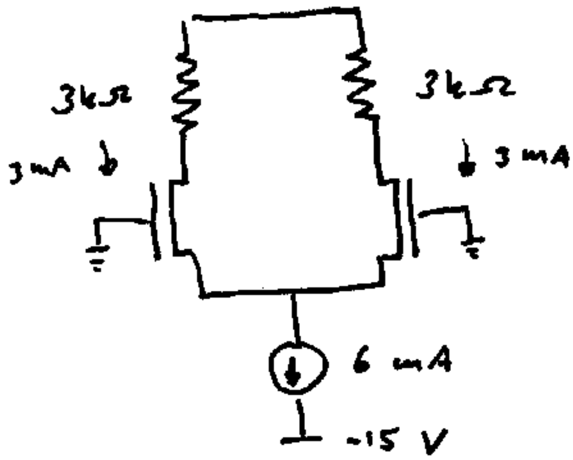
Electronics II 10-II-2010

1))

a)



$I_{D1} = I_{D2} = \frac{I_{source}}{2} = 3\ mA$

$V_{D1} = V_{D2} = 15\ V - 3\ mA \times 3k\Omega$

$= 6\ V$

$V_{DS} \overset{?}{>} V_{GS} - V_T$

$V_T = 0$, $V_G = 0$, $V_D = 6 \Rightarrow$

yes. saturation

$$I_D = \frac{K}{2}(V_{GS})^2 = 3\ mA \Rightarrow V_{GS} = \sqrt{\frac{2 \times 3\ mA}{K}}$$

$$g_m = \frac{\partial I_D}{\partial V_G} = K V_{GS} = 3{,}4\ mS'$$

$$\Rightarrow K = \frac{3.4\ mS'}{V_{GS}}$$

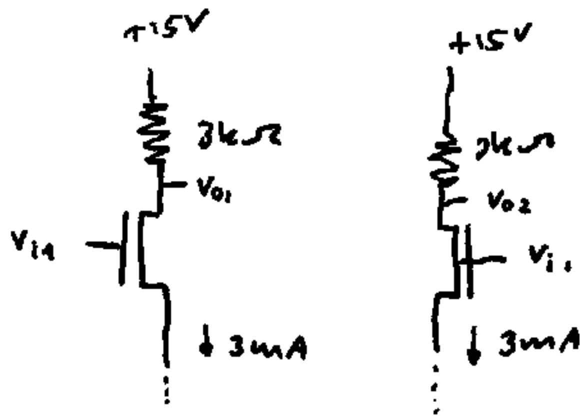
$$\Rightarrow K = \frac{3.4\ mS'}{\sqrt{6\ mA}} \times \sqrt{K} \Rightarrow \sqrt{K} = \frac{3.4\ mS'}{\sqrt{6\ mA}}$$

$$K = \frac{(3.4\ mS')^2}{6\ mA} = 1.93\ \frac{mA}{V^2}$$

$$V_{GS} = \sqrt{\frac{6\ mA}{1.93\ mA/V^2}} = 1.76\ V$$

$$V_G = 0 \Rightarrow V_S = -1{,}76\ V$$

b) common mode gain: $A_{cm} = 0$ because of symmetry and the fact that $I_G = 0$ (therefore $I_D = I_S$, always!):



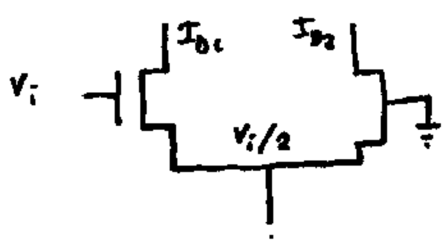
$V_{o1} = 6$ V, always, independent of V_i
$V_{o2} = 6$ V, always, independent of V_i

$V_{out} = V_{o2} - V_{o1} = 0$, always.

$$A_v = \frac{v_o}{v_i} = \frac{dV_{out}}{dV_i} = 0 \qquad \text{common mode.}$$

Differential - mode gain : A_{dm}

For small signals, the circuit and transistors work linearly. The input v_i thus divides equally between the two transistors.



$$\frac{dI_{D1}}{dv_i} = \frac{1}{2}\frac{dI_{D1}}{dV_{GS1}} = \frac{1}{2} K V_{GS} = \frac{1}{2}\, 1.93\ \frac{mA}{V^2} \times 1.76\ V = 1.7\ \frac{mA}{V}$$

$$\frac{dV_{D1}}{dv_i} = -R \times \frac{dI_{D1}}{dv_i} = 3\,k\Omega \times 1.7\ \frac{mA}{V} = -5.1\ \frac{V}{V}$$

