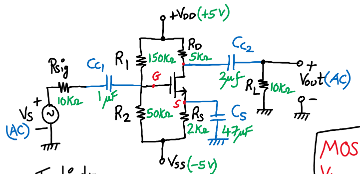
AEC 11.2 3/2/2022



To find:-
1. I_{DQ} and V_{GSQ}
2. g_m
3. A_{Vmid} in dB
4. f_H
5. Plot the high frequency response

MOSFET parameters:
$V_{tn} = 0.8V$, $k_n = 1\frac{mA}{V^2}$

Given:
$C_{gs} = 2pf$, $C_{gd} = 0.2pf$

4) Calculation of f_H:

$$f_{Hi} = \frac{1}{2\pi R_{eq} C_i} \quad ; \quad R_{eq} = \overset{10K}{R_{sig}} \,||\, \underbrace{R_1 || R_2}_{37.5K} = 7.895K\Omega$$

$$C_i = C_{gs} + C_{mi}, \quad C_{gs} = 2pf$$

$$C_{mi} = \underbrace{C_{gd}}_{0.2pf}(1 - \underbrace{A_{Vmid}}_{-3.684})$$

$$C_{mi} = 0.2\times10^{-12}\times(1+3.684)$$

$$C_{mi} = 0.9368pf$$

$$C_i = 2pf + 0.9368pf$$

$$C_i = 2.9368pf$$

$$f_{Hi} = \frac{1}{2\pi\times7.895K\times2.937p}$$

$$f_{Hi} = 6.86\,MHz$$

$$\rightarrow f_{Ho} = \frac{1}{2\pi R_{eq} C_o} \quad ; \quad R_{eq} = \overset{5K}{R_D} || \overset{10K}{R_L} = 3.33K\Omega$$

$$C_o = C_{mo} + \cancel{C_{ds}} + \cancel{C_{db}}$$

$$C_{mo} = \left(1 - \frac{1}{\underbrace{A_{Vmid}}_{-3.684}}\right)\underbrace{C_{gd}}_{0.2pf}$$

$$C_{mo} = 0.254pf$$

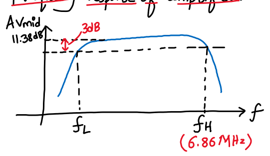
$$f_{Ho} = \frac{1}{2\pi\times333K\times0.25pf}$$

$$f_{Ho} = 187.99\,MHz$$

$$\rightarrow f_H = \min(f_{Hi}, f_{Ho})$$

$$\boxed{f_H = 6.86MHz} \rightarrow \text{Higher cutoff frequency}$$

5) Frequency response of amplifier:



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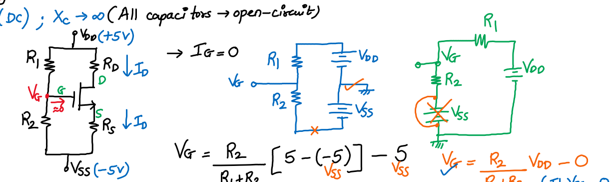
Solution:

1) DC Analysis

$f = 0\,(DC)$; $X_C \rightarrow \infty$ (All capacitors → open-circuit)



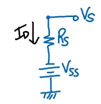
$\rightarrow I_G = 0$

$$V_G = \frac{R_2}{R_1+R_2}\left[5 - (\underbrace{-5}_{V_{SS}})\right] - \underbrace{5}_{V_{SS}}$$

$$V_G = \frac{R_2}{R_1+R_2} V_{DD} - 0 \quad (\text{If } V_{SS}=0)$$

$$V_G = \frac{50K}{150K+50K}\times10 - 5 = -2.5V$$

$$\rightarrow V_{GS} = V_G - V_S$$



$$V_S = I_D R_S - 5$$

$$\rightarrow V_{GS} = -2.5 - (I_D R_S - 5) = 2.5 - I_D(2000)$$

$$\text{i.e. } V_{GS} = 2.5 - I_D\times2000 \quad \text{— (1.1)}$$

→ Assume that the given NMOS transistor is operating in the saturation region

$$\rightarrow I_D = \underbrace{k_n}_{1m}(V_{GS} - \underbrace{V_{tn}}_{0.8})^2$$

