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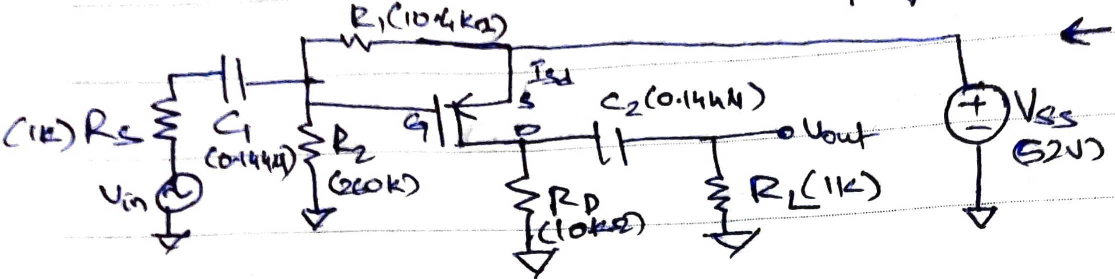
Assignment-3

1) PMOS Common Source Amplifier



← Complete Picture

Given $\mu_p C_{ox} \frac{W}{L} = 10^{-2}$ $\quad g_m R_L = 10$ (Gain assuming $R_D >> R_L$)

$R_L = R_S = 1k\Omega$ $\quad \Rightarrow \boxed{g_m = 10m}$

(ignoring 'λ' effects)

And $I_{sd} = \frac{\mu_p C_{ox} W}{2L}(V_{SG} - V_T)^2 \Rightarrow g_m = \frac{\mu_p C_{ox} W}{L}(V_{SG} - V_T)$

$\Rightarrow 10^{-2} = 10^{-2}(V_{SG} - 1)$

$\Rightarrow \boxed{V_{SG} = 2V}$

And for saturation we need, $V_{SD} \geq V_{SG} - V_T = 1V \Rightarrow \boxed{V_{SD} = 2V}$

As $R_D >> R_L$, lets take $\boxed{R_D = 10R_L = 10k\Omega}$. Then

$V_{SD} = V_{SS} - I_{SD}R_D \Rightarrow V_{SS} = V_{SD} + I_{SD}R_D$

$\Rightarrow V_{SS} = 2V + \left(\frac{10^{-2}(1)}{2} \times 10 \times 10^3\right) = 52V \quad \Rightarrow \boxed{V_{SS} = 52V}$

And for $V_{SG} = V_{SS}\frac{R_1}{R_1 + R_2} \Rightarrow \frac{R_1}{R_1 + R_2} = \frac{2}{52} = \frac{1}{26}$

$\Rightarrow R_1 = R$ then $R_2 = 25R$. But we know $R_1 \| R_2 > R_S$

So let $R_1 \| R_2 = 10 \times R_S \Rightarrow \frac{R \times 25R}{26R} = 10 \times 1k$

$\Rightarrow \boxed{R = \frac{260}{25}k}$

Hence we get,

$\boxed{R_1 = \frac{260}{25}k = 10.4k\Omega \text{ and } R_2 = 260k\Omega}$

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And for capacitances, at the input side, the effective time constant is given by

$\tau = C_1 C\,(R_s + (R_1 \| R_2))$ and we know minimum frequency is 1kHz $\Rightarrow \omega = 2\pi$ k rad/s and

$\omega_{in} >> \frac{1}{RC} \Rightarrow \omega_{in} = \frac{10}{RC} \Rightarrow C = \frac{10}{R \times \omega_{in}}$

$\Rightarrow C_1 = \frac{10}{(R_s + R_1 \| R_2) \times 2\pi k} = \frac{10}{11k \times 2\pi k} = \frac{10}{22\pi} \mu$

