npn BJT Amplifier Stages: Common-Emitter (CE)

1. Bias amplifier in high-gain region

Note that the source resistor $R_S$ and the load resistor $R_L$ are removed for determining the bias point; the small-signal source is ignored, as well.

Use the load-line technique to find $V_{BIAS} = V_{BE}$ and $I_C = I_{SUP}$.

2. Determine two-port model parameters
The small-signal model is evaluated at the bias point; we assume that the current gain is $\beta_0 = 100$ and the Early voltage is $V_{An} = 25$ V:

$$g_m = \frac{I_C}{V_{th}} \text{ (at room temperature)}$$

$$r_\pi = \frac{\beta_0}{g_m} = 10 \text{ k}\Omega$$

$$r_o = \frac{V_{An}}{I_C} = 100 \text{ k}\Omega$$

* Substitute small-signal model for BJT; $V_{CC}$ and $V_{BIAS}$ are short-circuited for small-signals
Two-Port Model: CE Amplifier

* Use transconductance amplifier form for model (*not* mandatory)

* \( R_{in} = r_{\pi} \), \( R_{out} = r_o \parallel r_{oc} \), \( G_m = g_m \) by inspection

* Compare with CS amplifier
  
  inferior input resistance
  
  superior transconductance
  
  about the same output resistance (assuming \( r_o \) dominates)
Common-Base Amplifier

Input current is applied to the emitter (with a bias current source) and the output current is taken from the collector
Common Base Two-Port Model

* See text for details of nodal analysis

\[ R_{in} \equiv 1/g_m, R_{out} \equiv r_{oc} \left| \left| r_o \left( 1 + g_m(r_\pi || R_S) \right) \right| \right|, A_i = -\beta_o / (1 + \beta_o) \equiv -1 \]

* CB stage is an excellent current buffer

Comparison with the CG stage:

Note the effect of the source resistance on the output resistance

If \( R_S \) is much greater than \( r_\pi \), then the output resistance is approximately:

\[ R_{out} \approx r_{oc} \left| \left| \beta r_o \right| \right| \]
Common-Collector Amplifier

* Circuit configuration

* Biasing: if transistor is “on” (i.e., not cutoff), then

\[ V_{BIAS} - V_{OUT} = 0.7 \text{ V.} \]

Alternative name ... emitter follower
Common Collector Two-Port Model

* Two-port model:

presence of rp makes the analysis more involved than for a common drain

\[ \frac{1}{g_m + R_S/\beta_o} \]

\[ r_{pi} + \beta_o (r_o \parallel r_{ox} \parallel R_L) \]

Note 1: both the input and the output resistances depend on the load and source resistances, respectively (note typo in Fig. 8.47 in text)

Note 2: this model is approximate and can give erroneous results for extremely low values of \( R_L \). However, it is very convenient for hand analysis.

Comparison with CD stage:

CC’s input resistance: high but not infinity

CC’s output resistance: generally lower (but watch out for large \( R_S \))
Summary of BJT Single-Stage Amplifiers

Why no pnp’s?
# Single-Stage MOS and BJT Amplifier

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