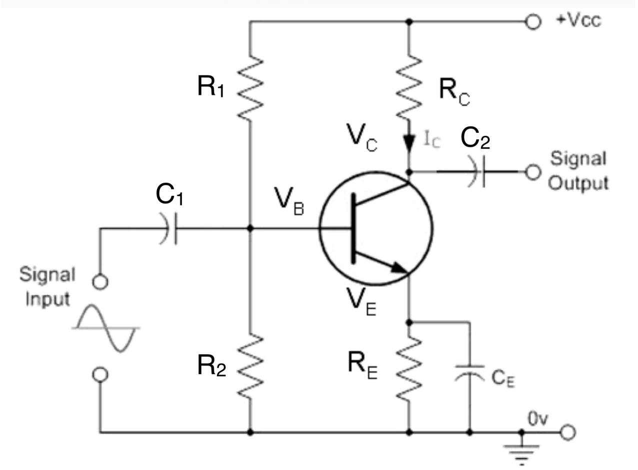
Goal: To construct a common emitter amplifier using the NPN bipolar junction transistor that was characterized last week in experiment 6.

Amplifier Circuit and Prelab Exercises:

(Refer to the introductory notes for experiment 6 as needed.)

With no ac input, the dc power supply ($+V_{cc}$) and the bias resistors establish the operating point.

The circuit will be built with and without capacitor C_E to see how it affects the performance of the circuit.



We will use: $V_{CC} = 18$ V, $R_1 = 33$ kΩ, $R_2 = 2.2$ kΩ, $R_C = 3.3$ kΩ, $R_E = 220$ Ω, $C_1 = C_2 = 0.47$ μF, $C_E = 10$ μF.

a) Assuming I_b is small, and that $V_{BE} = 0.6$ V when the BE junction is forward biased, determine the dc currents I_2 (flowing through R_2) and I_C for these component values.

b) What is the value of V_{CE}?

c) Using your measurement of β from expt. 6 ($\beta \approx 200$), what is the value of I_b?

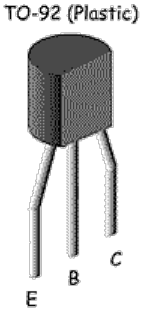
d) On a copy of the transistor characteristic curves from expt. 6, plot the load line: I_C versus V_{CE} for $V_{cc} = 18$ V. Identify and mark the operating point (I_C, V_{CE} and I_b).

(You may interpolate between the measured characteristic curves to illustrate this.)

e) Suppose $V_B \rightarrow V_B + \delta V_B$. Assume V_{BE} and V_{CC} are constant. What are the corresponding changes in I_E and I_C? What is δV_C? Show that $\delta V_C / \delta V_B \approx -R_C / R_E$. (This is essentially the gain of the amplifier circuit; the – sign indicates a phase shift of π)

Equipment List:

- 2N4400 NPN bipolar junction transistor, characterized in experiment 6
- Biasing circuit: R_1 = 33 kΩ, R_2 = 2.2 kΩ, R_C = 3.3 kΩ, R_E = 220 Ω
- Input / output capacitors: C_1 = C_2 = 0.47 μF
- $C_E = 10$ μF *(add later)*
- DC power supply, AC function generator
- DMM, digital scope

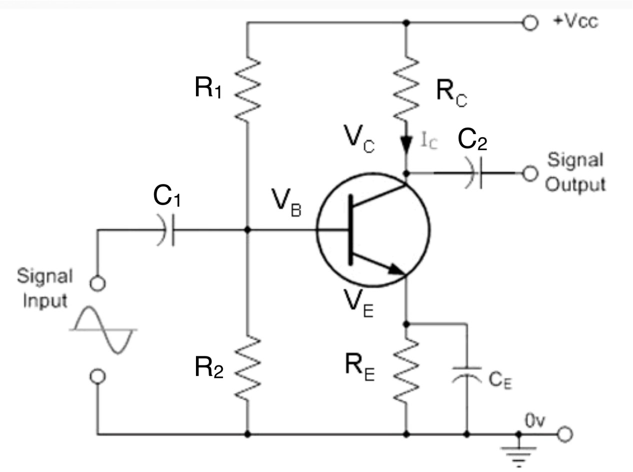


Measurements:

1. Preparation and dc tests:

Draw the circuit in your lab book, assemble the necessary resistors, measure them, and label the actual component values on your circuit diagram.

Assemble the transistor and DC biasing circuit (no capacitors!) on the breadboard. Take care to lay the circuit out neatly so you can see what is connected where. Trim the ends of the resistor leads as necessary so that they will not easily pull loose when you study the circuit with a scope.



The suggested resistors are only approximate, so your operating point may not be as calculated in the prelab exercise. Use a DMM to check that the potential difference V_{CE} is close to 9 V. If it is not within ½ volt or so, you can vary R_1 or R_2. Increasing R_2 will increase the base current and reduce V_{CE}. Increasing R_1 will do the opposite.

When V_{CE} is close to 9V, determine I_C and I_E by measuring potential drops across appropriate resistors, and compare to expectations.

If everything makes sense, proceed to part 2. If not, seek help!

2. AC amplifier characterization:

Connect the input and output capacitors C_1 and C_2 (omit C_E for now). Set up the function generator to apply a sinewave with a frequency of about 10 kHz. Watch the output as the input is increased from zero until effects of saturation and cutoff (clipping) are observed. If the operating point is symmetrically placed, distortion should appear at both ends at about the same input. Then decrease the input amplitude to give an undistorted output. This should be in the range of 100 mV.

Quickly scan through a range of frequencies from about 30 Hz to 150 kHz and observe how the output signal amplitude and phase vary with respect to the input. Identify the 3-dB point at low frequency. The high frequency 3-db attenuation probably happens beyond the maximum frequency of the signal generator. In the mid-range, the gain should be fairly constant.

The approximate gain of the circuit was already shown to be $a = \frac{v_o}{v_i} \approx \frac{-R_C}{R_E}$. A more detailed analysis gives the gain in the operating range to be:

$$a = \frac{v_o}{v_i} = \frac{-\beta R_C}{r_{be}+(\beta+1)R_E},$$

where β is the ac current gain at the operating point as measured in experiment 6. The resistance r_{be} represents base resistance which was measured in experiment 6. Evaluate the gain using both expressions and compare to what you measure at a mid-band frequency, say 20 kHz.

Now, add the emitter capacitor, and observe the change in the gain. Re-measure the gain at a mid-band frequency if you can, or place a lower limit on the gain if the output is distorted for the lowest input voltage. If you have time, and if necessary, you can use a voltage divider (10 kΩ and 2.2 kΩ) to attenuate the input for this measurement.

The expected value for this case is often approximated by $a = \frac{v_o}{v_i} = \frac{-\beta R_C}{r_{be}}$ (as in class, and in the text book). Compare your measured gain (or the lower limit) with this calculation. Only rough agreement should be expected here because the approximations are quite crude, particularly for the value of r_{be}, when the amplitude of the output is enough to produce distortion.