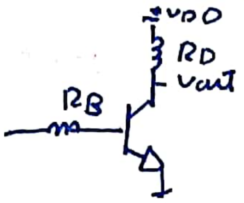
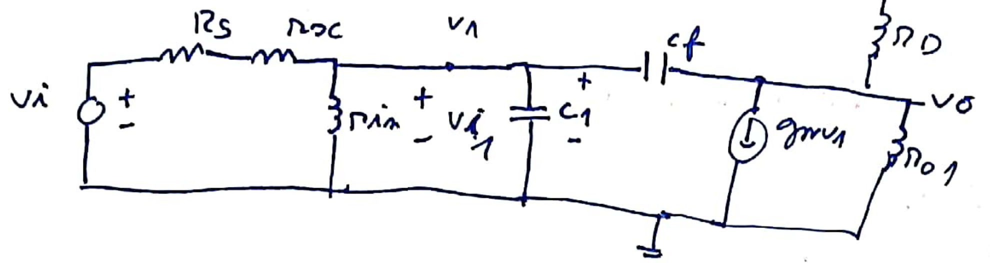
Resistive common emitter stage

ac ~~ttmp~~ analysis





$Z_1 = R_S + R_{bc}$

$Z_2 = R_D \,//\, r_{o1}$

$Z_3 = r_{in} \,//\, \frac{1}{C_1 s} = \frac{r_{in}}{r_{in} C_1 s + 1}$

~~atres)~~

$\cancel{\frac{V_1}{Z_3} + \frac{V_1 - V_{in}}{R_s + R_{bc}} + (V_1 - V_o) C f s = 0}$

~~Vin - V1~~

$\cancel{V_1 \left(\frac{1}{Z_3} + \frac{1}{R_s + R_{bc}} + C f s \right) = \frac{V_{in}}{R_s + R_{bc}} + V_o C f s}$

$\cancel{V_1 = \frac{\frac{V_{in}}{R_s + R_{bc}} + V_o C f s}{\left(\frac{1}{Z_3} + \frac{1}{R_s + R_{bc}} + C f s \right)}}$

{ sum of currents at V_1

$$\frac{V_1}{Z_3} + (V_1 - V_{out}) C f s + \frac{V_1 - V_{in}}{Z_1} = 0$$

$$V_1 \left(\frac{1}{Z_3} + C f s + \frac{1}{Z_1} \right) = V_{out} C f s + \frac{V_{in}}{Z_1}$$

$$V_1 = \frac{V_{out} C f s + \frac{V_{in}}{Z_1}}{\left(\frac{1}{Z_3} + C f s + \frac{1}{Z_1} \right)}$$

$$A_V(s) = \frac{- \frac{\frac{1}{Z_1}}{\frac{1}{Z_3} + C f s + \frac{1}{Z_1}}}{\frac{1}{Z_2} + C f s + \frac{C f s}{\left(\frac{1}{Z_3} + C f s + \frac{1}{Z_1} \right)} (g_{m1} - C f s)}$$

sum of currents at V_{out}

$$\frac{V_{out}}{Z_2} + g_m V_1 + (V_{out} - V_1) C f s = 0$$

$$V_{out} \left(\frac{1}{Z_2} + C f s + \frac{C f s}{\left(\frac{1}{Z_3} + C f s + \frac{1}{Z_1} \right)} (g_{m1} - C f s) \right) = - V_{in} \left(\frac{\frac{1}{Z_1}}{\frac{1}{Z_3} + C f s + \frac{1}{Z_1}} \right)$$

In Put Impedance

V_{Π} - Impedance InPut = ~~[illegible]~~ $(R_s + r_x) + \frac{r_{in}}{C_1 s r_{in} + 1}$

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out Put Impedance

at v_1

$$I_x = \frac{v_1}{R_x + r_s} + \frac{v_1}{Z_3} + \cancel{(\ldots)}$$

$$\frac{v_1}{R_x + r_s} + \frac{v_1}{Z_3} + (v_1 - v_{out}) C_f s = 0$$

$$\frac{V_{out}\, C_f s}{\frac{1}{Z_1} + \frac{1}{Z_3} + C_f s} = v_1$$

$$I_x = \frac{V_{out}}{Z_2} + g_m v_1 + (V_{out} - v_1) C_f s$$

$$I_x = V_{out}\left(\frac{1}{Z_2} + C_f s + \frac{C_f s}{\frac{1}{Z_1} + \frac{1}{Z_3} + C_f s}\left(g_{m1} - C_f s\right)\right)$$

