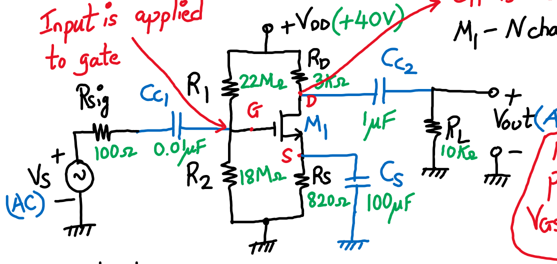
AEC 24 4/9/23

~~AEC 8.1~~ ~~27/1/2022~~

Input is applied to gate

O/p is sensed at drain

M_1 – N channel MOSFET



MOSFET parameters:

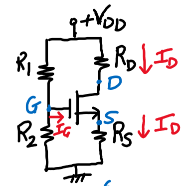
$V_{GS(th)} = 5V$; $k_n = 120\,\frac{\mu A}{V^2}$

To find:-
1. I_{DQ} and V_{GSQ}
2. g_m
3. $f_{LC_{C_1}}, f_{LC_{C_2}}$ and f_{C_S}
4. f_L
5. $A_{v_{mid}}$ in dB
6. Plot the frequency response

Solution:-

DC ⇒ f = 0
$X_c = \infty$
C → o.c

1) DC analysis:



$$V_G = \frac{R_2}{R_1+R_2} \times V_{DD} = \frac{18\times10^6}{18\times10^6 + 22\times10^6} \times 40$$

; $V_G = 18V$

$V_S = I_D R_S$

$V_S = I_D \times 820$ $\qquad V_{GS} = V_G - V_S$

$V_{GS} = V_G - I_D R_S = 18 - I_D \times 820 \ldots (1.1)$

$I_D = k_n(V_{GS} - V_{tn})^2 \ldots$ (Assuming given MOSFET is in saturation)

$I_D = 120\times10^{-6}(V_{GS}-5)^2 \ldots (1.2)$ $\qquad V_{GS(th)} = V_{tn}$

Put (1.2) in (1.1), we get

$V_{GS} = 18 - 0.0984 \times (V_{GS}^2 - 10V_{GS} + 25)$

$V_{GS} = 18 - 0.0984V_{GS}^2 + 0.984V_{GS} - 2.46$

i.e $0.0984V_{GS}^2 + 0.016V_{GS} - 15.54 = 0$

$\boxed{V_{GSQ} = 12.485V}$ ✓ ($\because V_{GSQ} > V_{tn}$) or $\cancel{V_{GSQ} = -12.64V}$

→ $I_{DQ} = k_n(V_{GS}-V_{tn})^2 = 120\times10^{-6}(12.485-5)^2$

$\boxed{I_{DQ} = 6.723\text{ mA}}$

2) Small-signal parameters:

$r_o = \frac{1}{\lambda I_{DQ}}$ $\qquad$ λ is not given. Assume $\lambda = 0$, $r_o \to \infty$

$r_o = \infty$ (Assumed)

$g_m = 2k_n(V_{GSQ} - V_{tn}) = 2\times120\times10^{-6}\times(12.485-5)$

i.e $\boxed{g_m = 1.7964\,\frac{mA}{V}}$

3) $f_{LC_{C_1}}, f_{LC_{C_2}}$ and f_{LC_S}:

a) $f_{LC_{C_1}} = \frac{1}{2\pi(R_{eq}+R_i)C_{C_1}}$; $R_{eq} = \underbrace{R_{sig}}_{100\Omega} + R_i \approx 9.9M\Omega$

$R_i = R_1 \| R_2 = 22M \| 18M = 9.9M\Omega$

$f_{LC_{C_1}} = \frac{1}{2\pi \times 9.9\times10^6 \times 0.01\times10^{-6}} = \underline{1.607Hz}$

b) $f_{LC_{C_2}} = \frac{1}{2\pi(R_o+R_L)C_{C_2}}$ $\qquad$ $C_{C_2} \to 1\mu F$ $\qquad$ $R_L = 10K\Omega$

$R_o = R_D = 3.3K\Omega$; $f_{LC_{C_2}} = \frac{1}{2\pi\times13.3\times10^3\times1\times10^{-6}} = \underline{11.97Hz}$

c) $f_{LC_S} = \frac{1}{2\pi R_{eq} C_S}$

$R_{eq} = \underbrace{R_S}_{820} \| \frac{1}{g_m}$ $\qquad g_m \to 1.7964\times10^{-3}$

$R_{eq} = 820 \| 556.67 = \underline{331.57}$

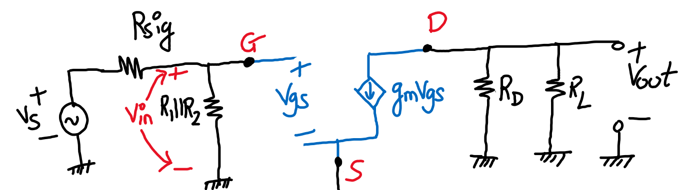
$f_{LS} = \frac{1}{2\pi\times331.57\times100\times10^{-6}} = \underline{4.8Hz}$

4) Calculation of f_L:

$f_L = \max(f_{LC_{C_1}}, f_{LC_{C_2}}, f_{LC_S})$

$\boxed{f_L = 11.97Hz}$ → Lower-cutoff frequency

5) Calculation of $A_{v_{mid}}$:-



Mid-frequency / Mid-band Small-signal equivalent circuit

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

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

→ Calculate $A_{v_{mid}} = \frac{V_{out}}{V_s} = \frac{V_{out}}{V_{in}} \times \frac{V_{in}}{V_s}$

→ Calculate $A_{v_{mid}}$ in dB $\qquad A_{v_{mid_{dB}}} = 20\log_{10}(A_{v_{mid}})$

→ $\frac{V_{out}}{V_{in}} = -g_m(\underbrace{R_D}_{3K} \| \underbrace{R_L}_{10K}) = -1.7964\times10^{-3}\times(2.3K\Omega)$

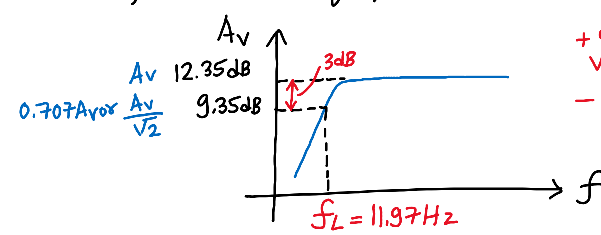
$\frac{V_{out}}{V_{in}} = \underline{-4.146}$

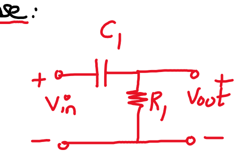
→ $\frac{V_{in}}{V_s} = \frac{R_1\|R_2}{R_1\|R_2 + R_{sig}} = \frac{9.9\times10^6}{9.9\times10^6 + 100} \approx 0.9999 \approx 1$

→ $\boxed{A_{v_{mid}} = -4.146}$

→ $A_{v_{mid_{dB}}} = 20\log_{10}(4.146) = \underline{12.35dB}$

6) Plot the frequency response:





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