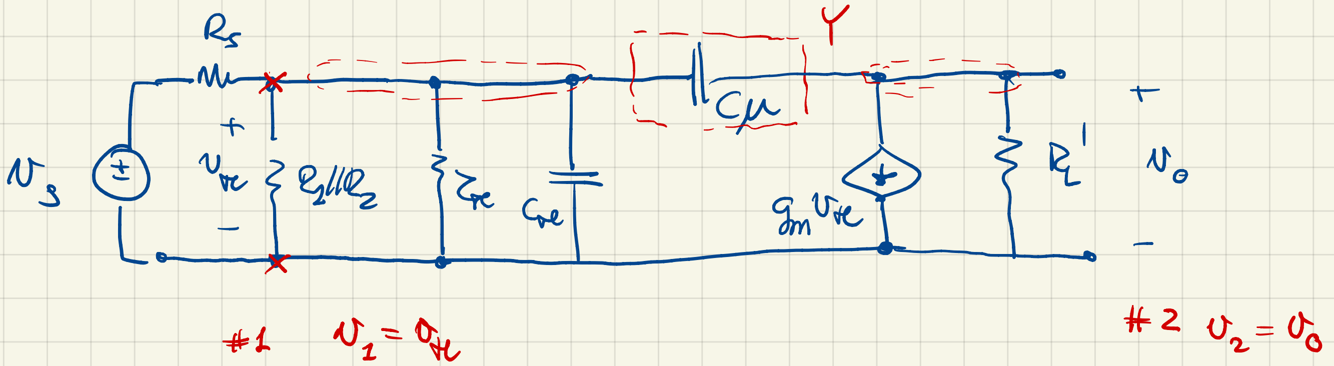
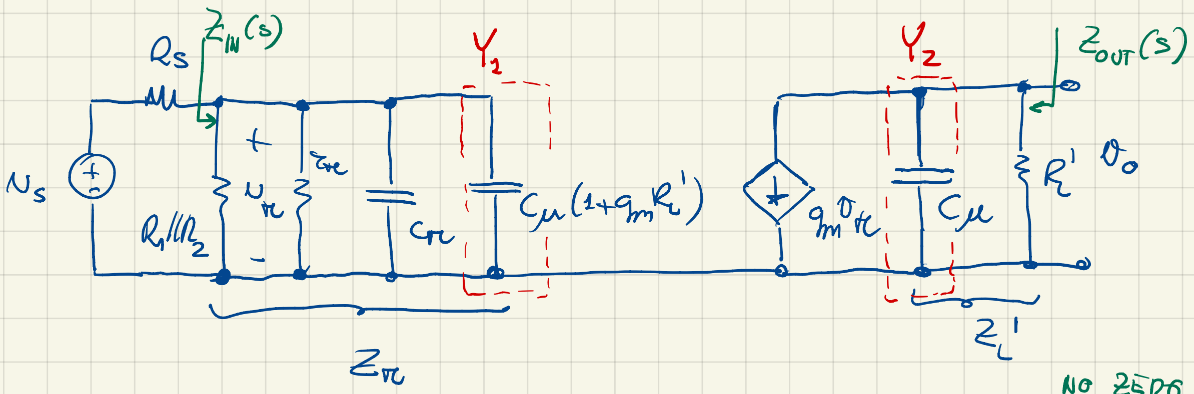
LET'S REVISE THE CE AMPLIFIER USING MILLER'S THEOREM



$$G \cong \left.\frac{v_o}{v_\pi}\right|_{MB} = -g_m R_L' \qquad |G| >> 1$$

APPLYING THE THEOREM WE CAN SIMPLIFY THE CIRCUIT AS



NO ZERO

$$A_v^{HF}(s) = -\frac{Z_\pi}{R_s + Z_\pi} \cdot g_m \cdot Z_L' = -\frac{R_\pi^0}{R_s} \cdot \frac{g_m R_L' \; (\quad)}{(1 + s R_\pi^0 C_{IN}) \cdot (1 + s C_\mu R_L')}$$

$$Z_\pi(s) = \frac{R_1 // R_2 // r_\pi}{1 + s R_1 // R_2 // r_\pi \, C_{IN}} \qquad Z_L' = \frac{R_L'}{1 + s C_\mu R_L'}$$

