# * CMOS amplifiers :-

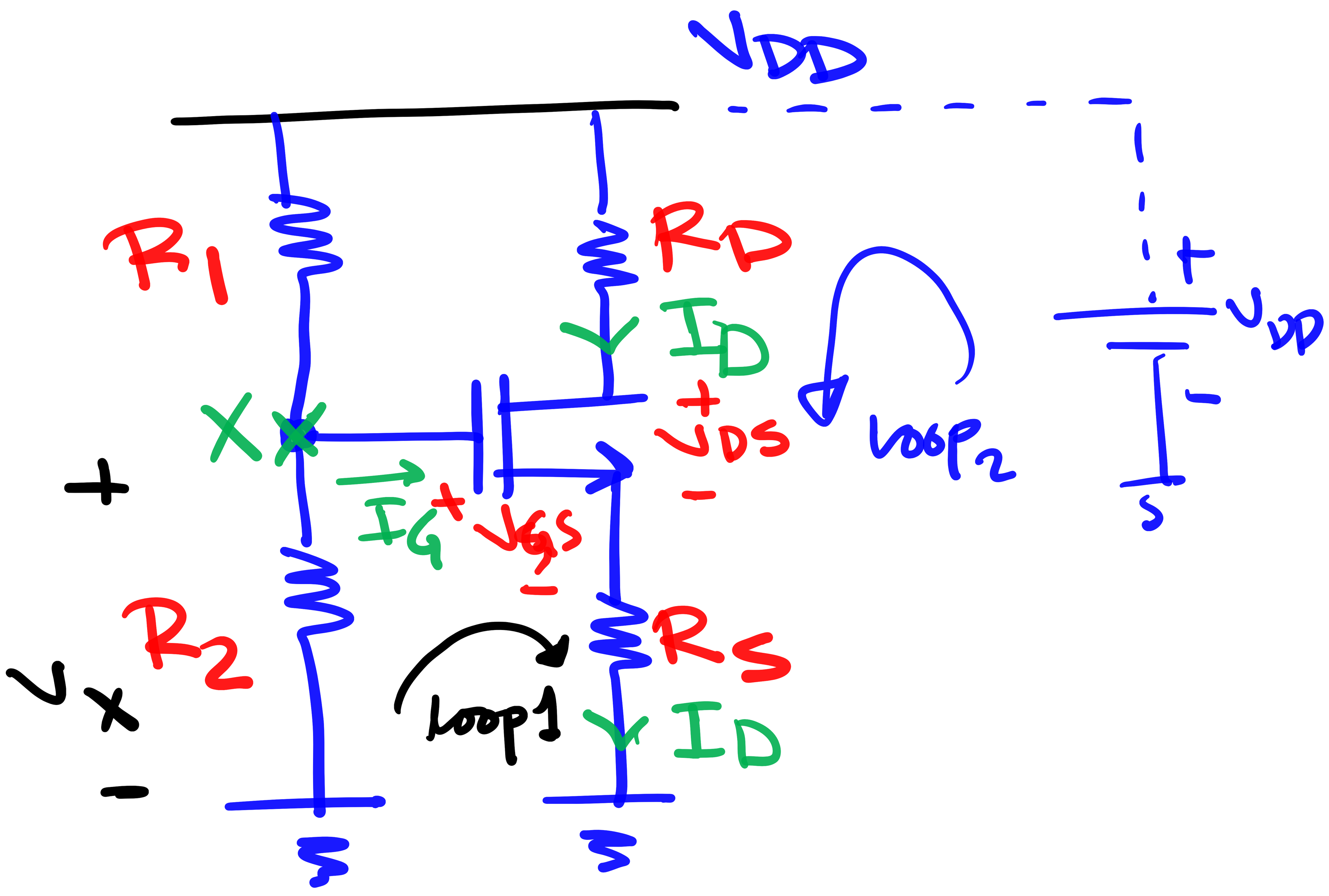
→ To design amplifiers using MOS devices, we need to learn how to turn the MOS devices ON such that they are in the saturation region. → This is called Biasing.

