BJT small signal Analysis

Small signal model (hybrid pi model)

The hybrid pi model of a BJT is a small signal model, named after the “p”-like equivalent circuit for a bipolar junction transistor. The model is shown in Figure 2.1.1. It consists of an input impedance, *r*p, an output impedance *r0*, and a voltage controlled current source described by the transconductance, *gm*. In addition it contains the base-emitter capacitances, the junction capacitance, *Cj,BE*, and the diffusion capacitance, *Cd,BE*, and the base-collector junction capacitance, *Cj,BC*, also referred to as the Miller capacitance

The transconductance, *gm*, of a bipolar transistor is defined as the change in the collector current divided by the change of the base-emitter voltage.

$$g_m \stackrel{\Delta}{=} \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{nV_t}$$

The base input resistance, *r*p, is defined as the change of the emitter-base voltage divided by the change of the base current.

$$r_\pi \stackrel{\Delta}{=} \frac{\partial V_{BE}}{\partial I_B} = \beta \frac{\partial V_{BE}}{\partial I_C} = \frac{\beta}{g_m} = \frac{nV_t}{I_B}$$

The output resistance, *ro*, is defined as:

$$r_o \stackrel{\Delta}{=} \frac{\partial V_{CE}}{\partial I_C} \cong \frac{\partial V_{CB}}{\partial I_C} = \frac{|V_A|}{I_C}$$

SMALL SIGNAL ANALYSIS OF CC AMP

In electronics, a **common collector** amplifier (also known as an **emitter follower**) is one of three basic single-stage bipolar junction transistor (BJT) amplifier topologies, typically used as a voltage buffer.

In this circuit the base terminal of the transistor serves as the input, the emitter is the output, and the collector is common to both (for example, it may be tied to ground reference or a power supply rail), hence its name. The analogous field-effect transistor circuit is the common drain amplifier.

The common collector circuit can be shown mathematically to have a voltage gain of almost unity:

$$A_{\mathrm{v}} = \frac{v_{\mathrm{out}}}{v_{\mathrm{in}}} \approx 1$$

A small voltage change on the input terminal will be replicated at the output (depending slightly on the transistor's gain and the value of the load resistance; see gain formula below). This circuit is useful because it has a large input impedance

$$r_{\mathrm{in}} \approx \beta_0 R_{\mathrm{E}}$$

and a small output impedance, so it can drive low-resistance loads:

$$r_{\mathrm{out}} \approx R_{\mathrm{E}} \| \frac{R_{\mathrm{source}}}{\beta_0}$$

Typically, the emitter resistor is significantly larger and can be removed from the equation

$$r_{\text{out}} \approx \frac{R_{\text{source}}}{\beta_0}$$

Characteristics

At low frequencies and using a simplified hybrid-pi model, the following small-signal characteristics can be derived. (Parameter $\beta = g_m r_\pi$ and the parallel lines indicate components in parallel.)

Definition	**Expression**	**Approximate expression**	**Conditions**
Current gain	$\beta_0 + 1$	$\approx \beta_0$	$\beta_0 \gg 1$
Voltage gain	$g_m R_E / g_m R_E + 1$	≈ 1	$g_m R_{\text{E}} \gg 1$
Input resistance	$r_\pi + (\beta_0 + 1) R_{\text{E}}$	$\approx \beta_0 R_{\text{E}}$	$(g_m R_{\text{E}} \gg 1)$
Output resistance	$R_{\text{E}} \parallel \left(\frac{r_\pi + R_{\text{sour}}}{\beta_0 + 1}\right.$	$\approx \frac{1}{g_m} + \frac{R_{\text{sou}}}{\beta_0}$	$(\beta_0 \gg 1) \wedge (r_{\text{in}} \gg R_{\text{so}}$

Where R_{source} is the Thévenin equivalent source resistance

SMALL SIGNAL ANALYSIS OF CB AMP

In electronics, a **common base** (also known as **grounded-base**) amplifier is one of three basic single-stage bipolar junction transistor (BJT) amplifier topologies, typically used as a current buffer or voltage amplifier.

In this circuit the emitter terminal of the transistor serves as the input, the collector the output, and the base is connected to ground, or"common", hence its name. The analogous field-effect transistor circuit is the common gate amplifier.

Low-frequency characteristics

At low frequencies and under small-signal conditions, the hybrid-pi model for the BJT has been employed. The input signal is represented by a Thévenin voltage source, v_s, with a series resistance R_s and the load is a resistor R_L. This can be used to derive the following characteristics of the common base amplifier.

Definition	Expression	Approximate expression	Conditions
Open circuit voltage gain	$\frac{(g_m r_O+1)R_C}{R_C+r_O}$	$g_m R_C$	$r_O \gg R_C$
Short circuit current gain	$\frac{r_\pi+\beta r_O}{r_\pi+(\beta+1)r_O}$	1	$\beta \gg 1$

Input resistance	$\frac{(r_O+R_C\|R_L)r_E}{r_O+r_E+\frac{R_C\|R_L}{\beta+1}}$	$r_E\left(\approx\frac{1}{g_m}\right)$	$r_O \gg R_C\|R_L$
Output resistance	Rc‖{[1+gm(rπ‖Rs)]r	$R_C\|\|r_O$	$R_S \ll r_E$
			$R_S \gg r_E$

In general the overall voltage/current gain may be substantially less than the open/short circuit gains listed above (depending on the source and load resistances) due to the loading effect.