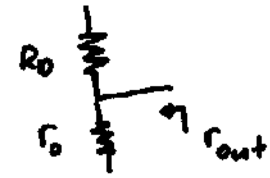
$$\frac{dI_{D2}}{dv_i} = -\frac{1}{2}\frac{dI_{D1}}{dV_{GS1}}, \quad \frac{dV_{D1}}{dv_i} = -R\frac{dI_{D1}}{dv_i} = +5.1\ \frac{V}{V}$$

$$A_{dm} = 5.1\ V/V - (-5.1\ V/V) = 10.2\ V/V$$

$$\text{CMRR} = \left| \frac{A_{dm}}{A_{cm}} \right| = \frac{10.2}{0} = \infty$$

c) $$r_{in} = 1 / \frac{\partial I_{in}}{\partial V_{in}} = 1 / \frac{\partial I_G}{\partial V_G} = 1/0 = \infty$$

$$r_{out} = R_D \,//\, r_o$$



$$r_o = V_A / I_D = \frac{100\ V}{3\ mA} =$$

$$= 33\ k\Omega$$

$$r_{out} = 3\ k\Omega \,//\, 33\ k\Omega = 2.75\ k\Omega$$

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2)) see lecture notes

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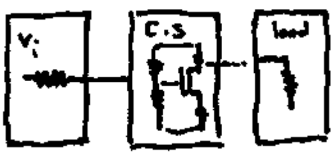
3)) a)



C.S : $r_{in} = R_{G2} \,//\, R_{G1} = 330\ k\Omega \,//\, 1.5\ M\Omega = 270\ k\Omega$

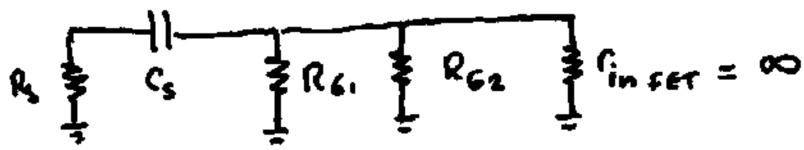
$r_{out} = R_D = 2\ k\Omega$

$$A_V = \frac{-R_D}{(1/g_m + R_S)} = \frac{2\ k\Omega}{294\ \Omega + 820\ \Omega} = -1.80$$

$$A_{total} = \frac{r_{in}}{R_{so} + r_{in}} \times A_V \times \frac{R_L}{R_{out} + R_L} = -1.59$$

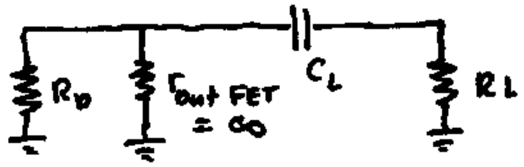
b) using short-circuit time constants and open-circuit time constants we will find time constants for each capacitance and the combine them to give f_L and f_H, the cut-off frequencies at lower and higher frequencies

C_S : is an HPF (high-pass filter)



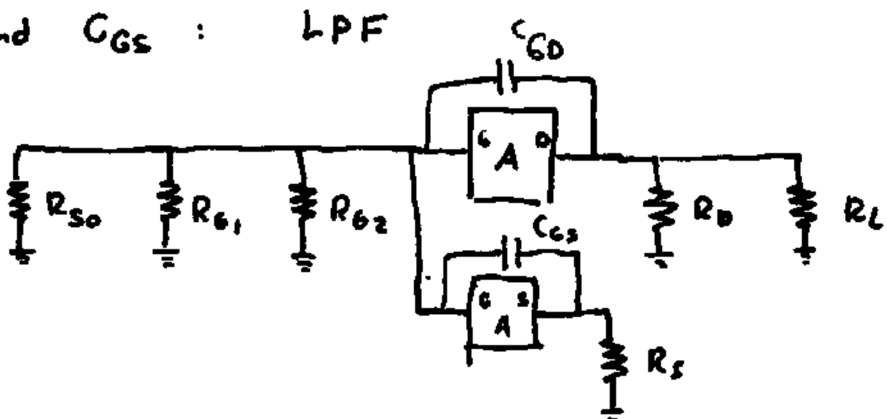
$$\tau_S = C_S\,(R_S + R_{G1} /\!/ R_{G2}) = 1\,\mu F \times (20\,k\Omega + 330\,k\Omega /\!/ 1.5\,M\Omega) = 0.29\ s$$

C_L : is an HPF



$$\tau_L = C_L\,(R_L + R_D) = 20\,nF \times (2\,k\Omega + 40\,k\Omega) = 8.4 \times 10^{-4}\ s$$

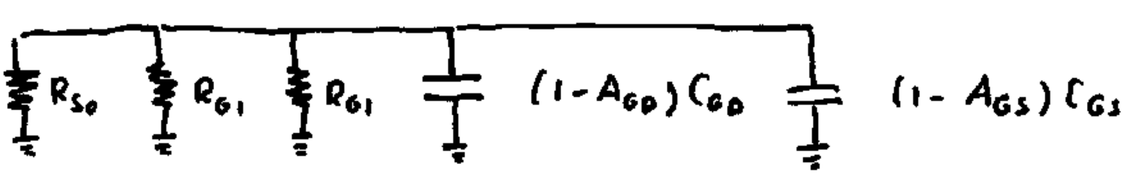
C_{GD} and C_{GS} : LPF



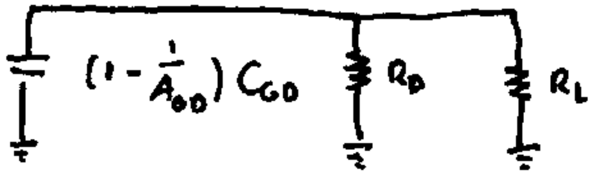
$$A_{GD} = -1.80\ ,\quad A_{GS} = +\frac{R_S}{1/g_m + R_S} = 0.74$$