* Biasing techniques :-

1. Resistive divide Biasing
2. Self - Biasing.

## I Resistive divider Biasing :-

Note that $I_G = 0$




→ knowing that $I_G = 0$

→ $V_X = \frac{R_2}{R_1 + R_2} \cdot V_{DD}$

$$\boxed{V_X = V_G = V_{R_2}}$$

applying KVL @ loop 1

$$-V_X + V_{GS} + R_S \cdot I_D \rightarrow V_{GS} = V_X - R_S I_D \quad \ldots \text{(1)}$$

if $V_{DS} > V_{GS} - V_{TH}$ then

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})^2, \quad \ldots \text{(2)} \quad \lambda = 0$$

To find $V_{GS}$, substitute $I_D$ in ② in ①

and solve for $V_{GS}$

$$V_{GS} = -(V_1 - V_{TH}) + \sqrt{V_1^2 + 2V_1\left(\frac{R_2 V_{DD}}{R_1+R_2} - V_{TH}\right)}$$

$$V_1 = \frac{1}{\mu_n C_{ox} \frac{W}{L} R_S}$$

after finding $V_{GS}$ find $I_D$ → then apply KVL

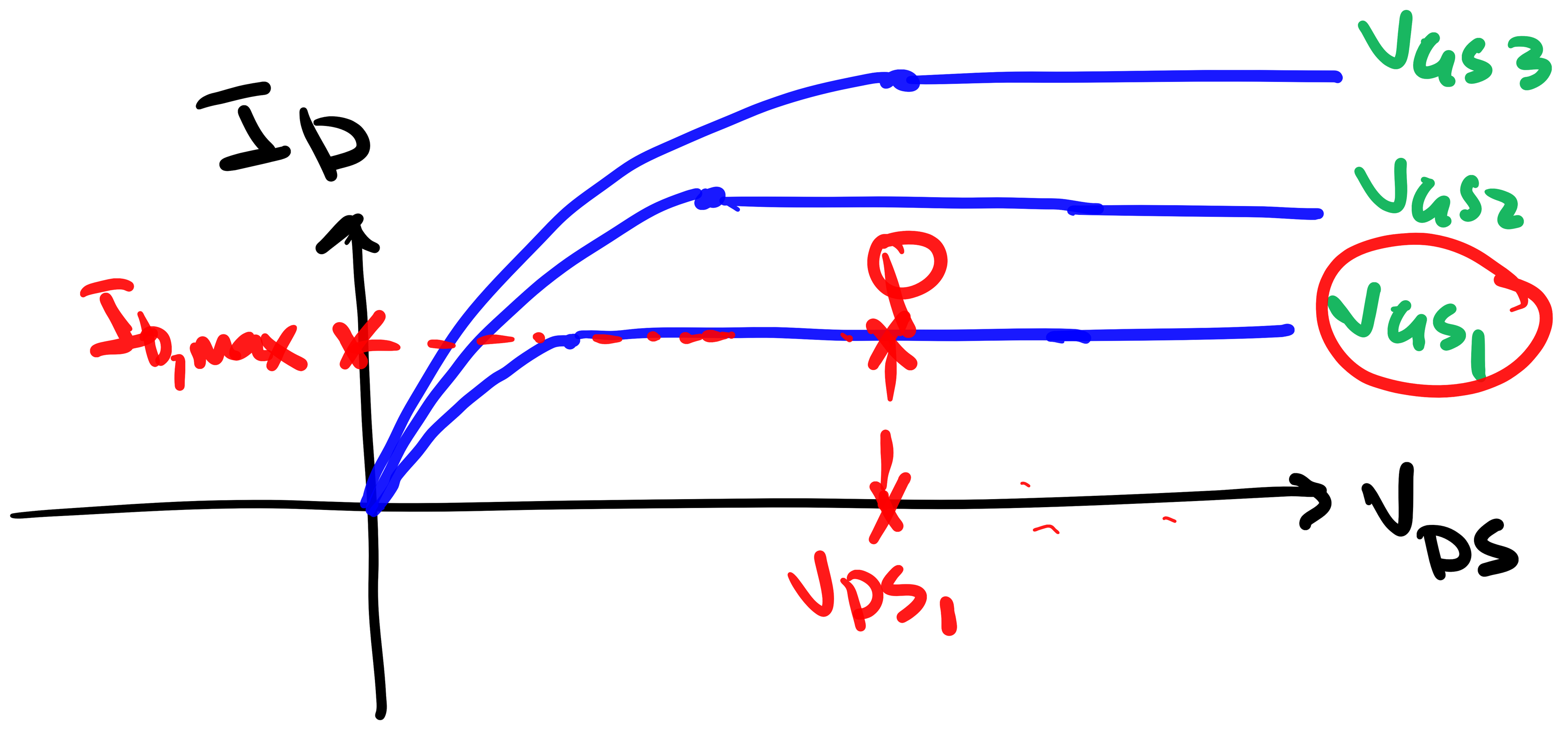
to loop 2 to find $V_{DS}$

$$V_{DS} = V_{DD} - I_D(R_S + R_D)$$

then check is $V_{DS} \overset{?}{>} V_{GS} - V_{TH}$

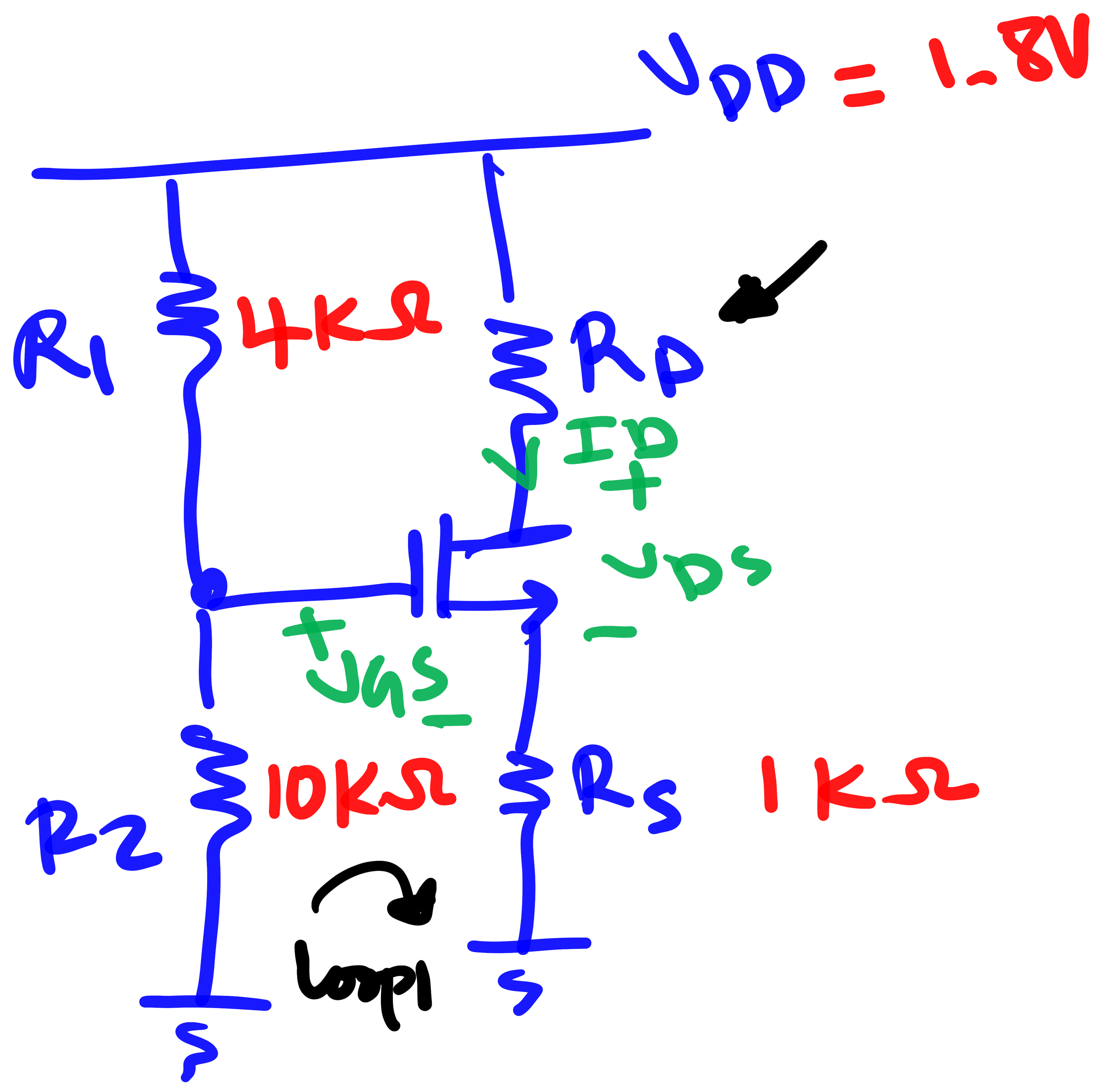
* Operating Point for a MOS :- Q-point.