$$C_{IN} = C_\pi + C_\mu (1 + g_m R_L')$$

EXACTLY THE SAME AS IN THE ORIGINAL CIRCUIT

$$\frac{\dfrac{R_1 // R_2 // r_\pi}{1 + s R_1 // R_2 // r_\pi \, C_{IN}}}{R_s + \dfrac{R_1 // R_2 // r_\pi}{1 + s R_1 // R_2 // r_\pi \, C_{IN}}} = \frac{R_1 // R_2 // r_\pi}{\underline{R_s + R_1 // R_2 // r_\pi} + s R_s \cdot (R_1 // R_2 // r_\pi) \cdot C_{IN}}$$

$$R_\pi^0 = R_s // R_1 // R_2 // r_\pi$$

WE CAN ALSO APPLY OCTC METHOD

$$a_1^M = R_{IN}^0 C_{IN} + C_\mu R_\mu^0 = R_H^0 \left[C_\pi + C_\mu (1 + g_m R_L') \right] + C_\mu R_L'$$

$$R_\mu^0 = R_L' \qquad R_{IN}^0 = R_H^0$$

$$a_1^M = R_H^0 C_\pi + \left[R_H^0 (1 + g_m R_L') + R_L' \right] C_\mu = a_1$$ OF THE ORIGINAL CIRCUIT (EXACT)

$$\omega_H \cong \frac{1}{a_1} = \frac{1}{a_1^M}$$

IF WE CALCULATE $Z_{IN}(s)$ NOW, WE EASILY FIND

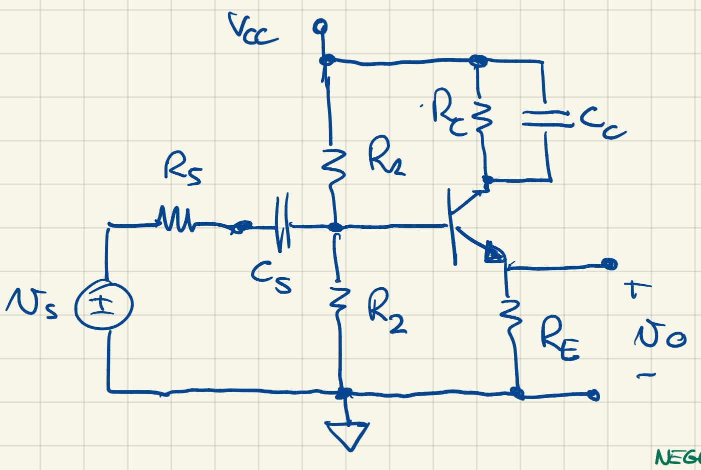
$$Z_{IN}(s) = r_\pi \| R_1 \| R_2 \| \frac{1}{s C_{IN}}$$

WE LOST THE $1/g_m$ RESISTANCE IN SERIES WITH C_μ

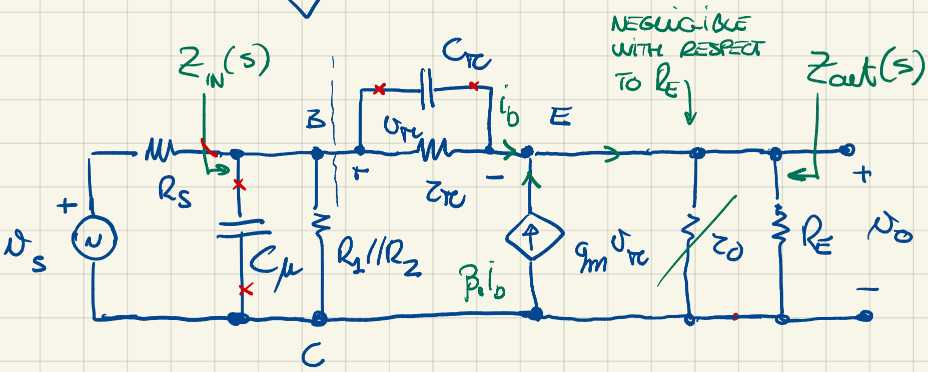
FOR THE REST, THE EXPRESSIONS ARE IDENTICAL.