$$\Downarrow$$

IN



OUT



$$\tau_{in} = \left[(1 - A_{GD}) C_{GD} + (1 - A_{GS}) C_{GS} \right] \times (R_{S0} \,//\, R_{G1} \,//\, R_{G1})$$

$$= \left[2.8 \times 1.2\ pF + 0.26 \times 4\ pF \right] \times 18.62\ k\Omega$$

$$= 8.19 \times 10^{-8}\ s$$

$$\tau_{out} = \left[\left(1 - \frac{1}{A_{GD}}\right) C_{GD} \right] \times \left[R_D \,//\, R_L \right]$$

$$= 1.56 \times 1.2\ pF \times 1.90\ k\Omega$$

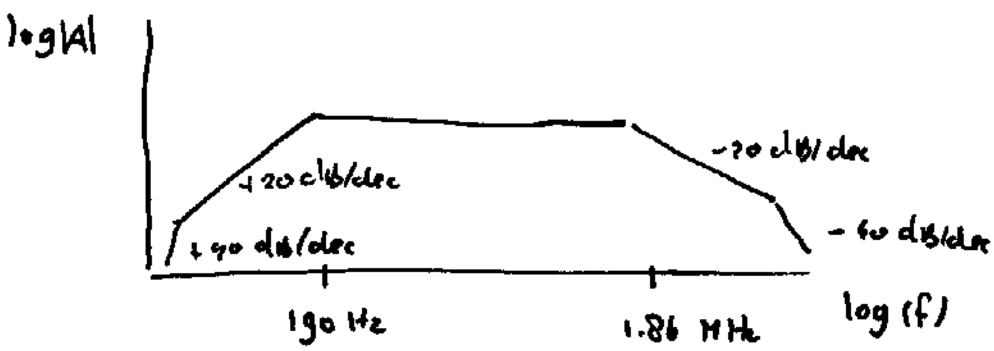
$$= 3.56 \times 10^{-9}\ s$$

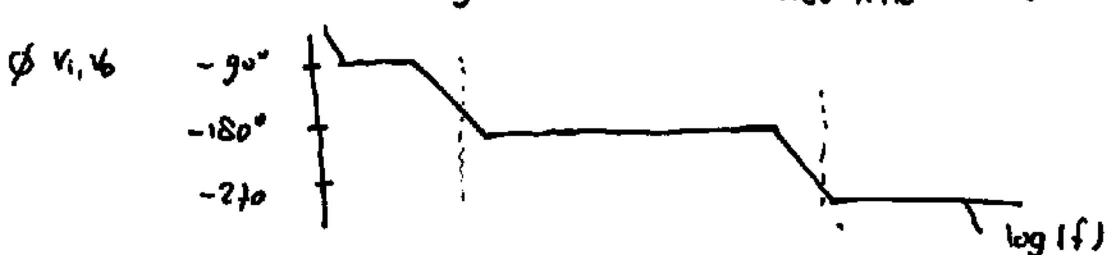
$$\tau_{lo} = \left(1/\tau_S + 1/\tau_L \right)^{-1} = 8.4\ 10^{-4}\ s$$

$$\Rightarrow f_{lo} = \frac{1}{2\pi \tau_{lo}} = 190\ Hz$$

$$\tau_{Hi} = \tau_{in} + \tau_{out} = 8.55 \times 10^{-8}\ s$$

$$\Rightarrow f_{hi} = 1.86\ MHz$$





c) 190 Hz — 1.86 MHz $\sim$ 1.86 MHz

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4)) See lecture notes

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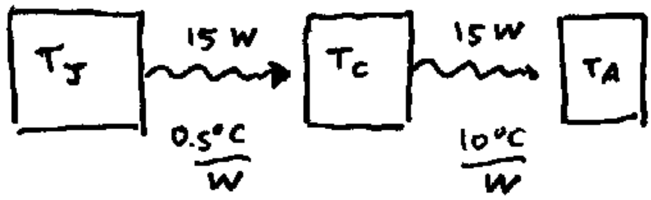
5))

a)



steady-state situation

Given the fact that $T_A = 40°C$,

$$T_c = 40°C + 15\,W \times \frac{10°C}{W} = 190°C$$

$$T_J = T_c + 15\,W \times \frac{0.5°C}{W} = 197.5°C \implies \text{too hot!}$$

b) A dissipater lowers the thermal resistance from T_c to T_A. Reasoning other way around:

$T_J = 150°C \implies$

$$T_c = T_J - 15\,W \times \frac{0.5°C}{W} = 142.5°C$$

$$T_A = T_c - 15\,W \times R_T = 40°C$$

$$142°C - 15W \times R_T = 40°C$$

$$\implies R_T = \frac{102.5°C}{15\,W} = 6.8\,°C/W$$