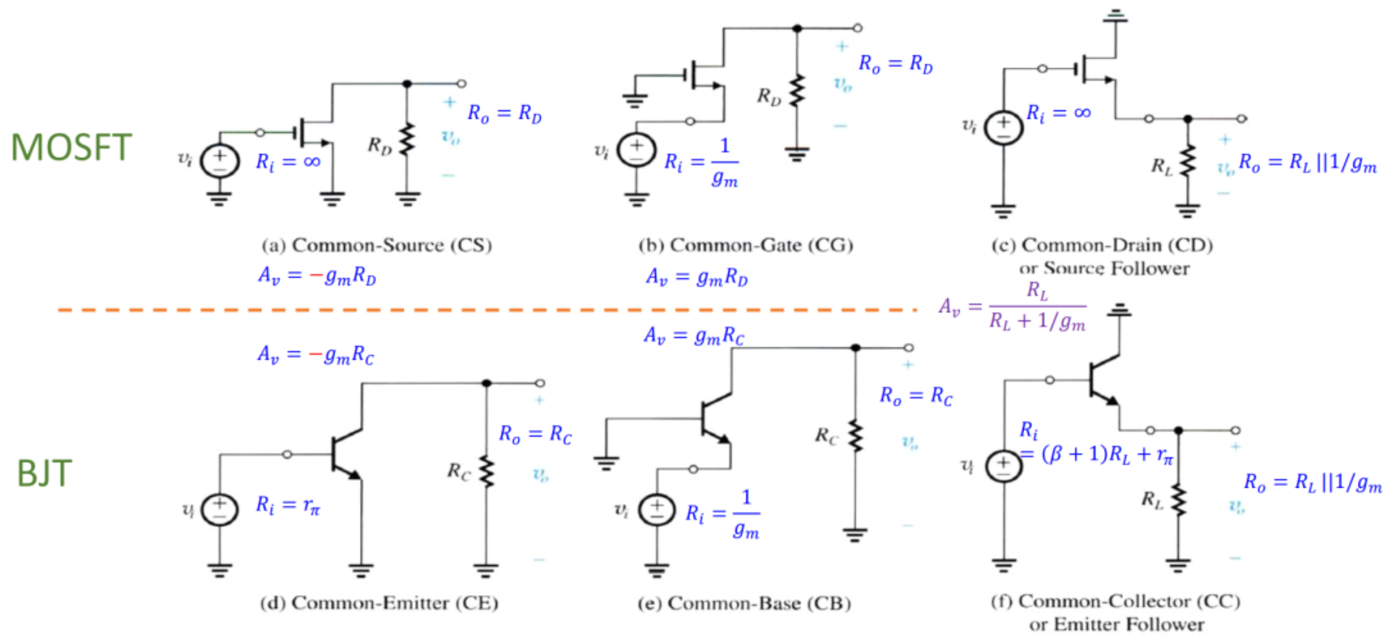
+OtherTypesOfBJT

Wednesday, 5 June 2024 08.10

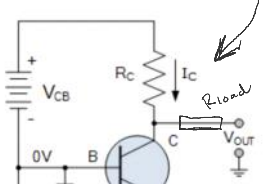
Three basic configurations: MOSFT VS. BJT



Parameter	Common Base	Common Emitter	Common Collector
Input terminal	Emitter	Base	Emitter
Output terminal	Collector	Collector	Collector
Voltage Gain	Low	Moderate	Slightly Less than 1 (Unity gain)
Current Gain	Medium	High	low current gain (current buffering)
Power Gain	Low to Moderate	Moderate to High	Very close to 1 (unity)
Phase inversion	No (0 degree or 360 degree)	Yes (180 degree)	No (0 degree or 360 degree)
Input Impedance	Low (50 Ohm)	Moderate (1 KOhm)	High (300 KOhm)
Output Impedance	High (1 M Ohm)	Moderate (50 K)	Low (300 Ohm)
Applications	High frequency amplifiers, RF Circuits	General purpose amplifiers, power amplifiers	Voltage buffering, impedance matching

* Common base *

Look's like this



Some basic formula's

Husk nu den

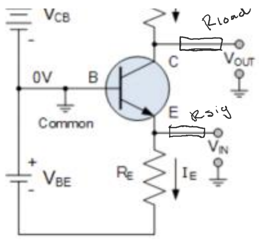
$V = R \cdot I$

$I_E = I_B + I_C$

$\text{Alpha}(\alpha) = \frac{I_C}{I_E}$ and $\text{Beta}(\beta) = \frac{I_C}{I_B}$

$\therefore I_C = \alpha \times I_E = \beta \times I_B$

β ≈ 1 α



$$\therefore I_C = \alpha \times I_E = \beta \times I_B$$

$$\text{thus:} \quad \alpha = \frac{\beta}{\beta + 1} \approx 1 \qquad \beta = \frac{\alpha}{1 - \alpha}$$

Amplifier Current Gain

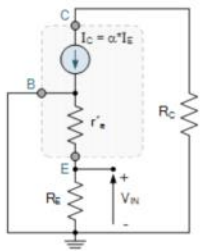
$$A_i = \frac{i_{OUT}}{i_{IN}} = \frac{\beta}{\beta + 1} \cong 1$$

Then we can say for a common base amplifier configuration that:

$$A_V = \frac{V_{OUT}}{V_{IN}} = \frac{V_C}{V_E} \cong \frac{I_C \times R_C}{I_E \times R_E}$$

As I_C/I_E is alpha, we can present the amplifiers voltage gain as:

$$A_V = \alpha \frac{R_C}{R_E} = A_i \left[\frac{R_C}{R_E} \right]$$



For AC input signals the emitter diode junction has an effective small-signal resistance given by: $r'e = 25mV/I_E$, where the 25mV is the thermal voltage of the pn-junction and I_E is the emitter current. So as the current flowing through the emitter increases, the emitter resistance will decrease by a proportional amount.

