The Common Collector (CC) Amplifier

For the CC amplifier, the signal is applied to the base and the output is taken from the emitter. A typical capacitively coupled CC amplifier is shown.

\[ V_+ \]
\[ R_s \]
\[ C_1 \]
\[ V_\text{in} \]
\[ R_z \]
\[ R_E \]
\[ R_L \]
\[ V_- \]
\[ R_1 \]
\[ C_2 \]
\[ V_0 \]

The dc bias currents and voltages are solved for in the same way as for the CE and CB amplifiers. For the ac small-signal solution, set \( V_+ = V_- = 0 \) and assume the capacitors are ac short circuits. The circuit reduces to
The input and output resistances are given by

\[ R_{\text{in}} = R_i \parallel R_2 \parallel R_{\text{ib}} \]
\[ R_{\text{out}} = R_E \parallel R_{\text{re}} \]

where

\[ R_{\text{ib}} = R_x + (1+\beta) \left( R_e + R_E \parallel R_L \right) \quad (R_{tc} = 0) \]
\[ R_{\text{re}} = R_e' \frac{R_0}{R_e' + R_0} = R_e' \parallel R_0 \quad (R_{tc} = 0) \]
\[ R_{e}' = \frac{R_5 \parallel R_i \parallel R_2 + R_x}{1 + \beta} + R_e \]
\[ R_e = \frac{V_T}{I_E} \]
Looking out of the base, the Thévenin equivalent circuit has the values

\[
 U_{tb} = U_n \frac{R_{11}R_2}{R_n + R_{11}R_2} \\
 R_{tb} = R_{011}R_{11}R_2
\]

To solve for \( U_0 \), we replace the BJT with the Thévenin emitter circuit.

By voltage division

\[
 U_0 = U_{e(oc)} \frac{R_{E11}R_L}{R_{ie} + R_{E11}R_L} \\
 = U_{tb} \frac{R_0}{R_n + R_0} \frac{R_{E11}R_L}{R_{ie} + R_{E11}R_L} \quad (R_{tb} = 0)
\]
Thus the voltage gain is given by

\[ A_v = \frac{V_o'}{V_i} = \frac{R_{11}R_2}{R_s + R_{11}R_2} \frac{R_o}{R_e' + R_o} \frac{R_{ELR}L}{R_{LE} + R_{ELR}L} \]

If \( R_s << R_{11}R_2 \), \( R_e' << R_o \), and \( R_{LE} << R_{ELR}L \), it follows that \( A_v \approx 1 \). In no case can \( A_v \) be greater than 1. The circuit is mainly used for current gain. It is often called an emitter follower or a buffer amplifier.

The above solution is exact. Often an approximate solution is made for rough calculations. Assume that \( R_e = 0 \) and \( R_o = \infty \) for the approximations. In this case
\[ \begin{align*}
    \beta \beta' = \beta^2 \\
    \beta \beta' = (1 + \beta) (R_e + R_{te}) \\
    \beta \beta' = \frac{g_m}{\alpha} \left( V_b - V_o \right) \\
    \beta \beta' = 2 \beta^2
\end{align*} \]

The signal equivalent circuit is

\[ V_o = I_e R_{te} = \frac{I_c}{\alpha} R_{te} = g_m (V_b - V_o) \frac{R_{te}}{\alpha} \]

\[ \Rightarrow V_o \left[ 1 + \frac{g_m R_{te}}{\alpha} \right] = V_b \frac{g_m R_{te}}{\alpha} \]

\[ \Rightarrow V_o = V_b \frac{g_m R_{te}}{\alpha} \frac{1 + \frac{g_m R_{te}}{\alpha}}{1 + \frac{g_m R_{te}}{\alpha}} \]

But \[ V_b = V_{tb} \frac{\beta \beta'}{R_{tb} + \beta \beta'} \]

\[ \Rightarrow V_o = V_{tb} \frac{\beta \beta'}{R_{tb} + \beta \beta'} 1 + \frac{g_m R_{te}}{\alpha} \]

\[ = V_o \frac{\beta \beta'}{R_{tb} + \beta \beta'} 1 + \frac{g_m R_{te}}{\alpha} \]

\[ = V_o \frac{R_{tb} + \beta \beta'}{R_t + R_{tb} + \beta \beta'} 1 + \frac{g_m R_{te}}{\alpha} \]

\[ = V_o \frac{R_{tb} + \beta \beta'}{R_t + R_{tb} + \beta \beta'} 1 + \frac{g_m R_{te}}{\alpha} \]
\[ A_v = \frac{V_0}{V_A} = \frac{R_{\text{II}R_{\text{Z}}}}{R_s + R_{\text{I}I}R_{\text{Z}}} \frac{R_{\text{ib}}}{R_{\text{tb}} + R_{\text{ib}}} \frac{g_mR_{\text{te}}}{d} \]

Note that this solution is exact if \( R_x \) is included in the expression for \( R_{\text{ib}} \) and \( R_0 \) is combined in parallel with \( R_{\text{tc}} \). The latter can be done because \( R_{\text{tc}} = 0 \). For \( R_{\text{tc}} \neq 0 \), \( R_0 \) complicates the solution if it is to be included. The exact solution above should be used in this case if node equations are to be avoided.

A second and simpler approximate solution is as follows:

\[ V_0 = i_e R_{\text{te}} = (1 + \beta) i_6 R_{\text{te}} \]

\[ = (1 + \beta) \frac{V_{\text{tb}}}{R_{\text{tb}} + R_{\text{ib}}} R_{\text{te}} \]

\[ = V_A \frac{R_{\text{I}I}R_{\text{Z}}}{R_s + R_{\text{I}I}R_{\text{Z}}} \frac{(1 + \beta) R_{\text{te}}}{R_{\text{tb}} + R_{\text{ib}}} \]
This solution is far simpler than the one which uses the equation $i_c = g_m(v_b - v_o)$ to calculate the currents. Again, it can be made exact by adding $R_x$ to $R_{ib}$ and combining $R_o$ in parallel with $R_{te}$. The latter cannot be done if $R_{tc} \neq 0$. 