$\Rightarrow \boxed{C_1 = 0.144\,\mu}$ Similarly for

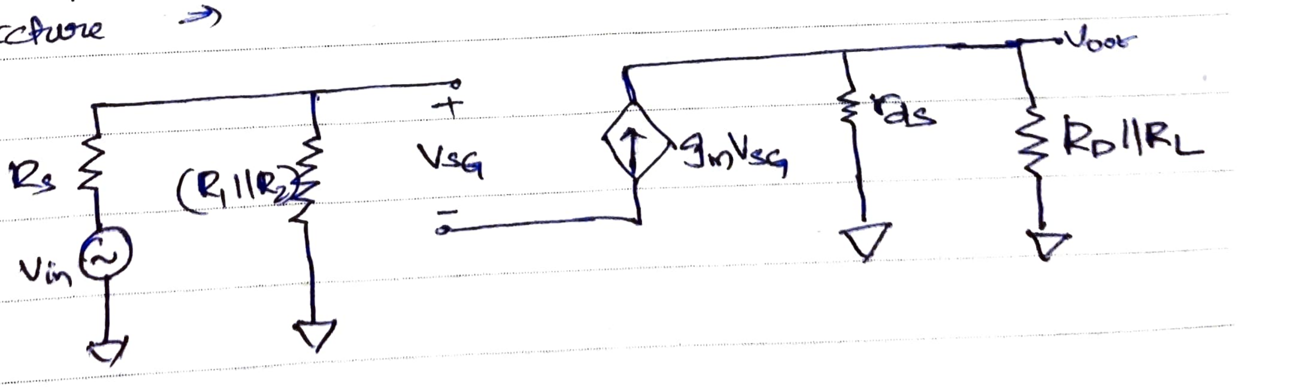
Output side $R_{eff} = R_D + R_L$ and $\omega_{in} >> \frac{1}{RC}$, then
$= 11k$

even C_2 turns out to be $\frac{10}{11k \times 2\pi k} \Rightarrow \boxed{C_2 = 0.144\mu}$

For the incremental picture, we have $\lambda = 0.001\,V^{-1}$

and $I_{SD} = 5mA \Rightarrow g_{sd} = \lambda I_{ds} = 5\mu$ and $\boxed{r_{ds} = 0.2M\Omega}$

Incremental Gain Picture $\rightarrow$



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2) Given NMOS device Characteristics parame:

$\frac{W}{L} = 1$ $\mu_n C_{ox} = 100\,\mu A V^{-2}$ $V_T = 1V$ $\lambda = 0.001 V^{-1}$

Assume that region of operation is always in saturation $\Rightarrow$ $I_{ds} = \frac{\mu_n C_{ox} W}{2L}(V_{GS} - V_T)^2$ (neglecting λ)

Intrinsic gain: $\frac{V_o}{V_{in}} = -g_m r_{ds}$; $r_{ds} = \frac{1}{g_{ds}} = \frac{1}{I_{ds} \cdot \lambda}$

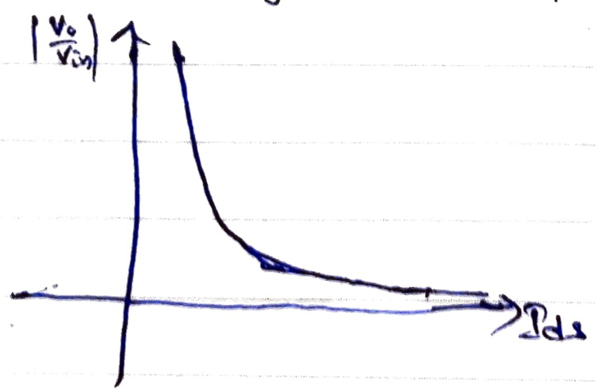
$$\Rightarrow \frac{V_o}{V_{in}} = -\left(\frac{\mu_n C_{ox} W}{L}(V_{GS} - V_T)\right) \cdot \frac{1}{\frac{\mu_n C_{ox} W}{2L}(V_{GS} - V_T)^2 \lambda}$$

$$= \frac{-2}{(V_{GS} - V_T)\lambda} = \frac{-2}{\sqrt{\frac{2 L I_{ds}}{\mu_n C_{ox} W}}\ \lambda}$$

