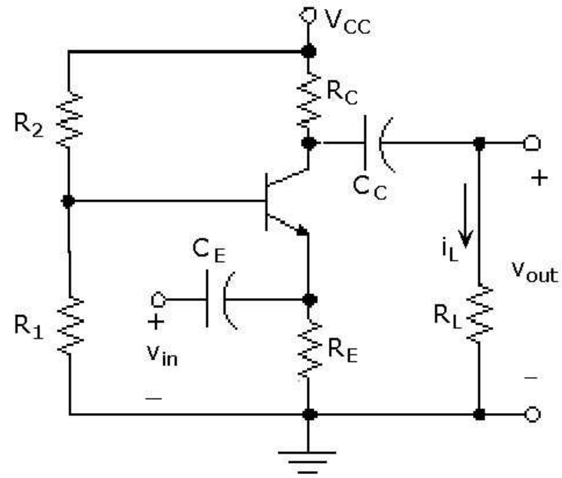
Section D5: The Common-Base Amplifier

The last of the four basic amplifier configurations we're going to look in detail is the common-base, illustrated in Figure 5.11a of your text and reproduced (slightly modified) to the right. In this configuration, the input is applied at the emitter terminal and the output taken at the collector. This will result in the base terminal being grounded for ac operation – common to both the input and output – hence the name!



Once again, in an attempt to clarify what's going on, we have more than one version of the small signal model for the common base configuration. The figure shown below on the left is the ac small signal drawn directly from the amplifier above. As usual, we are assuming that the capacitors are shorts for the frequency range of interest. The figure below on the right is the same small signal model with the transistor terminals reoriented to make the drawing easier. In each of these figures, the "look-in" points for R_{in} and R_{out} are defined. ***Make sure that you are comfortable with how these small signal models are drawn, and that they indeed do represent the same circuit (like you've never heard that before, right?).***

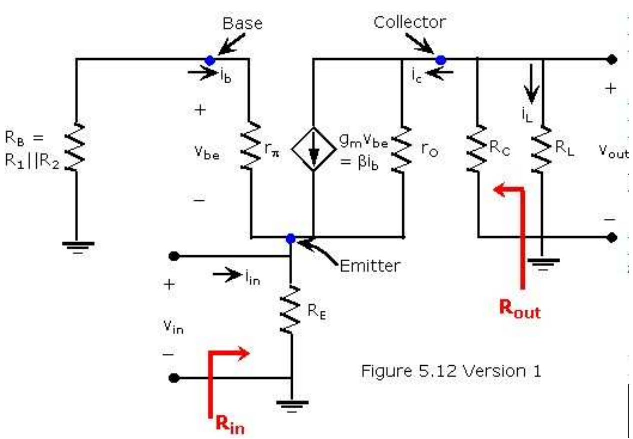


Figure 5.12 Version 1

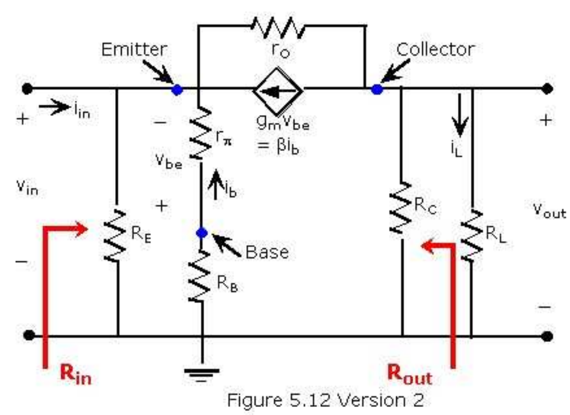


Figure 5.12 Version 2

And, the standard caution (for the last time, thank heavens!). Keep in mind the advice about practical sources and complex impedances…and that we're assuming ideal capacitors (opens for dc and shorts for ac operation in the frequency range of interest).

Input Resistance, R_{in}

The input resistance for the common-base amplifier is derived in your text using circuit analysis techniques. An alternate strategy uses either of the figures above, but is probably most obvious in Version 2. R_{in} may be found by recognizing that between the input and ground there are two parallel resistances: R_E in the emitter path and $r_\pi+R_B$ in the base path. Using the technique of impedance reflection, the base resistance can be moved to the emitter (notice that we're looking into the emitter this time) by dividing by $\beta+1$. If we make our standard assumption that $\beta>>1$ and $\beta+1=\beta$, R_{in} may be expressed as:

$$R_{in} = R_E \parallel \left(\frac{r_\pi + R_B}{\beta} \right) = R_E \parallel \left(r_e + \frac{R_B}{\beta} \right). \qquad \text{(Equation 5.43)}$$

Notice that, in Equation 5.43, both r_e and R_B/β are generally quite small. Since R_E is usually much larger, the sum of these terms dominates the parallel combination and results in a low R_{in}. As we will see later, this low input resistance is a serious limitation of the common-base configuration.

Output Resistance, R_{out}

If we assume that r_o is very large, it may be neglected in the calculation of output resistance. This simplification leaves only R_C in the output circuit so, like the common-emitter amplifier, the output resistance for the common-base configuration is

$$R_O = R_C. \qquad \text{(Equation 5.48)}$$

As was discussed in the common-emitter derivation, if we cannot neglect r_O, the output resistance is the parallel combination of R_C and r_O.

Current Gain, A_i

Using current division (refer to Figure 5.12, Version 2). Assuming r_O is very large and that $\beta+1=\beta$), the load current is

$$i_L = \frac{-R_C \beta i_b}{R_L + R_C}.$$

The base current is also found by using current division, but notice that we must consider the resistance reflected into the base to define i_b:

$$i_b = \frac{-R_E i_{in}}{\beta R_E + r_\pi + R_B} = \frac{-R_B i_{in}}{\beta (R_E + r_e + R_B/\beta)}. \qquad \text{(Equation 5.45)}$$

Solving Equation 5.45 for i_{in} and substituting the expressions for i_L and i_{in} into Equation 5.7:

$$A_i = \frac{i_L}{i_{in}} = \left(\frac{R_C}{R_C + R_L}\right)\left(\frac{R_E}{R_E + r_e + R_B/\beta}\right). \qquad \text{(Equation 5.46)}$$

Voltage Gain, A_v

Making use of the Gain Impedance Formula again, the voltage gain is

$$A_v = \frac{v_{out}}{v_{in}} = A_i \frac{R_L}{R_{in}}. \qquad \text{(Equations 5.4 \& 5.21)}$$

Using the expressions for R_{in} and A_i, and expanding the parallel relationship of the input resistance:

$$A_v = \left(\frac{R_C}{R_C + R_L}\right)\left(\frac{R_E}{R_E + r_e + R_B/\beta}\right)\left(\frac{R_L\left(R_E + r_e + R_B/\beta\right)}{R_E\left(r_e + R_B/\beta\right)}\right) = \frac{R_C R_L}{\left(R_C + R_L\right)\left(r_e + R_B/\beta\right)}.$$

Recognizing the parallel relationship between R_C and R_L, and remembering that $r_e = 1/g_m$, two expressions for the voltage gain of a common-base amplifier are found:

$$A_v = \frac{R_C \parallel R_L}{r_e + R_B/\beta} = \frac{g_m (R_C \parallel R_L)}{1 + g_m R_B/\beta}. \qquad \text{(Equation 5.47)}$$

NOTE: Placing a bypass capacitor between the base terminal and ground will short R_B for ac operation, significantly increasing the voltage gain.

Finally, notice that the voltage gain is positive (as was the current gain). This indicates that the input and output signals are in phase.