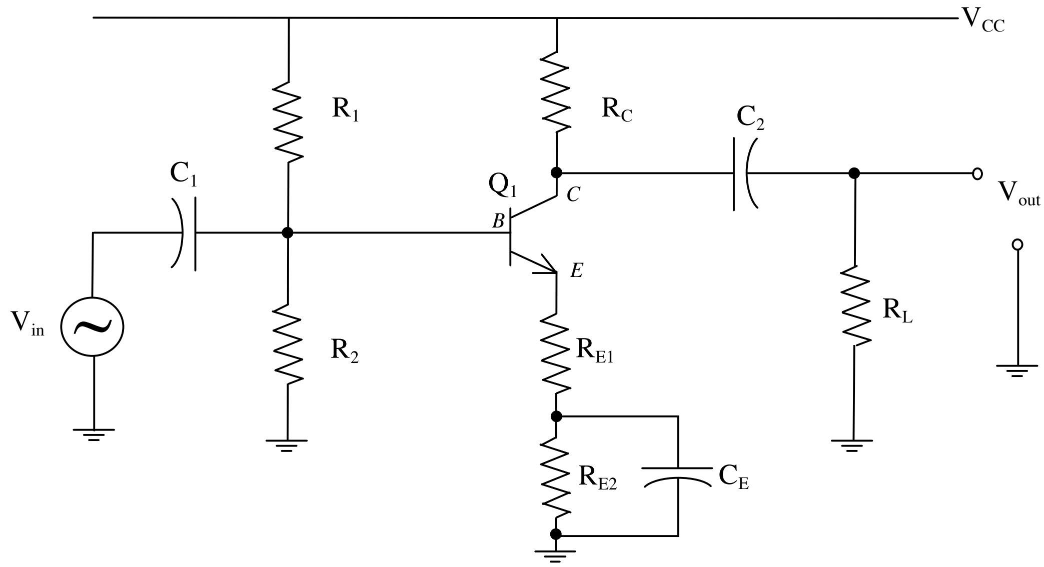
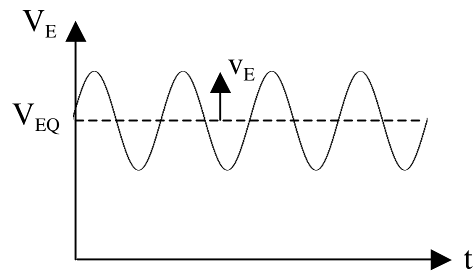
PHY2250, Dr. Hawley: AC Operation of a Common-Emitter Amplifier

We've previously discussed the DC operation of a common-emitter amplifier, DC load lines, Q points, etc. We now consider the AC operation of such an amplifier. We're going to put two resistors on the emitter, along with a bypass capacitor as shown:



(R_{E1} can either be an explicit resistor or it can represent the effective "resistance" which appears in real-world performance of diodes, i.e. the fact that there is a finite slope to the line on current-vs.-voltage graph for a diode, rather than an "instant" transition at 0.7V.)

Let's break all quantities into their DC and AC parts, which will be denoted by a subscript "Q" and a lower-case letter, respectively. So, *e.g.*, $V_E = V_{EQ} + v_E$, as shown in the following graph:



Note that because of the "diode drop" between the base and the emitter, $V_E = V_B + 0.7V$. The "AC part" of this equation tells us that $v_E = v_B$. A simple proof follows:

$$V_E = V_B - 0.7V$$
$$V_{EQ} + v_E = V_{BQ} + v_B - 0.7V$$
$$V_{EQ} + v_E = (V_{EQ} + 0.7V) + v_B - 0.7V$$
$$v_E = v_B. \qquad (1)$$

Because of bypass capacitor C_E allows AC signals to go "around" R_{E2}, the AC part of the emitter voltage, v_E, is given by

$$v_E = i_E R_{E1}. \qquad (2)$$

The collector voltage, V_C, is given by

$$V_C = V_{CC} - I_C R_C$$

$$V_{CQ} + v_C = V_{CC} - (I_{CQ} + i_C)R_C,$$

and the "AC part" of this means that

$$v_C = -i_C R_C. \qquad (3)$$

We are now ready to compute the voltage gain of this amplifier.

The **AC Voltage Gain A_V** is defined to be the ratio of the AC parts of output voltage to input voltage,

$$A_V = v_{out} / v_{in}.$$

Considering that $v_{in} = v_B = v_E$, and $v_{out} = v_C$, we find

$$A_V = v_C / v_E = -i_C R_C / i_E R_{E1}.$$

Given that the AC beta $\beta \equiv i_C / i_B$ is a large number (close to the value of $\beta_{DC} \equiv I_C/I_B$, which is on the order of 100), i_C and i_E are approximately equal. Therefore the gain of the amplifier is

$$\boxed{A_V = -\frac{R_C}{R_{E1}}.}$$

So by lowering the value of R_{E1}, we can increase the gain of the amplifier.

What then is the function of the resistor R_{E2}? It affects the DC operation of the amplifier, i.e. it controls the placement of the Q point on the DC load line. Recall that $I_{EQ} = V_{EQ} / (R_{E1} + R_{E2})$, and since I_E is approximately equal to I_C,

$$\begin{aligned} V_C &= V_{CC} - I_C R_C \\ &= V_{CC} - V_{EQ} R_C / (R_{E1} + R_{E2}). \end{aligned}$$

So the combination $R_{E1} + R_{E2}$ takes the place of the single R_E in our previous studies of the DC characteristics of the amplifier.