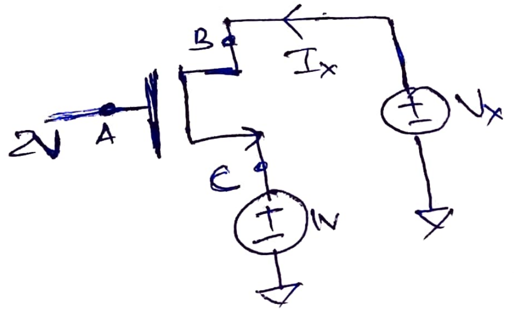
$$= -\frac{\sqrt{2}}{\lambda}\sqrt{\frac{\mu_n C_{ox} W}{L}} \cdot \frac{1}{\sqrt{I_{ds}}}$$

$$= -\sqrt{\frac{2 \times 100 \times 10^{-6} \times 1}{10^{-3} \times 10^{-3}}} \cdot \frac{1}{\sqrt{I_{ds}}} = -\sqrt{\frac{200}{I_{ds}}}$$

Ignoring the sign for magnitude, we get



3)



$\mu_n C_{ox} = 100\,\mu A V^{-2}$

$V_T = 1V$

$\frac{W}{L} = 1$

If we consider that NMOS, is symmetric w.r.t drain and source, i.e, the ~~the~~ driving voltage is at the drain then A will remain Gate but, for

$0V \leq V_x \leq 1V$: C → Drain B → ~~Gate~~ Source

and when $V_x > 1V$: B → Drain C → Source

When $0V \leq V_x \leq 1V$: $V_{DS} = 1 - V_x$ $V_{GS} = 2 - V_x$

$V_{GS} - V_T = 1 - V_x$

Just in saturation,

Then $I_x = -I_{DS} = -100\mu \cdot \frac{1}{2}(1-V_x)^2$

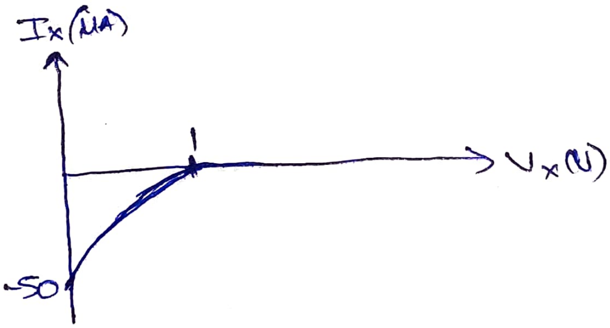
$= -50(1-V_x)^2\ \mu A$

And when $V_x > 1V$: The $V_{DS} = V_x - 1$ $V_{GS} = 2 - 1 = 1V$

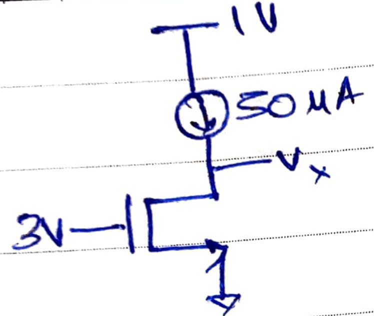
$V_{GS} - V_T = 0V$ → Cut off

$I_x = 0$

∴



4)



$\mu_n C_{ox} = 100 \mu A V^{-2}$

$V_T = 1V \quad \frac{W}{L} = 1$

Here I_{ds} is driven at 50 μA.

Assume that NMOS is in saturation, then the corresponding

max $I_{ds} = \frac{\mu_n C_{ox} W}{2L} (V_{GS} - V_T)^2 = 100 \times 10^{-6} \times \frac{1}{2} (3-1)^2$

$= 200 \mu A$, but we only need 50 μA.

∴ The NMOS ~~is~~ in Linear region (triode region). Then we get

$I_{ds} = 50 \mu A = \mu_n C_{ox} \frac{W}{L} \left((V_{GS} - V_T) V_{DS} - \frac{V_{DS}^2}{2} \right)$

$\Rightarrow \cancel{50} \times 10^{-6} = \overset{2}{\cancel{100}} \times 10^{-6} \times 1 \left(2(V_x) - \frac{V_x^2}{2} \right)$

$\Rightarrow 1 = 4 V_x - V_x^2 \Rightarrow V_x^2 - 4 V_x + 1 = 0$

$\Rightarrow V_x = \frac{4 \pm \sqrt{16 - 4}}{2} = \frac{4 \pm 2\sqrt{3}}{2}$

$= 2 \pm \sqrt{3}$ V

As the NMOS is in linear region, $V_{DS} > \underbrace{V_{GS} - V_T}_{2}$

$\Rightarrow V_x > 2$

∴ $\boxed{V_x = 2 + \sqrt{3} \text{ V}}$