Some of the input current flows through this internal base-emitter junction resistance to the base as well as through the externally connected emitter resistor, R_E. For small-signal analysis these two resistances are connected in parallel with each other.

Since the value of r'e is very small, and R_E is generally much larger, usually in the kilohms (kΩ) range, the magnitude of the amplifiers voltage gain changes dynamically with different levels of emitter current.

Thus if $R_E \gg r'e$ then the true voltage gain of the common base amplifier will be:

$$A_V = \alpha \frac{R_C}{r'e} = A_i \left[\frac{R_C}{r'e} \right]$$

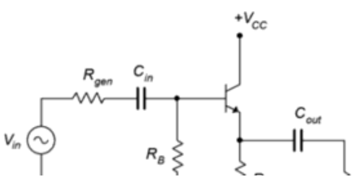
Because the current gain is approximately equal to one as $I_C \cong I_E$, then the voltage gain equation simplifies to just:

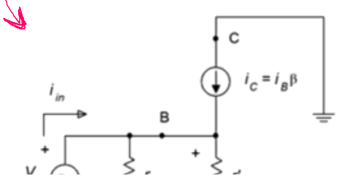
$$\boxed{A_V = \frac{R_C}{r'e}}$$

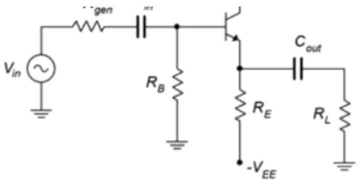
$$r'_e = \frac{V_T}{I_E}$$

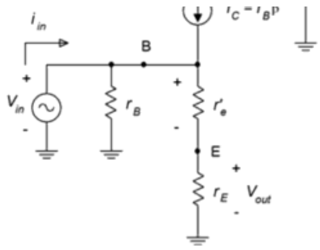
Common Collector

AC eq.









7.4.1: Voltage Gain

The derivation for the emitter follower's voltage gain equation is similar to that shown for the common emitter amplifier. We begin with the basic definition of voltage gain and then expand using Ohm's law.

$$A_v = \frac{v_{out}}{v_{in}} = \frac{v_E}{v_B}$$

$$A_v = \frac{i_C r_E}{i_C(r'_e + r_E)}$$

$$\boxed{A_v = \frac{r_E}{r'_e + r_E}} \tag{7.4.1}$$

$$r'e = \frac{V_T}{I_C}$$

$$I_C = \frac{V_{cc} - V_{BE}}{R_E}$$

This equation is very similar to that of Equation 7.3.1. Here we see that the output signal is in phase with the input and that if \(r_E \gg r'_e\), the gain approaches unity. Signal distortion tends to be low in followers because a gain of one is a desired goal.

7.4.2: Input Impedance

The derivation for \(Z_{in}\) and \(Z_{in(base)}\) are unchanged compared to the common emitter configuration. The formulas are repeated below for convenience.

$$Z_{in(base)} = \beta(r'_e + r_E)$$

$$Zin = r_B || Z_{in(base)}$$

7.4.3: Output Impedance

The derivation for common collector output impedance varies considerably from that of the common emitter. We shall use Figure \(\PageIndex{3}\) for the analysis.

First, note that this diagram splits the AC emitter resistance into its two components, \(R_L\) and the biasing resistor \(R_E\). This is because we want to find the effective resistance of the source that drives the load, so logically we can't include the load in that value. We begin by looking back into the emitter from the perspective of the load. We see the emitter bias resistor in parallel with whatever the impedance is looking back into the emitter terminal.

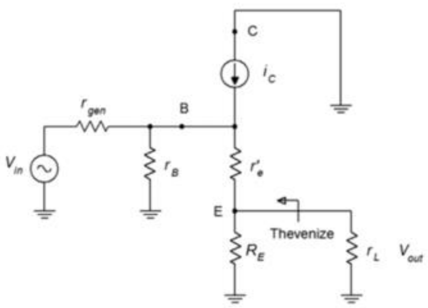


Figure \(\PageIndex{3}\): Common collector output impedance analysis.

$$Z_{out} = R_E || Z_{out(emitter)} \tag{7.4.2}$$

\(Z_{out(emitter)}\) is equal to \(r'_e\) in series with the equivalent resistance of the network above it and to the left. The internal resistance of the current source is high enough to ignore so we're left with the equivalent resistance looking back off the base. We'll call this \(Z_{B(equivalent)}\). At first glance this might appear to be the parallel combination of \(r_{gen}\) and \(r_B\), but this ignores the effect of the collector current source. What we really want is the effective resistance as seen from the perspective of \(r'_e\), not as seen from the base terminal.

$$Z_{out(emitter)} = r'_e + Z_{B(equivalent)} \tag{7.4.3}$$

$$Z_{B(equivalent)} = \frac{v_B}{i_C} \tag{7.4.4}$$

$$Z_{B(equivalent)} = \frac{i_B(r_B || r_g en)}{\beta i_B}$$

$$Z_{B(equivalent)} = \frac{r_B || r_{gen}}{\beta}$$

$$r'e = \frac{V_T}{I_C} \leftarrow \text{Temp co.ef} \approx 26\,\text{mV}$$

$$I_C = \frac{V_{CC} - U_{BE}}{R_E}$$ ← Voltage lost in the diode $\approx 0.7V$