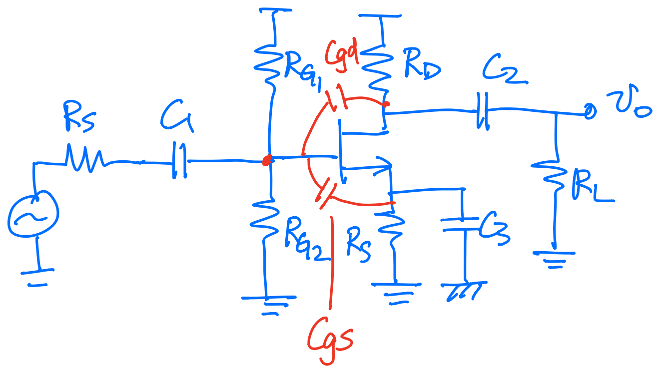
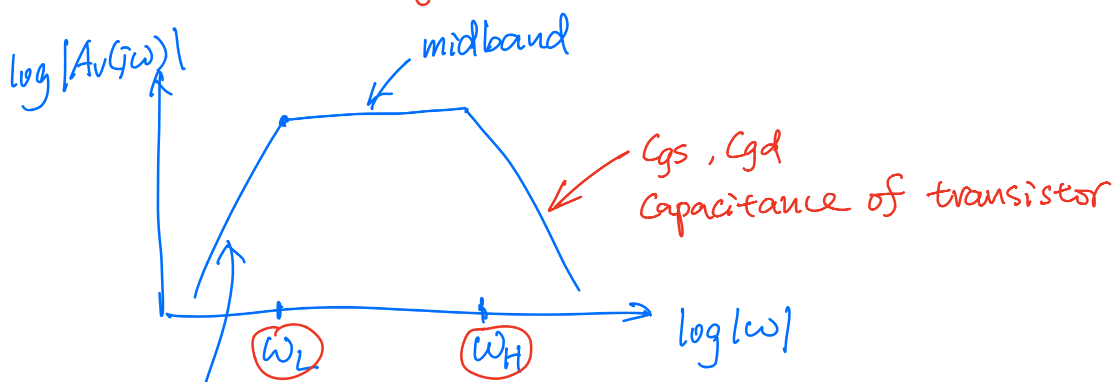
Frequency Response



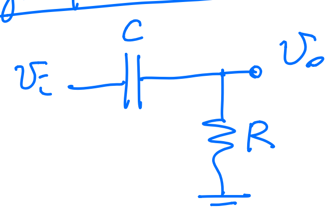


Coupling and bypass

$\downarrow$ C_1, C_2 $\sim 10\,nF$

$\downarrow$ C_3

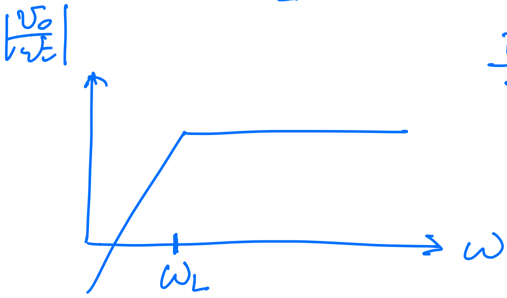
High-pass filter



$$\frac{v_o}{v_i} = \frac{R}{\frac{1}{j\omega C} + R} = \frac{j\omega RC}{1 + j\omega RC} = \frac{j\omega}{\underbrace{\frac{1}{RC}}_{\omega_L} + j\omega}$$

$$s = j\omega$$

$$\frac{v_o}{v_i} = \frac{s}{s + \omega_L}$$



$s \to 0 \quad \frac{v_o}{v_i} \to \frac{s}{\omega_L}$

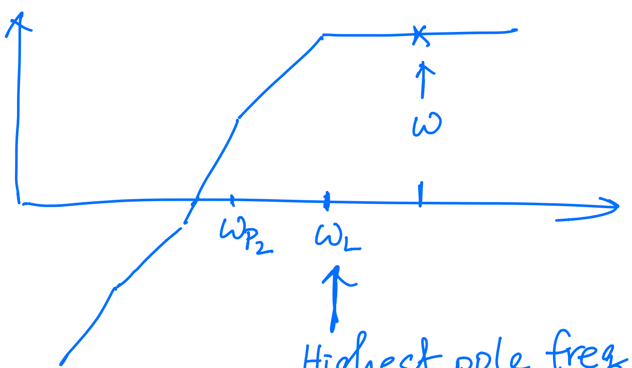
$s = j\omega_L \quad \frac{v_o}{v_i} \to \left|\frac{1}{1+j}\right| = \frac{1}{\sqrt{2}}$

