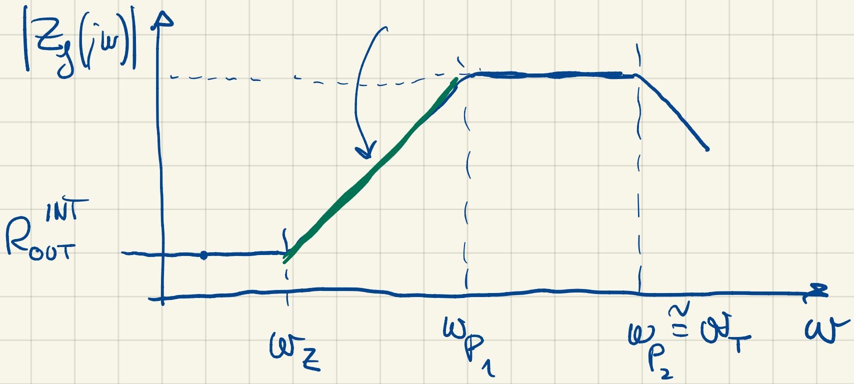
$$Z_y(s) = R_{OUT}^{INT} \cdot \frac{1+\frac{s}{\omega_z}}{\left(1+\frac{s}{\omega_{p_1}}\right)\left(1+\frac{s}{\omega_{p_2}}\right)}$$

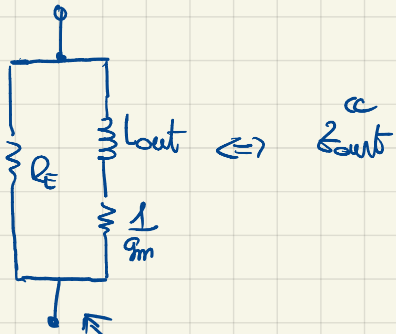
IT IS POSSIBLE THAT $\omega_z < \omega_{p_1} < \omega_{p_2} \cong \omega_T$

INDUCTIVE REGION !



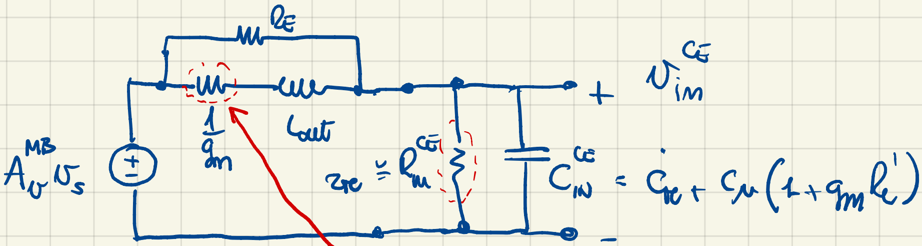
IN THE INDUCTIVE REGION

$\omega < \omega_{p_1}$



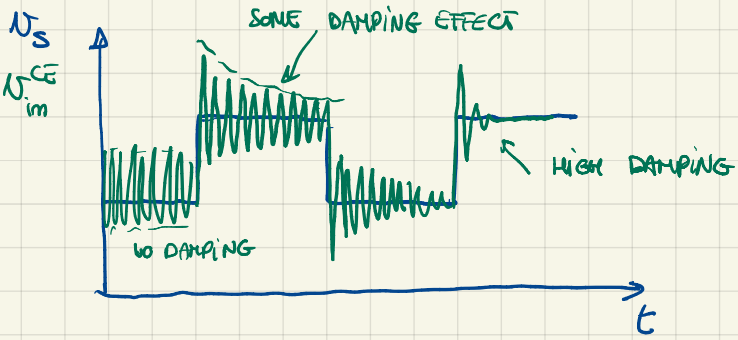
EQUIVALENT CIRCUIT REPRESENTING THE CC AMPLIFIER OUTPUT IMPEDANCE FOR $\omega < \omega_{p_1}$

THIS CAN BE A PROBLEM FOR C.C. + C.E STAGES (BUFFERED COMMON EMITTER).