$V_{GS} \longrightarrow I_D \longrightarrow V_{DS}$




$V_{GS1} < V_{GS2} < V_{GS3}$

Ex: Determine the bias current of $M_1$ in this cct. if $V_{TH} = 0.5V$, $\mu_n C_{ox} = 100\,\mu A/V^2$, $W/L = 5/0.18$ and $\lambda = 0$? What is the max. allowable $R_D$ for $M_1$ to remain in saturation?




$I_D = ?$

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS}-V_{TH})^2$$

→ $V_{GS}$ can be found using the equation in the previous section:

→ $V_{GS} = 0.974\,V$ → check is $V_{GS} > V_{TH}$ ✓

→ $I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_{ov}^2 = 312\,\mu A$

→ $I_D$ ⇒ applying KVL to loop 1

$$-V_X + V_{GS} + I_D R_S = 0 \Rightarrow I_D = \frac{V_X - V_{GS}}{R_S}$$

$$V_X = \frac{R_2}{R_1+R_2}\cdot V_{DD} = 1.286V$$

$$\Rightarrow I_D = 312\,\mu A.$$

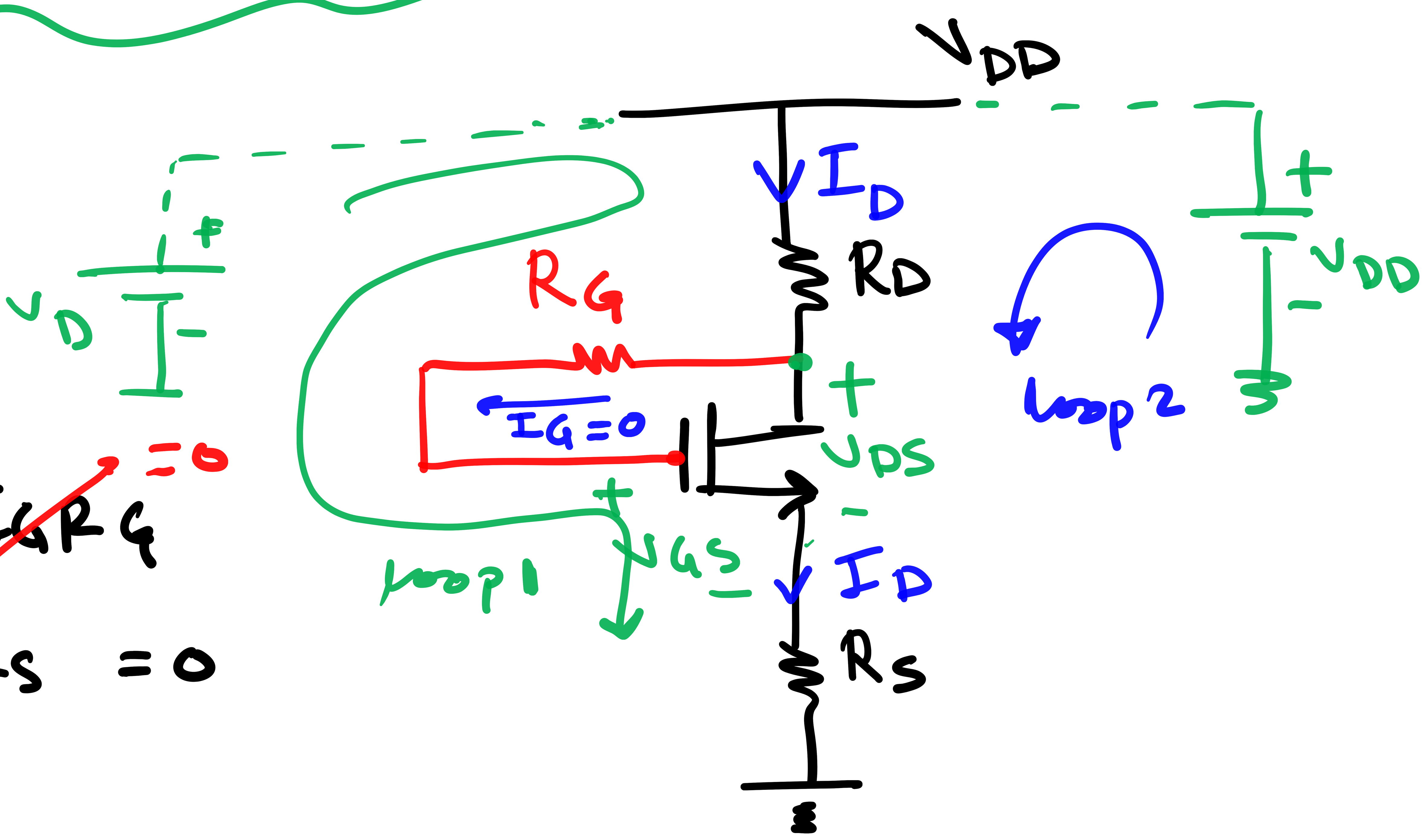
⇒ check if $M_1$ is in saturation?

$$V_{DS} \overset{?}{>} V_{OV} \Rightarrow V_{DS} = V_{DD} - I_D(R_D + R_S)$$

$$V_{DD} - I_D(R_D + R_S) > V_{GS} - V_{TH} \rightarrow \text{solve for}$$

$$R_D \Rightarrow \boxed{R_D < 3.24\ K\Omega}$$

## * Self_Biasing technique :-




Applying KVL @ loop 1 :

$$-V_{DD} + I_D R_D + \cancel{I_G}\overset{=0}{} R_G + V_{GS} + I_D R_S = 0$$

but $I_G = 0$

$$\Rightarrow V_{GS} = V_{DD} - (R_D + R_S) \cdot I_D$$

$\Rightarrow$ Applying KVL @ loop 2 :