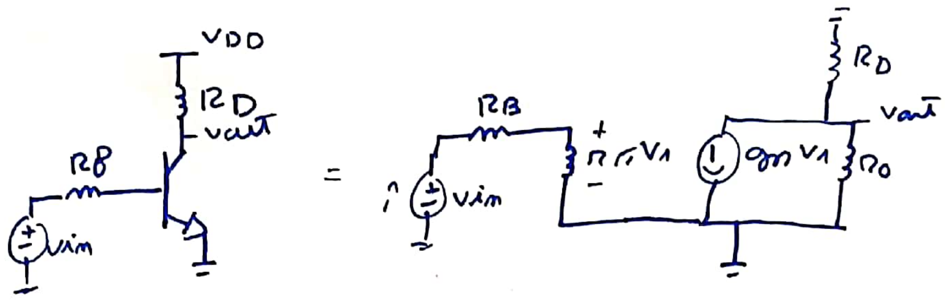
$$\frac{V_{out}}{I_x} = \frac{1}{\left(\frac{1}{Z_2} + C_f s + \frac{C_f s}{\frac{1}{Z_1} + \frac{1}{Z_3} + C_f s}\left(g_{m1} - C_f s\right)\right)}$$

$\downarrow$ get smaller with frequency

Resistive common emitter stage

Full analyses

Dc amaylisis



Input Impedance

$$r_{In} = \frac{v_{in}}{I_n} = \frac{v_{in}}{R_B + r_\pi} = I_{in} = \frac{v_{in}}{R_{in}} = \underbrace{R_B}_{\text{controllable}} + r_\pi$$

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gm

g_m $\quad \cancel{\frac{V_{in}}{I_{out}}} \quad \frac{I_{out}}{v_{in}}$

$$v_1 = \frac{r_\pi}{r_B + r_\pi} v_{in}$$

$$g_m \frac{r_\pi}{r_B + r_\pi} v_{in} = I_o$$

$$g_m \frac{r_\pi}{\underbrace{r_B}_{\text{only controllable}} + r_\pi} = \underline{G_M} \rightarrow \text{current gain}$$

Av gain

$$v_1 = v_{in} \frac{r_\pi}{r_B + r_\pi}$$

$$\frac{V_{out}}{R_D} + \frac{V_{out}}{r_o} + g_m v_1 = 0$$

$$V_{out}\left(\frac{1}{r_D} + \frac{1}{r_o}\right) = -v_{in}\, g_m \frac{r_\pi}{r_B + r_\pi}$$

$$\frac{V_{out}}{V_{in}} = \frac{-g_m r_\pi}{(r_B + r_\pi) \times \left(\frac{1}{r_D} + \frac{1}{r_o}\right)} = \frac{-g_m r_\pi \overset{\text{controllable}}{r_D}\, r_o}{(\underbrace{r_B}_{\text{controllable}} + r_\pi)(r_D + r_o)}$$

outPut Impedance

$R_o \parallel R_D = \underline{R_{outPut}}$

~~Big~~ large signal analysis

$$I_C \approx I_B \times \beta \quad \text{when } V_{CE} > V_{CEsat}$$

$$V_{CE} = V_{DD} - I_C R_D$$

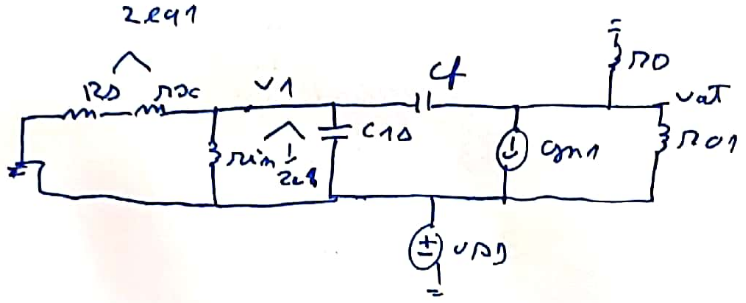
$$I_B \approx \frac{V_{in} - 0,7}{R_B}$$

~~Knowing the average β value the value of the gain~~

$$I_C = \beta\left(\frac{V_{in} - 0,7}{R_B}\right)$$

$$\overset{V_{out}}{V_{CE}} = V_{DD} - \beta\left(\frac{V_{in} - 0,7}{R_B}\right) \times \underbrace{R_D}_{\text{controls the gain}}$$