$s \to \infty \quad \frac{v_o}{v_i} \to 1$

General Expression

$$F_L(s) = \frac{s^{n_L} + d_1 s^{n_L-1} \cdots}{s^{n_L} + e_1 s^{n_L-1} \cdots} = \frac{(s+\omega_{z_1})(s+\omega_{z_2}) \cdots}{(s+\omega_{p_1})(s+\omega_{p_2}) \cdots}$$

n_L = # of poles = # of zeros



Highest pole freq $= \omega_L$: Low cut-off freq.

$$(s+\omega_{p_1})(s+\omega_{p_2}) \cdots (\omega + \omega_{p_{n_L}})$$

$$= \underbrace{s^{n_L} + s^{n_L-1}(\omega_{p_1} + \omega_{p_2} + \cdots + \omega_{p_{n_L}})}_{} + s^{n_L-2}(\omega_{p_1}\omega_{p_2} + \cdots)$$

$$s = |j\omega| \gg \omega_{p_i}$$

$$\approx \Big(s + \underbrace{\sum_{i=1}^{n_L} (\omega_{p_i})}_{= \omega_L}\Big)\left(s^{n_L-1} + \cdots \right)$$

$$\omega_L = \sum_{i=1}^{n_L} \omega_i = \sum_{i=1}^{n_L} \frac{1}{R_i C_i}$$

C_i = coupling or bypass caps.

Short-Circuit Time Constant (SCTC) Method:

1. Find all coupling and bypass caps.
2. Solve one cap at a time,
   Replace all other capacitor with short circuits
3. Replace indep voltage source by short circuit,

" current " by open "

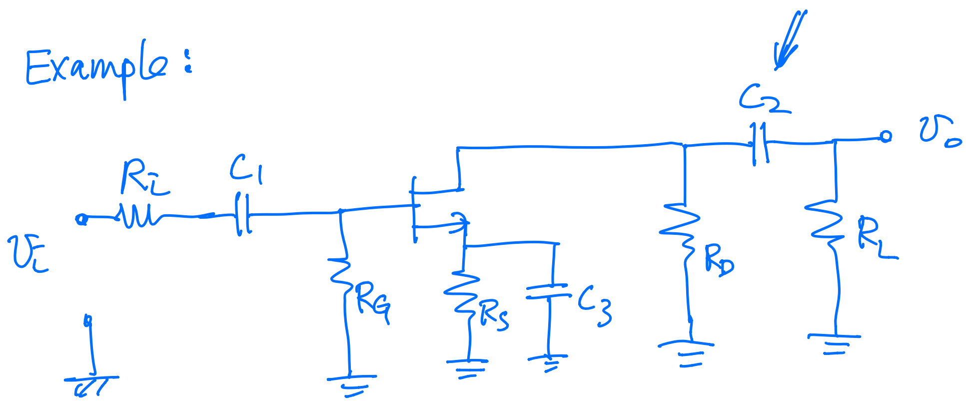
4. Calculate resistance R_i that's in parallel with C_i

5. Find time constant associate with C_i

$$\frac{1}{R_i C_i}$$

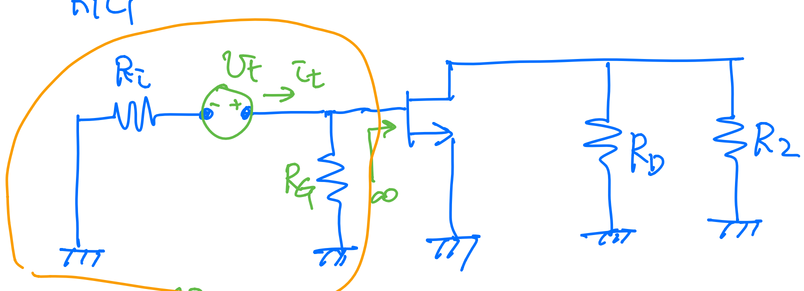
6. $$\omega_L = \sum_{i=1}^{n_L} \frac{1}{R_i C_i}$$

Example:



$R_G = R_{G1} // R_{G2}$

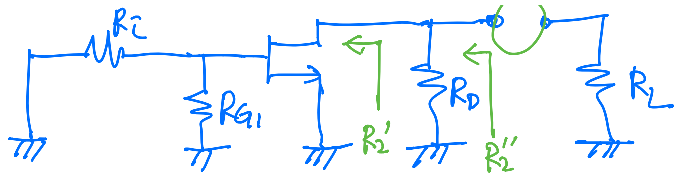
$\tau_1 = \frac{1}{R_1 C_1} \Rightarrow$ Find R_1



