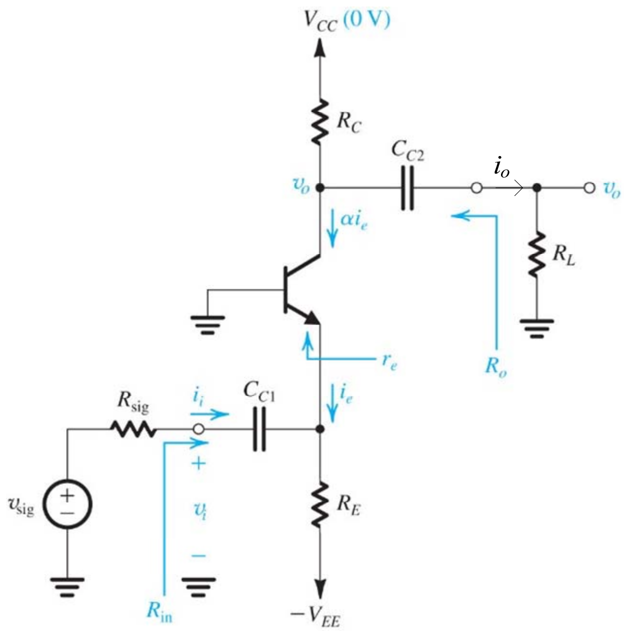
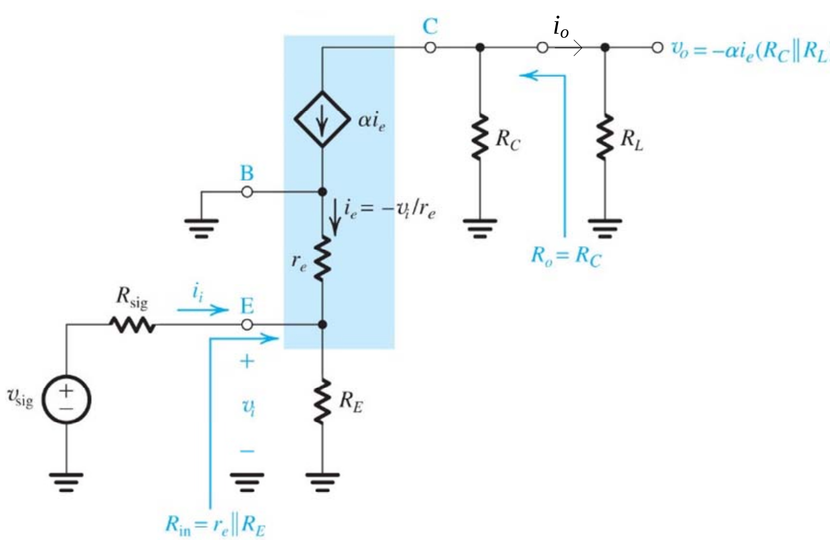
Lecture 20: Common Base Amplifier.

We will cover the second of the three families of BJT amplifiers in this lecture by discussing the common base amplifier shown in Fig. 7.58a:



(Fig. 7.58a)

The small-signal equivalent circuit for this amplifier is shown in Fig. 7.58b (ignoring r_o):



(Fig. 7.58b)

As before, let's determine the small-signal AC characteristics of this amplifier by solving or R_{in}, G_v, G_i, A_{is}, and R_{out}.

- Input resistance, R_{in}. From direct inspection of the small-signal equivalent circuit, we see that
$$R_{\text{in}} = r_e \parallel R_E \tag{1}$$
Since r_e is often small (on the order of 20 to 30 Ω), then R_{in} of the CB amplifier is very small. Generally this is not desirable, though in the case of certain high frequency amplifiers input impedances near 50 Ω is very useful (to reduce so-called "mismatch reflections" at the input).

- Small-signal voltage gain, G_v. We'll first calculate the partial voltage gain
$$A_v \equiv \frac{v_o}{v_i} \tag{2}$$
At the output,
$$v_o = -\alpha i_e \left(R_C \parallel R_L \right) \tag{3}$$
The small-signal emitter current is
$$i_e = \frac{-v_i}{r_e} \tag{4}$$
Substituting (3) and (4) into (2) gives the partial voltage gain to be
$$A_v = \frac{\alpha}{r_e}\left(R_C \parallel R_L \right) = g_m \left(R_C \parallel R_L \right) \tag{5}$$

This is the same gain as for the CE amplifier (without r_o), except the gain here for the CB amplifier is positive.

The overall (from the input to the output) small-signal voltage gain G_v is defined as

$$G_v \equiv \frac{v_o}{v_{\text{sig}}} \tag{6}$$

We can equivalently write this voltage gain as

$$G_v = \frac{v_i}{v_{\text{sig}}} \cdot \frac{v_o}{v_i} \underbrace{=}_{(2)} \frac{v_i}{v_{\text{sig}}} A_v \tag{7}$$

with A_v given in (5).

By simple voltage division at the input to the small-signal equivalent circuit

$$v_i = \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} v_{\text{sig}} \tag{8}$$

Substituting this result and (5) into (7) yields the final expression for the overall small-signal voltage gain

$$G_v = \frac{\alpha\left(R_C \parallel R_L\right)}{r_e} \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} \tag{9}$$

or since $r_e = \alpha / g_m$ as in (7.74)

$$G_v = g_m\left(R_C \parallel R_L\right) \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} \qquad (7.155),(10)$$

This gain can be fairly large, though if R_{sig} is nearly the same size as R_{in}, or larger, the gain will be small. In other words, if this amplifier is connected to a high output impedance stage at the input, it will be difficult to realize high gain.

- Overall small-signal current gain, G_i. By definition

$$G_i \equiv \frac{i_o}{i_i} \tag{11}$$

Using current division at the output of the small-signal equivalent circuit above

$$i_o = \frac{-R_C}{R_C + R_L} i_c = \frac{-\alpha R_C}{R_C + R_L} i_e \tag{12}$$

With

$$i_i = \frac{-R_E}{R_E + R_{\text{sig}}} i_e$$

then substituting this into (12) gives

$$G_i = \frac{i_o}{i_i} = \frac{\alpha R_C}{R_C + R_L} \frac{R_E + R_{\text{sig}}}{R_E} \tag{13}$$

- Short circuit current gain, A_{is}. In the case of a short circuit load ($R_L = 0$), G_i in (13) reduces to the short circuit current gain:

$$A_{is} = \frac{i_{os}}{i_i} = \alpha \frac{R_E + R_{\text{sig}}}{R_E} \tag{14}$$

- Output resistance, R_o. Referring to the small-signal equivalent circuit above and shorting out the input $v_{\text{sig}} = 0$

$$R_o = R_C \tag{15}$$

which is the same as the CE amplifier (when ignoring r_o).

Summary

Summary of the CB small-signal amplifier:

1. Low input resistance.
2. G_v is positive and can be very large, though critically dependent on R_{sig}.
3. From (13), if $R_{\text{sig}} \ll R_E$ and $R_L \ll R_C$, then $G_i \approx \alpha$.
4. Potentially large output resistance (dependent on R_C).

One very important use of the CB amplifier is as a unity-gain current amplifier, which is also called a current buffer amplifier. This type of amplifier accepts an input signal current at a low impedance level ($\approx r_e \,||\, R_E$ in Fig. 7.58b) and outputs nearly the same current amplitude, but at a high output impedance level ($\approx R_C$). (See 3. above.) Even though this is a buffer amplifier, there can still be power gain.