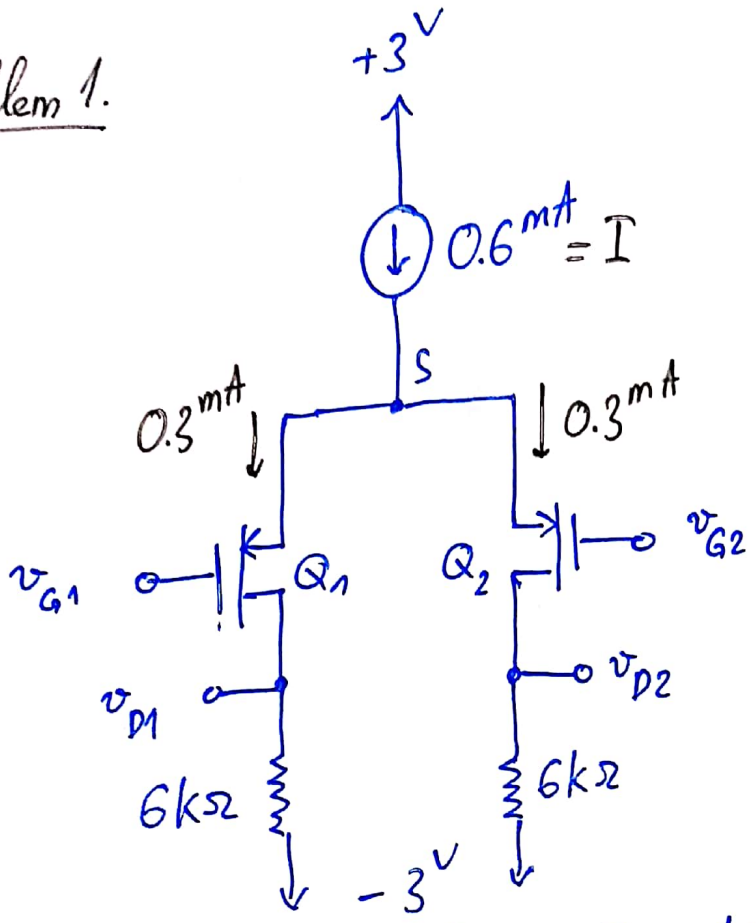
Analog Electronics

Homework #2.

Problem 1.



a) $I_D = \frac{1}{2} k_p' \left(\frac{W}{L}\right) V_{ov}^2 \Leftrightarrow \frac{I}{2} = \frac{1}{2} k_p' \left(\frac{W}{L}\right) V_{ov}^2$