EQUIVALENT THEVENIN MODEL OF C.C. STAGE

DAMPING $\xi \propto \frac{1}{g_m}, \frac{1}{r_\pi}$ IS RELATIVELY SMALL

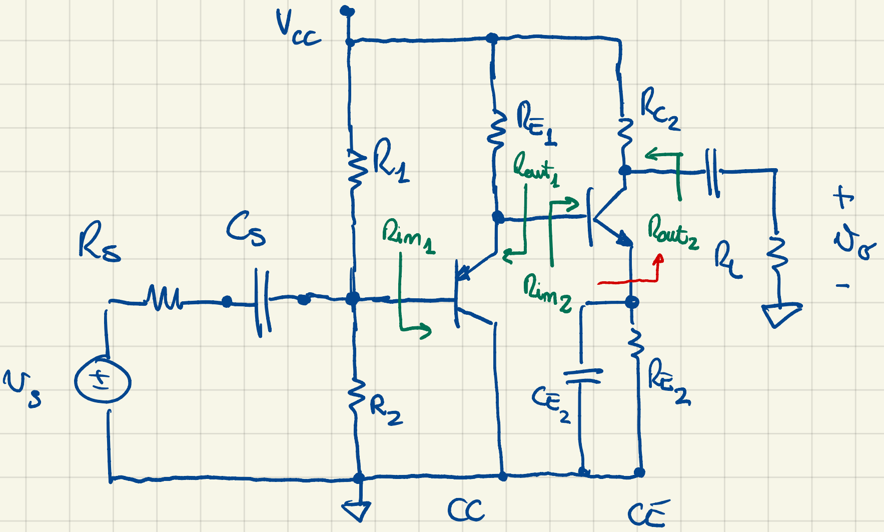


$$\omega_R \cong \frac{1}{\sqrt{L_{out}^{CC} C_{IN}^{CE}}}$$

FREQUENCY RESPONSE OF MULTI-STAGE AMPLIFIER

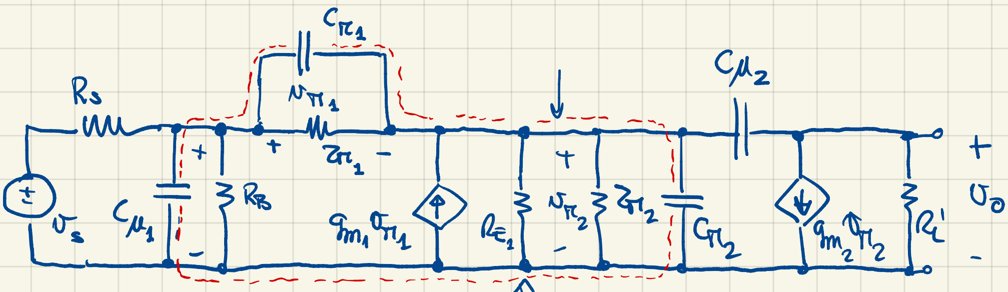
1. BUFFERED CE STAGE (CC + CE)
2. CASCODE STAGE (CE + CB)

1.



TO DO LIST

- FIND THE BIAS POINTS
  - $Q_1: (V_{CE_1}, I_{C_1})$
  - $Q_2: (V_{CE_2}, I_{C_2})$
- VERIFY THE BIAS POINTS FALL INTO THE FORWARD ACTIVE REGION
- CALCULATE (OR FIND) THE SMALL CIRCUIT PARAMETERS r_π, g_m, C_π, r_o, ...
- SOLVE THE SMALL SIGNAL CIRCUIT TO FIND: A_v^{MB}, Z_{in}, Z_{out}, ω_L, ω_H



$R_B = R_1 // R_2$ NEGLECTING r_{o_1} $R_L' = R_L // R_{C_2} // r_{o_2}$

$$R_{in_1} = R_{in_{CC}}^{INT} = r_{\pi_1} + (\beta_{o_1} + 1) R_{E_1} // R_{in_2}$$ LOADING EFFECT !

$$R_{out_1} = R_{out_{CC}}^{INT} = R_{E_1} // \underbrace{\frac{R_S // R_B + r_{\pi_1}}{\beta_o + 1}}_{\simeq \frac{1}{g_{m_1}}} \simeq \frac{1}{g_{m_1}}$$

$$R_{in_2} = R_{in_{CE}}^{INT} = r_{\pi_2}$$

$$R_{out_2} = R_{out_{CE}}^{INT} = R_{C_2} // r_{o_2}$$

LOADING EFFECT

- $$A_v^{MB} = \frac{v_o}{v_s} = -g_{m_2} R_L' \cdot \frac{(\beta_{o_1} + 1) R_{E_1} // R_{in_2}}{r_{\pi_1} + (\beta_{o_1} + 1) R_{E_1} // R_{in_2}} \cdot \frac{R_B // R_{in_1}}{R_S + R_B // R_{in_1}}$$

- ω_L → USE OF SCTC METHOD UNDER DOMINANT POLE ASSUMPTION.

