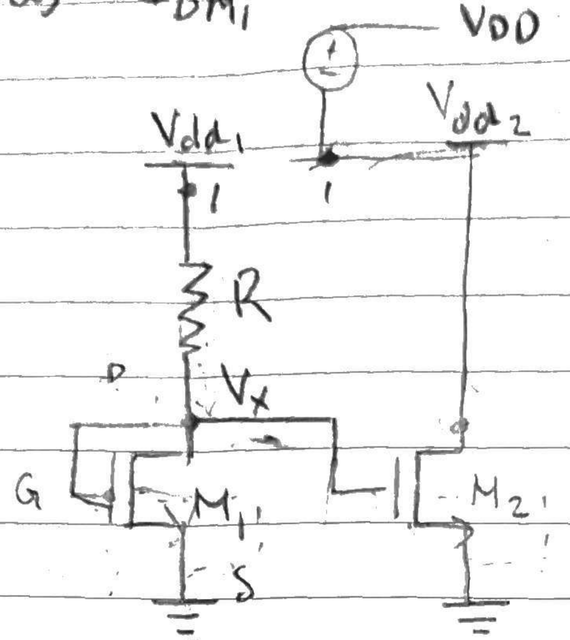
TFE 4152

Excercise 3

$\boxed{1}$ a) $I_{DM_1} \approx 10\mu A$, $V_{DD} = 1,8V$



NMOS-transistors

$V_x = V_{GS}$, same node for V_x and V_{GS}

$V_x = V_{eff} + V_{tn}$

b) $V_{eff} = V_{GS} - V_{tn} = \sqrt{\dfrac{2 I_D}{\mu_n C_{ox} W/L}} =$

$V_{eff} = 0,126\ V$

$V_x = V_{eff} + V_{tn} = 0,126V + 0,45 = \underline{\underline{0,576V}}$

c) $V = R \cdot I \Rightarrow R = \dfrac{V}{I}$

$R = \dfrac{V_{DD} - V_x}{I} = \dfrac{1,8V - 0,576V}{10\mu A} = \underline{\underline{122,4\ k\Omega}}$

$I_{DM_1} = \underline{\underline{-1,02 \cdot 10^{-5} A}}$ $I_{DM_2} = \underline{\underline{-1,17 \cdot 10^{-5} A}}$

d) $I_{DM_2} = -1,17 \cdot 10^{-5}$ A   tt

$I_{DM_2} = -1,06 \; 10^{-5}$ A   SS

$I_{DM_2} = -1,29 \cdot 10^{-5}$ A   ff

All the current values are positive! They are negative because of the direction and how we define it.

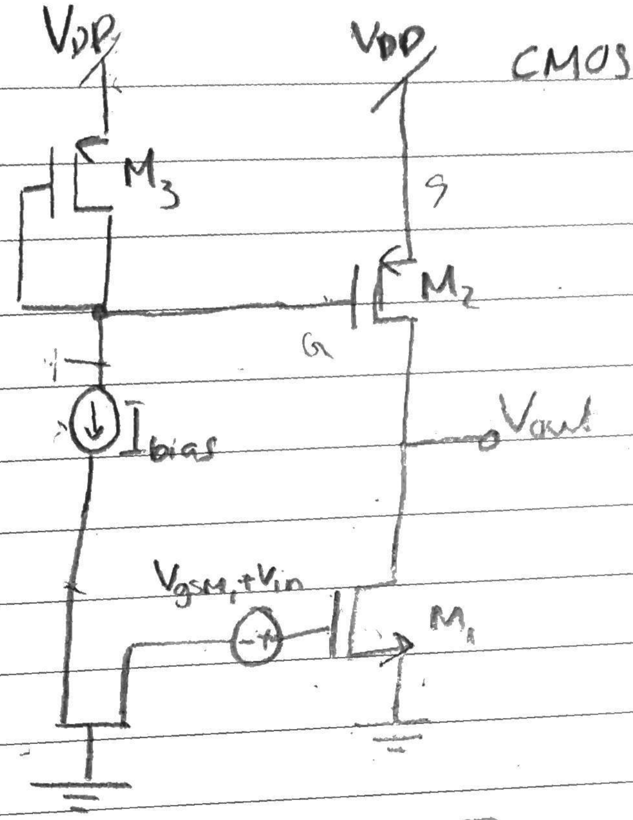
e)

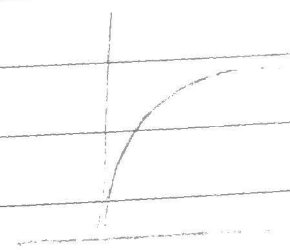
type	rds
ff	300 kΩ
tt	390 kΩ
SS	500 kΩ

f) We always look for the absolute value for the gain, by doing this we get positive gain The gain is proportional with the transconductance and output impedance