$\Leftrightarrow V_{ov}^2 = \frac{0.6}{6} = 0.1$

$\Leftrightarrow |V_{ov}| \simeq 0.32\,(V) = |V_{ov_1}| = |V_{ov_2}|$

$V_{SG1} = V_{SG2} = |V_{ov}| + |V_{tp}| = 0.32 + 0.8 = 1.12\,(V)$

$V_{D_1} = V_{D_2} = -3 + I_D \times 6^K = -3 + 0.3 \times 6 = -1.2\,(V)$

$V_S = V_{SG1} + V_{G1} = 1.12 + 0 = 1.12\,(V)$

b) In order for Q_1 and Q_2 to operate in saturation mode

$V_{SD} \geq |V_{ov}| \Leftrightarrow V_{DG} \leq |V_{tp}|$

$\Leftrightarrow V_D - V_{CM} \leq |V_{tp}|$

$\Leftrightarrow -1.2 - 0.8 \leq V_{CM}$

$\Leftrightarrow V_{CM\,min} \geq -2^V$

- $V_{CM} = V_G = V_{DD} - V_{CS} + V_{GS}$

$\Rightarrow V_{CM\,max} = V_{DD} - V_{CS\,min} + V_{GS}$

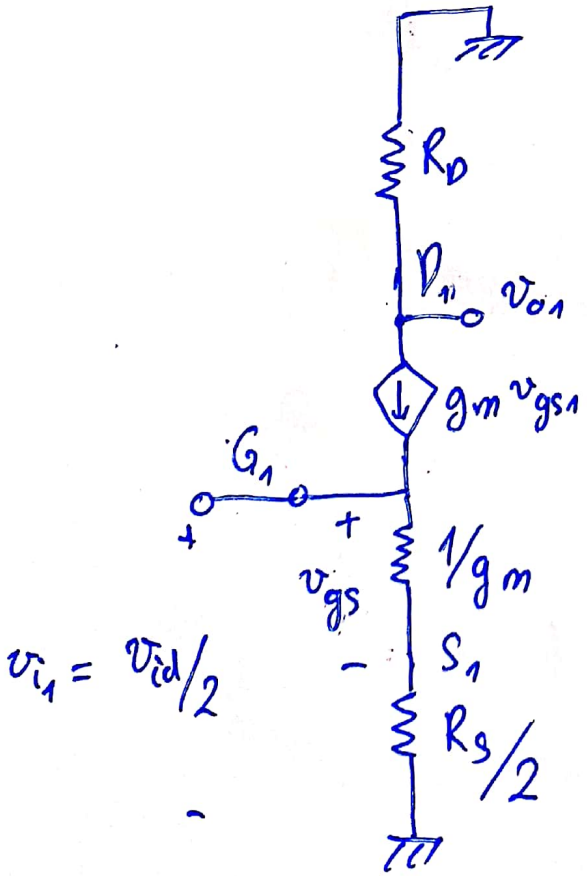
$\Leftrightarrow V_{CM\,max} = 3 - 0.5 - 1.12$

$\Leftrightarrow V_{CM\,max} = 1.38^V$

Therefore, $V_{CM} \in [-2^V, 1.38^V]$

Problem 2:

+ Small-signal equivalent half-circuit:



$$v_{gs1} = v_{i1} \frac{1/g_m}{1/g_m + R_S/2} = \frac{v_{i1}}{(1+g_m R_S/2)}$$

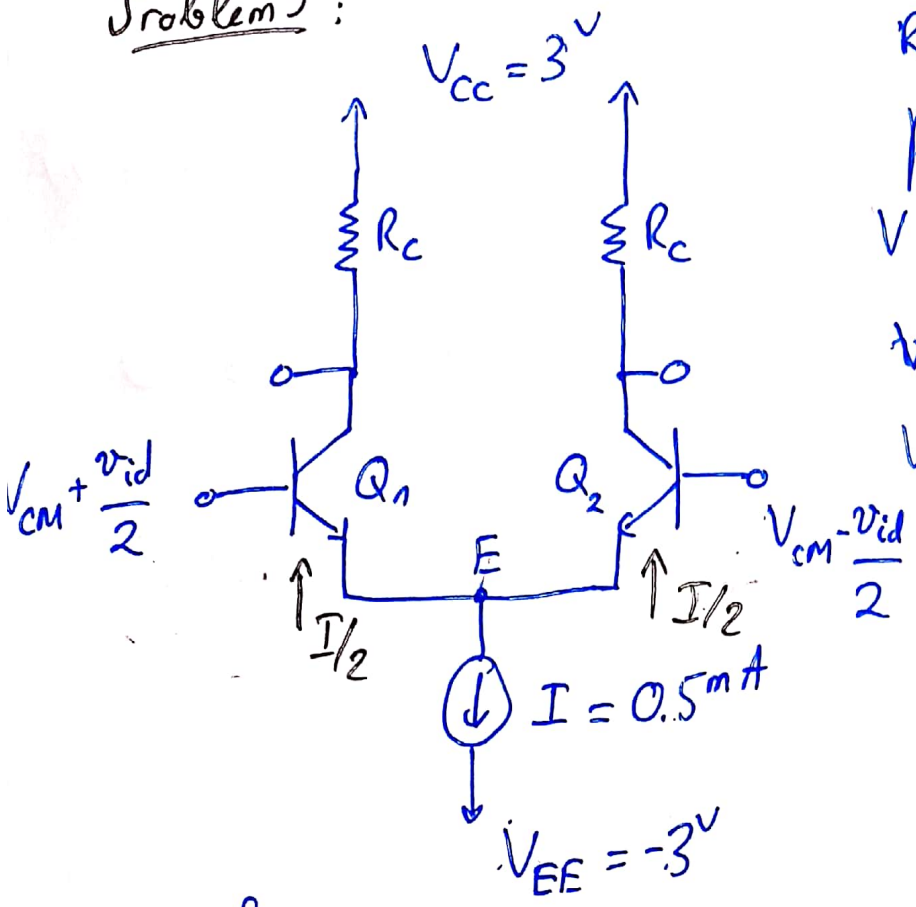
$$v_{o1} = -g_m v_{gs1} R_D$$

$$A_d = \frac{v_{od}}{v_{id}} = \frac{-v_{o1}}{v_{i1}} = \frac{g_m R_D}{1+g_m R_S/2}$$

- $R_S = 0 \Rightarrow A_d = g_m R_D$
- For A_d to be reduced by half

$$1 + g_m \frac{R_S}{2} = 2 \Leftrightarrow R_S = \frac{2}{g_m}$$

Problem 3 :



$R_C = 4^{k\Omega}$

$\beta = 100$

$V_{BE_o} = 0.7^V$ at $I_{C_o} = 1^{mA}$

$V_{CE\,min} = 0.2^V$

$V_{CS\,min} = 0.4^V$

- We have :

$$i_C = I_S e^{v_{BE}/V_T} \Rightarrow V_{BE_o} - V_{BE} \simeq V_T \ln \frac{i_C}{I/2}$$

$$\Leftrightarrow V_{BE} \approx 0.7 - 0.025 \ln \frac{1}{0.25}$$

$$\Leftrightarrow V_{BE} \approx 0.68^V$$

- For the current source to function properly : $V_{CS\,min} = 0.4^V$

- We have : $\begin{cases} V_E = V_{CM} - V_{BE} = V_{CM} - 0.68 \\ V_E = V_{EE} + V_{CS} = -3 + V_{CS} \end{cases}$

$$\Rightarrow V_{CM\,min} = -2.32 + V_{CS\,min} = -2.32 + 0.4 = -1.92^V$$

- For the BJT to work in active region :

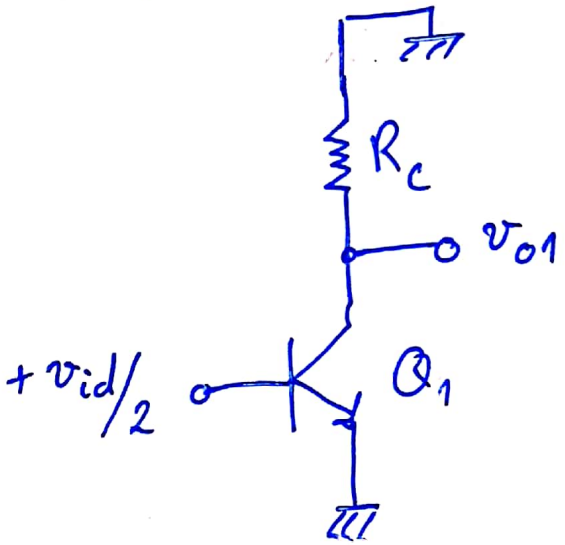
$$V_{CE\,min} = 0.2^V \simeq V_{CC} - I/2\, R_C - V_{E\,max}$$

$$\Leftrightarrow 0.2 = 3 - 0.25 \times 4 - V_{CM\,max} + 0.68$$

$$\Leftrightarrow V_{CM\,max} = 2.48^V$$

Therefore, $V_{CM} \in [-1.92^{V}, 2.48^{V}]$

- Differential half-circuit: equivalent



$$g_m = \frac{I_C}{V_T} \approx \frac{0.25^{mA}}{25^{mV}} = 0.01\,(A/V)$$

$$A_d = \frac{v_{od}}{v_{id}} = \frac{v_{o2} - v_{o1}}{v_{id}} = g_m R_C \approx 40$$