HW, Exam, Quiz scores posted on Canvas please report any discrepancies.

Single-transistor amplifier circuits

CE amplifier

Intrinsic gain \( \frac{v_o}{v_i} = -G_m R_o \)

\( v_o = -G_m v_i R_o \)

\( \frac{v_o}{v_i} = -G_m R_o \)

\( v_o = -G_m R_o \frac{R_o + R_L}{R_i + R_o + R_L} \)

\( A_{v3} = \frac{-G_m R_o R_L}{R_o + R_L} \frac{R_i}{R_i + R_o + R_L} \)

Voltage amplifier: \( R_e \) large, \( R_o \) low, \( A_v \) large

Short-circuit current gain

\( A_i = \frac{i_o}{i_i} \)

\( i_i = \frac{v_i}{R_i} \)

\( i_o = G_m v_i \Rightarrow \frac{i_o}{i_i} = G_m R_i \)
CE amplifier with emitter degeneration

\[ R_i = \frac{v_i}{i_i} = r_k + R_E \left( 1 + g_m r_k \beta \right) \]

\[ v_E = R_E \left( i_t + g_m v_k \right) \]

\[ = R_E \left( i_t + g_m r_k i_t \right) \]

\[ = R_E \left( 1 + g_m r_k \right) i_t \]

\[ v_t = v_k + v_E = r_k i_t + R_E \left( 1 + g_m r_k \right) i_t \]

\[ R_i = \frac{v_t}{i_t} = r_k + R_E \left( 1 + g_m r_k \beta \right) \]

\[ R_E \rightarrow (\beta + 1) R_E \quad \text{when seen at the base} \]
\[ R_1 = \frac{R_S}{\beta+1} + \frac{r_k}{\beta+1} \]

Resistance reflection rule: base-emitter

\[ R_i = r_k + (\beta+1) R_E \]

\[ \approx r_k + \beta R_E \quad \text{when } \beta \text{ is large} \]

\[ \approx r_k + g_m r_k R_E = r_k \left( 1 + g_m R_E \right) \]

\[ G_m = \frac{i_o}{v_t} \]

\[ i_o = g_m v_k \]

\[ v_k = \frac{r_k}{r_k + (\beta+1) R_E} v_t \]

\[ G_m = \frac{i_o}{v_t} = \frac{g_m r_k}{r_k + (\beta+1) R_E} \approx \frac{g_m r_k}{r_k + \beta R_E} \]

\[ \approx \frac{g_m r_k}{r_k + g_m r_k R_E} = \frac{g_m}{1 + g_m R_E} \]

\[ i_t = \frac{v_t}{R_C} + g_m v_k \]

\[ v_k = i_t r_k \Rightarrow i_t = \frac{v_k}{r_k} \]

\[ v_E = R_E \left( i_t + g_m v_k \right) \]

\[ = R_E \left( \frac{v_k}{r_k} + g_m v_k \right) \]

\[ v_t R_s + v_k + v_E = 0 = \frac{v_k}{r_k} R_s + v_k + R_E \left( \frac{v_k}{r_k} + g_m v_k \right) \]
\[ v_K \left[ \frac{R_S}{V_K} + 1 + R_E \left( \frac{1}{V_K} + g_m \right) \right] = 0 \]
\[ \Rightarrow v_K = 0 \]

\[ u_t = \frac{v_t}{R_C} \Rightarrow R_o = R_C \]

\[ R_i = \frac{R_E (1 + g_m R_E)}{R_C} \]

\[ G_m = \frac{g_m}{1 + g_m R_E} \]

\[ R_o = R_C \]

Recall for a CE stage:
\[ A_v = -g_m R_C \]

So the gain is reduced by a factor of \((1 + g_m R_E)\) relative to the CE stage.

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**The common base (CB) amplifier**

\[ R_i = \frac{R_K}{\beta + 1} \]