$\boxed{2}$

CMOS

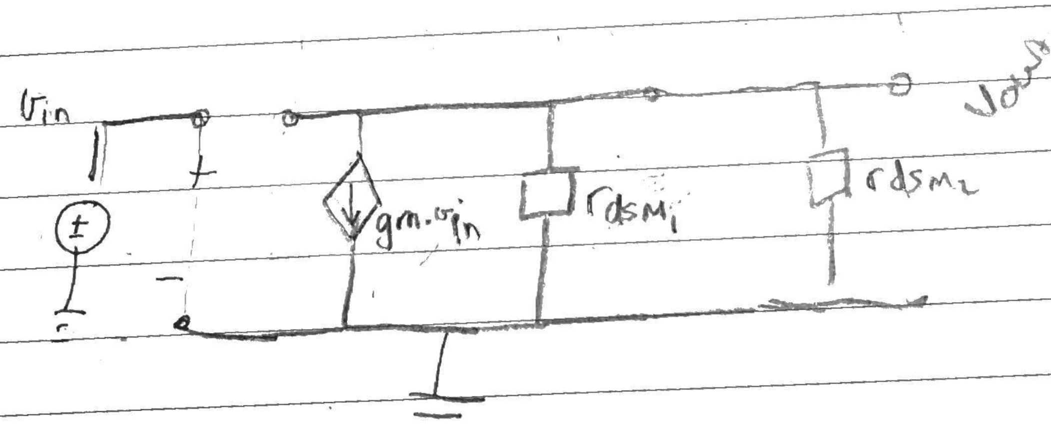




DC gain $|A| \geq 50$, $I_{D,M_1} \approx 25\,\mu A$

$V_{DD} = 1{,}8\,V$, $I_{bias} = 10\,\mu A$

I_{bias} = Brudd $\Rightarrow$ no current:



$A = \dfrac{V_{out}}{V_{in}} \Rightarrow |A| = g_{m,M_1} \cdot r_{tot}$, $r_{tot} = (r_{dsM_1} \| r_{dsM_2})$

$V_{out} = g_m \cdot V_{in} \cdot (r_{dsM_1} \| r_{dsM_2}) \Rightarrow \dfrac{V_{out}}{V_{in}} = A = \underline{\underline{g_m \cdot r_{tot}}}$

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b) Active Region:

$$V_{eff} = \sqrt{\frac{2 I_D}{\mu_o C_{ox} \frac{W}{L}}} \Rightarrow V_{eff}^2 \cdot \mu_o C_{ox} \frac{W}{2L} = I_D$$

$$g_m = \mu_o C_{ox} \frac{W}{L} \cdot V_{eff}$$

$$\frac{g_m}{I_D} = \frac{\cancel{\mu_o C_{ox} \left(\frac{W}{L}\right)} \cdot V_{eff}}{\frac{V_{eff}^2 \cdot \cancel{\mu_o C_{ox}}}{2} \cancel{\frac{W}{L}}} = \frac{2}{V_{eff}}$$

$$\frac{g_m}{I_D} = \frac{2}{(V_{GSM_1} - V_{th})}$$

$$\left(V_{GSM_1} - V_{th}\right) = \frac{2 I_D}{g_m}$$

$$\underline{\underline{V_{GSM_1} = \frac{2 I_{D,M_1}}{g_{m,M_1}} + V_{th}}}$$

$$V_{GSM_1} = \frac{2 \cdot 25\ \mu A}{250\ \mu S} + V_{th} = \underline{\underline{0{,}2V + V_{th}}}$$

$$V_{GSM_1} = 0{,}2V + 0{,}45V\ 0{,}65V$$

$\boxed{2}$ c) $g_m \propto \frac{W}{L}(V_{GS} - V_{th})$

$\uparrow$ proportional

the transconductance is proportional with $\frac{W}{L}(V_{GS} - V_{th})$

d) if $r_{dsM_1} = r_{dsM_2}$ then

$(r_{dsM_1} \| r_{dsM_2}) = \frac{1}{2} r_{dsM_1}$

$$\frac{r_{dsM_1} \cdot r_{dsM_2}}{r_{dsM_1} + r_{dsM_2}} \Rightarrow \frac{1}{2} r_{dsM_1}$$

e) $A \geq 50 \Rightarrow A = 50$, $g_{m,M_1} = 250 \mu S$

$(r_{dsM_1} \| r_{dsM_2}) = \frac{1}{2} r_{dsM_1}$

$A = g_{m,M_1} \cdot \frac{1}{2} r_{dsM_1} \Rightarrow \frac{2A}{g_{m,M_1}} = r_{dsM_1}$

minimum

$$r_{dsM_1} = \frac{2 \cdot 50}{250 \mu S} = \underset{M}{0{,}4 \cdot 10^6} \Omega = 400 k\Omega$$