$R_1 = \frac{v_t}{i_t}$

$R_1 = R_i + R_G$

$\tau_2 = \frac{1}{R_2 C_2}$

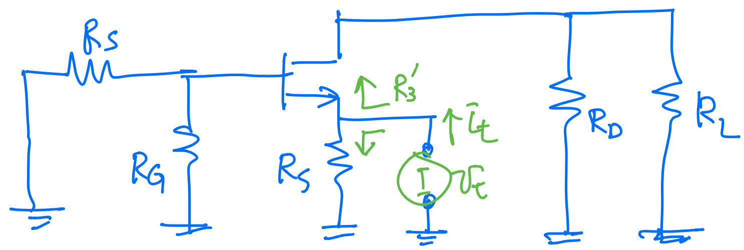


$R_2' = r_o$

$R_2'' = r_o /\!/ R_D \approx R_D \quad \because r_o \gg R_D$

$R_2 = R_2'' + R_L = R_D + R_L$

$$\tau_3 = \frac{1}{R_3 C_3}$$



$R_3' \approx \frac{1}{g_m}$

$R_3 = \left(\frac{1}{g_m}\right) /\!/ R_3$

smallest time constant dominant

$$\omega_L = \frac{1}{R_1C_1} + \frac{1}{R_2C_3} + \frac{1}{R_3C_3} = \frac{1}{(R_i+R_G)C_1} + \frac{1}{(R_D+R_L)C_2} + \frac{1}{\left[\left(\frac{1}{g_m}\right)/\!/R_S\right]C_3}$$

Much simpler than solving small signal circuit with C_1, C_2, C_3

$\frac{1}{g_m}$ smallest resistance

As a designer, determine the minimum capacitance you need for C_1, C_2, C_3

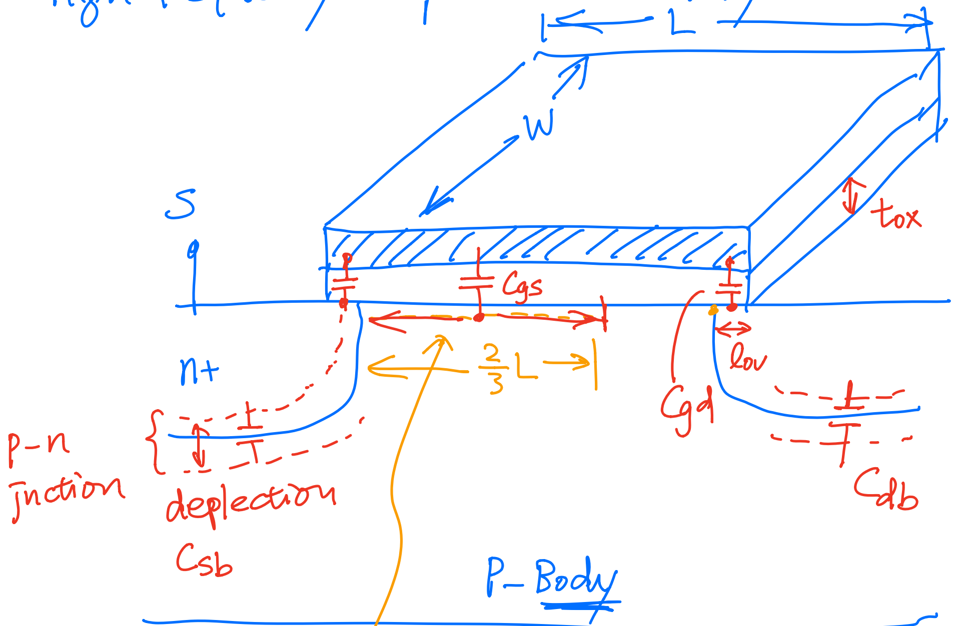
$\omega > \omega_L$

$\left|\frac{1}{j\omega C_1}\right| < R_1 = R_i + R_G \Rightarrow C_1 \gg \frac{1}{\omega(R_1+R_G)}$. ω = operating freq.

$$\left|\frac{1}{j\omega C_2}\right| < R_2 = R_D + R_L \Rightarrow C_2 \gg \frac{1}{\omega(R_D+R_L)}$$

$$\left|\frac{1}{j\omega C_3}\right| < R_3 = \left(\frac{1}{g_m}\right) // R_S \Rightarrow C_3 \gg \frac{1}{\omega\cdot\left(\frac{1}{g_m} // R_S\right)}$$

High frequency Responce limited by transistor cap.



electron inversion layer covers partially channel

$$C_{gs} = C_{ox}\left(\tfrac{2}{3}L\right)\cdot W = \tfrac{2}{3}W\cdot L\cdot C_{ox} \quad ; \quad C_{ox} = \frac{\epsilon_{ox}}{t_{ox}}$$

$\left[\frac{F}{cm^2}\right]$

usually the largest cap of MOSFET

$$C_{gd} = C_{overlap} = C_{ox}\, l_{ov}\cdot W \qquad l_{ov} \ll L$$

$$C_{gd} \ll C_{gs}$$

$$C_{sb} = C_{jsb} \cdot \text{area}$$

$$C_{jsb} = \frac{C_{j0}}{\sqrt{1+\frac{V_{bs}}{V_{bi}}}} \quad \text{junction cap.}$$