N.B. MILLER'S THEOREM CANNOT BE USED TO SIMPLIFY THE CALCULATION OF $Z_{out}(s)$, BUT PROVIDES ACCURATE RESULTS FOR $\omega \ll \omega_T$ BOTH IN $A_V^{HF}(s)$ AND IN THE CALCULATION OF $Z_{IN}(s)$

◇ HF ANALYSIS OF THE COMMON COLLECTOR AMPLIFIER



IF ALL CIRCUIT PARAMETERS ARE KNOWN, WE CAN FIND THE BIAS POINT (V_{CE}, I_C) AND THE SMALL SIGNAL CIRCUIT PARAMETERS LIKE g_m, r_o, C_π ...



FROM WHICH WE CAN FIND:

$A_V^{HF}(s)$

$Z_{IN}(s)$

$Z_{out}(s)$

1. $A_v^{HF}(s)$ USING OCTC METHOD

2 INDEPENDENT CAPACITORS $\Rightarrow$ $m = N = 2$

$$A_v^{HF}(s) = A_v^{MB} \cdot \frac{1 + s\,\frac{C_\pi}{g_m}}{1 + a_1 s + a_2 s^2}$$

CIRCUIT INSPECTION SHOWS $v_o \rightarrow \emptyset$ AS $\omega \rightarrow +\infty$ LIKE $1/s$ $\Rightarrow$
THERE MUST BE A ZERO AT THE NUMERATOR $\Rightarrow$ $m = 1$.

TO FIND THE ZERO WE NEED TO FIND A CONDITION ON s SUCH THAT

$$v_o \equiv \emptyset \quad \forall\, v_s$$

THIS IS FOUND TO BE

$$\cancel{v_\pi} \cdot \left(sC_\pi + \frac{1}{r_\pi} \right) + g_m \cancel{v_\pi} = \emptyset$$

$$s = -\left(g_m + \frac{1}{r_\pi} \right) \cdot \frac{1}{C_\pi} = -\frac{\beta_0 + 1}{r_\pi C_\pi} \cong -\frac{g_m}{C_\pi} = -\omega_T$$

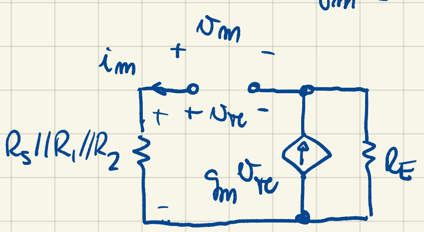
SO, WE HAVE A NEGATIVE REAL PART ZERO AT $\omega_z \cong \omega_T$

$$A_v^{MB} = \underbrace{\frac{R_{in}^{INT} /\!/ R_1 /\!/ R_2}{R_s + R_{in}^{INT} /\!/ R_1 /\!/ R_2}}_{\alpha_{in}} \cdot \frac{(\beta_0 + 1) R_E}{\underbrace{r_\pi + (\beta_0 + 1) R_E}_{R_{in}^{INT}}} \cong 1$$

LET'S FIND THE DENOMINATOR COEFFICIENTS

$$a_1 = R_\pi^0 C_\pi + R_\mu^0 C_\mu \quad \propto \quad 10^{-10} \cdot 10^2 + 10^{-11} \cdot 10^1 \qquad 10 \text{ ns}$$

$$R_\pi^0 = r_\pi /\!/ \frac{R_E + R_s /\!/ R_1 /\!/ R_2}{1 + g_m R_E} \quad \propto 10^2 \; [\Omega]$$



$$v_{in} = R_s /\!/ R_1 /\!/ R_2 \; i_{in} + R_E \left(i_{in} - g_m v_{in} \right)$$

$$\frac{v_{in}}{i_{in}} = \frac{R_E + R_s /\!/ R_1 /\!/ R_2}{1 + g_m R_E}$$

$$R_\mu^0 = R_s /\!/ R_1 /\!/ R_2 /\!/ R_{in}^{INT} \quad \propto 10^1 \; [\Omega]$$

IF WE CAN ASSUME A DOMINANT POLE EXISTS THEN

$$\omega_H \cong \frac{1}{a_1} \geq 100 \text{ M rad/s}$$

NORMALLY, THE CC STAGE HAS LARGER BANDWIDTH WITH RESPECT TO COMMON EMITTER STAGES.