$$\text{i.e. } I_D = 1\times10^{-3}\times(V_{GS}-0.8)^2 \quad \text{— (1.2)}$$

→ Put equation (1.2) in (1.1),

$$V_{GS} = 2.5 - \underbrace{1\times10^{-3}\times2000}_{2}\times(V_{GS}-0.8)^2$$

$$\text{i.e. } V_{GS} = 2.5 - 2\times(V_{GS}^2 - 1.6V_{GS} + 0.64)$$

$$\text{i.e. } V_{GS} = 2.5 - 2V_{GS}^2 + 3.2V_{GS} - 1.28$$

$$\text{i.e. } 2V_{GS}^2 - 2.2V_{GS} - 1.22 = 0$$

$V_{GS} = 1.5V$ ✓ $(V_{GS} > \underbrace{V_{tn}}_{0.8V})$ or $V_{GS} = -0.4V$ ✗ Reject

$$\rightarrow V_{GSQ} = 1.5V$$

$$\rightarrow I_{DQ} = k_n(V_{GSQ} - V_{tn})^2 = 1\times10^{-3}\times(1.5-0.8)^2$$

$$I_{DQ} = 0.49mA$$

2) Small-signal parameters:

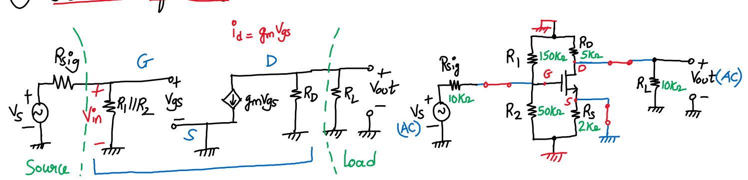
$$g_m = 2k_n(V_{GSQ} - V_{tn}) = 2\times1\times10^{-3}\times(1.5-0.8)$$

$$g_m = 1.4\,\frac{mA}{V}$$

$$r_o = \frac{1}{\lambda I_D}$$

∵ λ is not given, assume $\lambda = 0$
$r_o \rightarrow \infty$

3) Calculation of A_{Vmid}:



$$A_{Vmid} = \frac{V_{out}}{V_s} = \frac{V_{out}}{V_{in}}\times\frac{V_{in}}{V_s} \quad ; \quad V_{out} = (R_D||R_L)\times -i_d$$

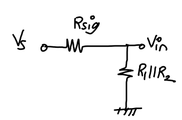
$$V_{out} = -g_m V_{gs}\times(R_D||R_L)$$

$$V_{out} = -g_m V_{in}\times(R_D||R_L)$$

$$\frac{V_{out}}{V_{in}} = -g_m(R_D||R_L)$$

$$\rightarrow \frac{V_{out}}{V_{in}} = -\underbrace{g_m}_{1.4m}(\overset{5K\Omega}{R_D} || \overset{10K\Omega}{R_L})$$

$$\boxed{\frac{V_{out}}{V_{in}} = -4.667}$$



$$\frac{V_{in}}{V_s} = \frac{R_1||R_2}{R_1||R_2 + R_{sig}}$$

$$\rightarrow \frac{V_{in}}{V_s} = \frac{R_1||R_2}{R_1||R_2 + \underbrace{R_{sig}}_{10K}}$$

$$R_1||R_2 = 150K \,||\, 50K = 37.5K\Omega$$

$$\frac{V_{in}}{V_s} = \frac{37.5\times10^3}{37.5\times10^3 + 10\times10^3} = 0.789$$

$$\rightarrow A_{Vmid} = -4.667\times0.789$$

$$\boxed{A_{Vmid} = -3.684}$$

$$A_{Vmid\,dB} = 20\log_{10}(3.684) = 11.327dB$$