A - gain



$$Z_{eq2} = \frac{r_{in}}{R_{in} c_f s + 1}$$

$$Z_1 = R_D + r_{DC}$$

$$\frac{V_1 - V_{DD}}{Z_{eq1}} + \frac{V_1 - V_{DD}}{Z_{eq2}} + (V_1 - V_{out}) c_f s = 0$$

$$V_1 \cancel{\left(\frac{1}{Z_{eq}} + \frac{1}{Z_{eq2}} + c_f s \right)} = \frac{V_{DD}\left(\frac{1}{Z_{eq1}} + \frac{1}{Z_{eq2}}\right) + V_{out} c_f s}{\left(\frac{1}{Z_{eq1}} + \frac{1}{Z_{eq2}} + c_f s\right)}$$

$$\frac{V_{out}}{R_D} + \frac{V_{out} - V_{DD}}{r_{o1}} + g_m V_1 + (V_{out} - V_1) c_f s = 0$$

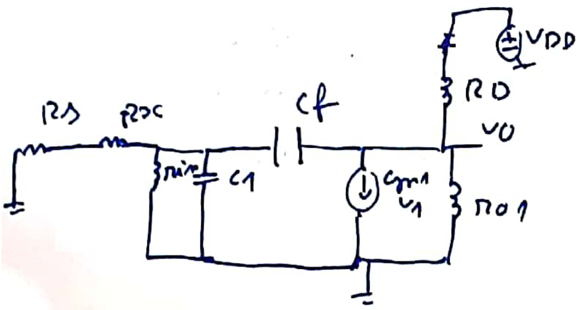
$$V_{out}\left(\frac{1}{R_D} + \frac{1}{r_{o1}} + c_f s + \frac{c_f s}{\left(\frac{1}{Z_{e1}} + \frac{1}{Z_{e2}} + c_f s\right)} (g_m - c_f s) \right) =$$

$$V_{DD}\left(\frac{1}{r_{o1}} + \frac{\left(\frac{1}{Z_{e1}} + \frac{1}{Z_{eq2}}\right)}{\left(\frac{1}{Z_{eq1}} + \frac{1}{Z_{eq2}} + c_f s\right)} (c_f s - g_m) \right)$$

$$\frac{V_{out}}{V_{DD}} = \frac{\left(\frac{1}{r_{o1}} + \frac{\frac{1}{Z_{e1}} + \frac{1}{Z_{eq2}}}{\left(\frac{1}{Z_{eq1}} + \frac{1}{Z_{e2}} + c_f s\right)} (c_f s - g_m) \right)}{\left(\frac{1}{R_D} + \frac{1}{r_{o1}} + c_f s + \frac{c_f s}{\left(\frac{1}{Z_{eq}} + \frac{1}{Z_{eq}} + c_f s\right)} (g_m - c_f s) \right)}$$

↓ low freq; ↘ decreases with frequency

At gain



$$\cancel{Z_1 = R_s + r_x}$$
$$\cancel{Z_2 = r_{in} \,//\, \frac{1}{C_1 s} \,//\, Z_2}$$
$$\cancel{Z_3 = \frac{1}{C_f s} + Z_2}$$

$$Z_4 = r_{o1} \,//\, Z_3$$

$$Z_1 = R_s + r_x$$
$$Z_2 = \frac{1}{C_1 s} \,//\, r_{in} = \frac{R_{in}}{r_{in} C_1 s + 1}$$

sum of currents at v_1

$$\frac{v_1}{Z_1} + \frac{v_1}{Z_2} + (v_1 - v_{out})\, C_f s = 0$$

$$v_1 = \frac{C_f s}{\frac{1}{Z_1} + \frac{1}{Z_2} + C_f s} = \frac{1}{\frac{1}{Z_1 C_f s} + \frac{1}{Z_2 C_f s} + 1}$$

sum of currents at v_{out}

$$\frac{v_{out}}{r_{o1}} + g_m v_1 + \frac{V_{out} - V_{DD}}{R_D} = 0$$

$$v_{out}\left(\frac{1}{r_{o1}} + \frac{g_m}{\frac{1}{Z_1 C_f s} + \frac{1}{Z_2 C_f s} + 1} + \frac{v_{out}}{r_D} \right) = \frac{V_{DD}}{R_D}$$

$$\frac{v_{out}}{V_{DD}} = \frac{\frac{1}{R_D}}{\frac{1}{r_{o1}} + \frac{g_m}{\frac{1}{Z_1 C_f s} + \frac{1}{Z_2 C_f s} + 1}}$$

$Z_1 \rightarrow$ constant

$Z_2 \rightarrow$ decreases with frequency

$\rightarrow$ at low frequency

$$\frac{\frac{1}{r_{D}}}{\frac{1}{r_{o1}} + \frac{g_m}{Z_1}} \rightarrow \text{only''} \rightarrow \text{decreases with frequency}$$