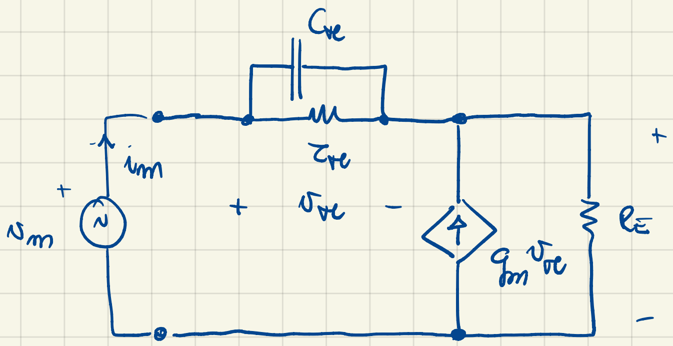
$$a_2 = C_\pi C_\mu R_\pi^0 R_\mu^\pi = C_\pi C_\mu R_\pi^0 \cdot R_1 // R_2 // R_S // R_E \propto 10^{-17}$$

$$10^{-10} \quad 10^{-11} \quad 10^{2} \quad 10^{2}$$

$$\frac{a_1^2}{a_2} = \frac{10^{-16}}{10^{-17}} = 10$$ THERE IS A DOMINANT POLE!

2. LET'S DISCUSS $Z_{IN}(s)$ NOW

BY INSPECTION, WE SEE THAT $Z_{IN}(s) = R_B // \frac{1}{sC_\mu} // Z_x(s)$ WHERE $Z_x(s)$ CAN BE FOUND LIKE THIS:



$$v_\pi = z_\pi i_{in}$$

$$v_{in} = v_\pi + R_E \left(i_{in} + g_m z_\pi i_{in}\right)$$

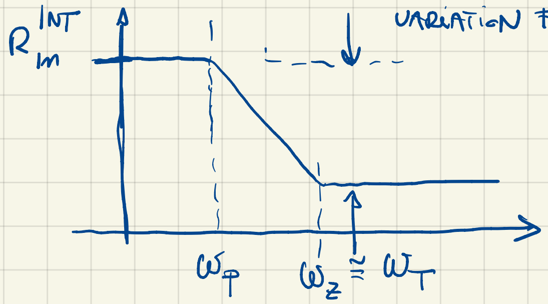
$$Z_x(s) = \frac{v_{in}}{i_{in}} = z_\pi + R_E\left(1 + g_m z_\pi\right) = R_E + z_\pi(s) \cdot \left(1 + g_m R_E\right)$$

$$Z_x(s) = R_E + \frac{r_\pi (1 + g_m R_E)}{1 + sC_\pi r_\pi} = \frac{R_E + sC_\pi r_\pi R_E + r_\pi + \beta_0 R_E}{1 + sC_\pi r_\pi} =$$

$$= R_{in}^{INT} \cdot \frac{1 + sC_\pi \frac{r_\pi // R_E(\beta_0+1)}{\beta_0+1}}{1 + s r_\pi C_\pi} = R_{in}^{INT} \frac{1 + \frac{s}{\omega_Z}}{1 + \frac{s}{\omega_P}}$$

$$\omega_z = \frac{\beta_0+1}{C_\pi \cdot \left[r_\pi // R_E(\beta_0+1)\right]} \cong \omega_T \qquad \omega_p = \frac{1}{r_\pi C_\pi}$$

$$\omega_z \gg \omega_p$$



VARIATION FROM R_{in}^{INT} TO $\frac{R_{in}^{INT}}{\beta_0+1} \cdot \underbrace{\frac{R_E(\beta_0+1)}{r_\pi + R_E(\beta_0+1)}}_{\cong 1}$

IN THE LAST FORM, $Z_x(s)$ IS REVEALED TO BE OF THE TYPE:

$$Z_x(s) = R_{in}^{INT} // \frac{1}{sC_\pi'} \qquad \text{WITH} \quad C_\pi' \ll C_\pi$$

INDEED @ $\omega \ll \omega_T$ WE CAN WRITE

TYPICALLY

$$Z_x(s) \cong \frac{R_{in}^{INT}}{1 + sC_\pi r_\pi} = \frac{R_{in}^{INT}}{1 + sC_\pi' R_{in}^{INT}} \qquad \text{WITH} \quad C_\pi' = C_\pi \cdot \frac{r_\pi}{R_{in}^{INT}} < C_\mu$$