$$\omega_L \cong \frac{1}{C_S R_S^{SC}} + \frac{1}{C_{E_2} R_{E_2}^{SC}} + \frac{1}{C_L R_L^{SC}}$$

$$R_S^{SC} = R_S + R_B // R_{in_1}$$ LARGE $10^5\ \Omega$

$$R_{E_2}^{SC} = R_{E_2} // \frac{r_{\pi_2} + R_{out_1}}{\beta_{0_2} + 1} \simeq R_{E_2} // \frac{1}{g_{m_2}}$$ SMALL ← DOMINANT $10^1\ \Omega$

$$R_L^{SC} = R_L + R_{out_2}$$ MEDIUM $10^3\ \Omega$

- ω_H USING OCTC METHOD AND DOMINANT POLE ASSUMPTION

$$\omega_H \simeq \frac{1}{\underbrace{C_{\pi_1} R_{\pi_1}^0 + C_{\mu_1} R_{\mu_1}^0}_{a_{11}} + \underbrace{C_{\pi_2} R_{\pi_2}^0 + C_{\mu_2} R_{\mu_2}^0}_{a_{12}}} = \frac{1}{\frac{1}{\omega_{H_1}} + \frac{1}{\omega_{H_2}}}$$

a_{11} WITH LOADING EFFECTS

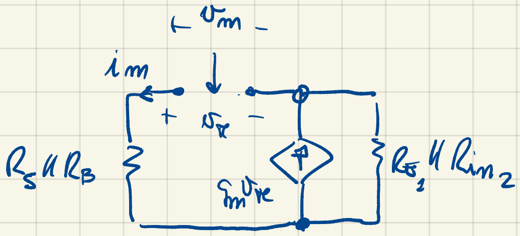
a_{12} WITH LOADING EFFECT

$$\omega_H < \min\{\omega_{H_1}, \omega_{H_2}\}$$ BUT $$\omega_H > \omega_{HCE}$$ UNLOADED!

LET'S SEE WHY!

LOADING EFFECT

$$R_{\pi_1}^0 = r_{\pi_1} // \frac{R_S // R_B + R_{E_1} // R_{in_2}}{1 + g_{m_1}(R_{E_1} // R_{in_2})}$$



$$v_m = (R_S // R_B) i_m + R_{E_1} // R_{in_2} (i_m - g_m v_m)$$

$$R_{\mu_1}^0 = R_S // R_B // R_{in_1} = R_S // R_B // \left[r_{\pi_1} + (\beta_{0_1} + 1) R_{E_1} // R_{in_2}\right]$$

LOADING EFFECT

THE LOADING EFFECT OF THE C.E. STAGE OVER THE C.C. STAGE IS NOT STRONG BECAUSE TYPICALLY $r_\pi > R_E$!!

$$a_{11} \simeq a_1^{CC}$$ WITH NO LOAD

LOADING EFFECT MAKES $R_{\pi_2}^0$ SMALL

$$R_{\pi_2}^0 = r_{\pi_2} // R_{out_1} \simeq r_{\pi_2} // \frac{1}{g_{m_1}}$$ SMALL!

$$R_{\mu_2}^0 = R_{\pi_2}^0 + R_L' \cdot (1 + g_{m_2} R_{\pi_2}^0) = R_L' + R_{\pi_2}^0 (1 + g_{m_2} R_L')$$

THANKS TO THE LOADING EFFECTS $a_{12} \ll a_1^{CE}$ AS THE MILLER MULTIPLIER IS STRONGLY REDUCED.

AS A RESULT $\omega_{H_2} \gg \omega_H^{CE} \Rightarrow \omega_H > \omega_H^{CE}$!!

THE BUFFER STAGE ALLOWS TO MAKE THE AMPLIFIER BANDWIDTH LARGER.

N.B. DO NOT FORGET THE POTENTIAL RESONANCE BETWEEN Z_{out}^{CC} AND Z_{in}^{CE}

ADDITIONAL DETAILS: $m = 3$ EVEN IF $N = 4$ AT HIGH FREQUENCY, BECAUSE WE HAVE A LOOP INVOLVING $C_{\pi_1}, C_{\mu_1}, C_{\pi_2}$.

- BESIDES, N_0 GOES TO ZERO LIKE $\frac{1}{s}$ AS $s \to +\infty$ WHICH MEANS $m = 2$.
  NOTICE THE CAPACITIVE VOLTAGE DIVIDER MADE UP BY C_{π_1} AND C_{π_2}!

- THE TWO ZEROS CAN BE FOUND AS IN THE SINGLE STAGE CE AND CC AMPLIFIER.