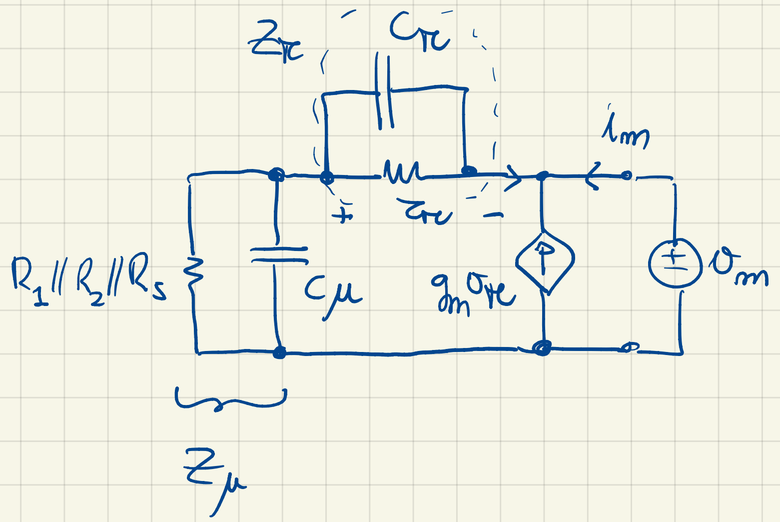
FINALLY, THE INPUT IMPEDANCE IS FOUND TO BE:

$$Z_{IN}(s) = R_B // R_{in}^{INT} // \frac{1}{s(C_\pi' + C_\mu)} \cong R_B // R_{in}^{INT} // \frac{1}{sC_\mu}$$

CONCLUSION: THE CC INPUT IMPEDANCE IS RESISTIVE - CAPACITIVE.
THE INPUT CAPACITANCE IS $C_{IN} \cong C_\mu$ (SMALL)

3. LET'S CONSIDER NOW THE OUTPUT IMPEDANCE

$$Z_{OUT}(s) = R_E \,\|\, Z_y(s)$$



$$\begin{cases} i_m = -\left(g_m v_\pi + i_{Z_\pi}\right) = -v_\pi\left(g_m + \dfrac{1}{Z_\pi}\right) \\[2ex] v_\pi = -\dfrac{Z_\pi}{Z_\pi + Z_\mu}\, v_m \end{cases}$$

$$\frac{i_m}{v_m} = \frac{1 + g_m Z_\pi}{Z_\pi + Z_\mu} = \frac{1 + g_m \dfrac{r_\pi}{1 + sC_\pi r_\pi}}{\dfrac{r_\pi}{1 + sC_\pi r_\pi} + \dfrac{R_1 /\!/ R_2 /\!/ R_s}{1 + sC_\mu R_1 /\!/ R_2 /\!/ R_s}} =$$

$$= \frac{\dfrac{1 + \beta_0 + sC_\pi r_\pi}{\cancel{1 + sC_\pi r_\pi}}}{\dfrac{r_\pi + R_1 /\!/ R_2 /\!/ R_s + s(C_\pi + C_\mu)(r_\pi \cdot R_1 /\!/ R_2 /\!/ R_s)}{(\cancel{1 + sC_\pi r_\pi})(1 + sC_\mu R_1 /\!/ R_2 /\!/ R_s)}}$$

$$Z_y(s) = \frac{r_\pi + R_1 /\!/ R_2 /\!/ R_s + s(C_\pi + C_\mu)(r_\pi \cdot R_1 /\!/ R_2 /\!/ R_s)}{(1 + \beta_0 + sC_\pi r_\pi)(1 + sC_\mu R_1 /\!/ R_2 /\!/ R_s)}$$

$$Z_y(s) = \underbrace{\frac{r_\pi + R_1 /\!/ R_2 /\!/ R_s}{1 + \beta_0}}_{R_{out}^{INT} \simeq \frac{1}{g_m}} \cdot \frac{1 + s(C_\pi + C_\mu)\, r_\pi /\!/ R_1 /\!/ R_2 /\!/ R_s}{(1 + sC_\mu R_1 /\!/ R_2 /\!/ R_s)\left(1 + s\underbrace{C_\pi \cdot \dfrac{r_\pi}{1 + \beta_0}}_{\simeq 1/\omega_T}\right)}$$

$$Z_y(s) = R_{OUT}^{INT} \cdot \frac{1+\frac{s}{\omega_z}}{\left(1+\frac{s}{\omega_{p_1}}\right)\left(1+\frac{s}{\omega_{p_2}}\right)}$$

IT IS POSSIBLE THAT $\omega_z < \omega_{P_1} < \omega_{P_2} \cong \omega_T$

INDUCTIVE REGION !