$$-V_{DD} + I_D R_D + V_{DS} + I_D R_S = 0$$

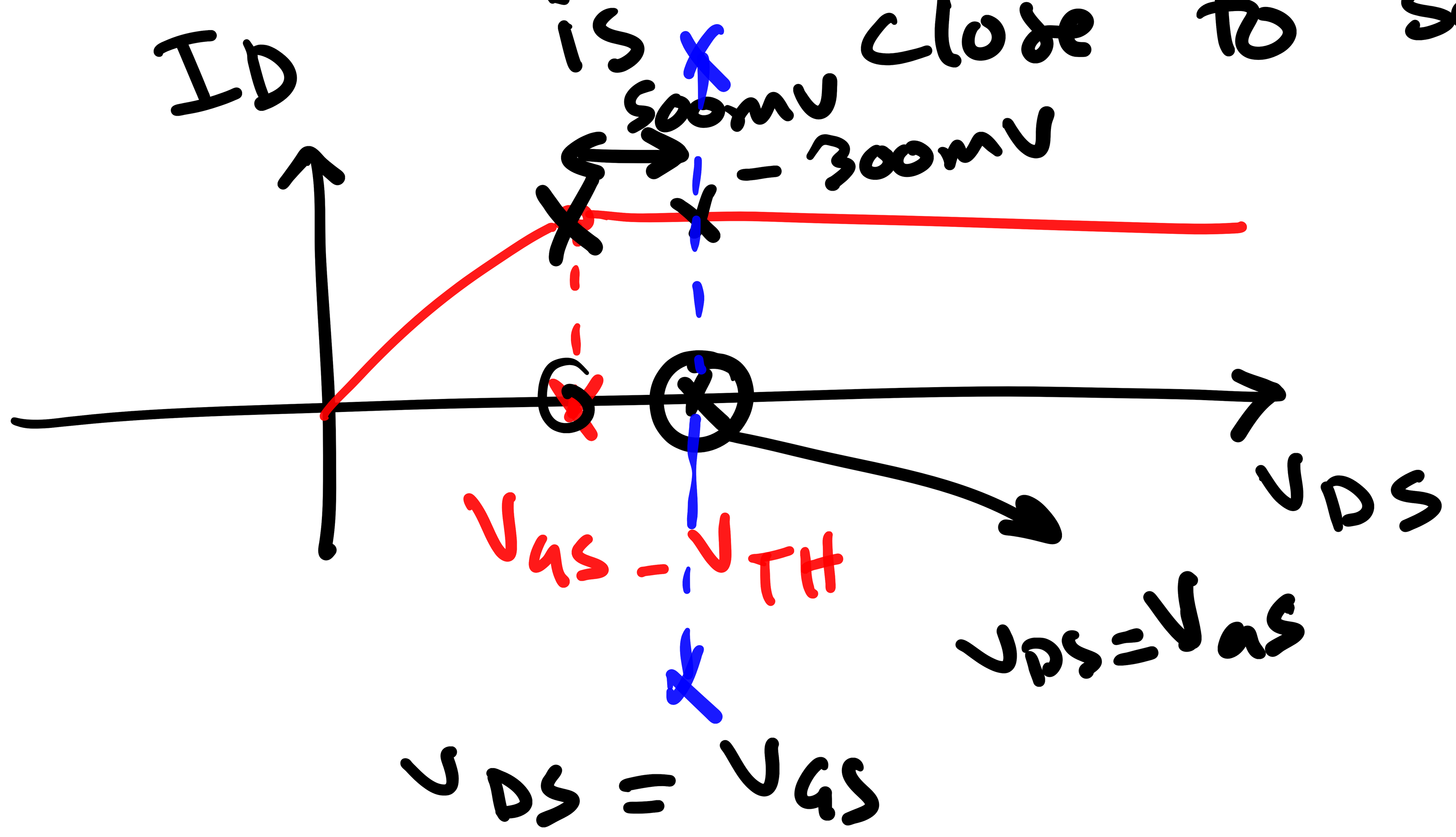
$$V_{DS} = V_{DD} - I_D(R_D + R_S)$$

with self biasing we conclude that

$$V_{DS} = V_{GS} \Longrightarrow$$

For saturation operation

$V_{DS} > V_{GS} - V_{TH}$, However with self biasing obviously the operation is close to saturation




* Deriving the current $I_D$:

→ Referring to the KVL @ loop 1

$$V_{GS} = V_{DD} - I_D(R_S + R_D) \quad , \quad \text{if } \lambda = 0$$

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_{TH})^2$$

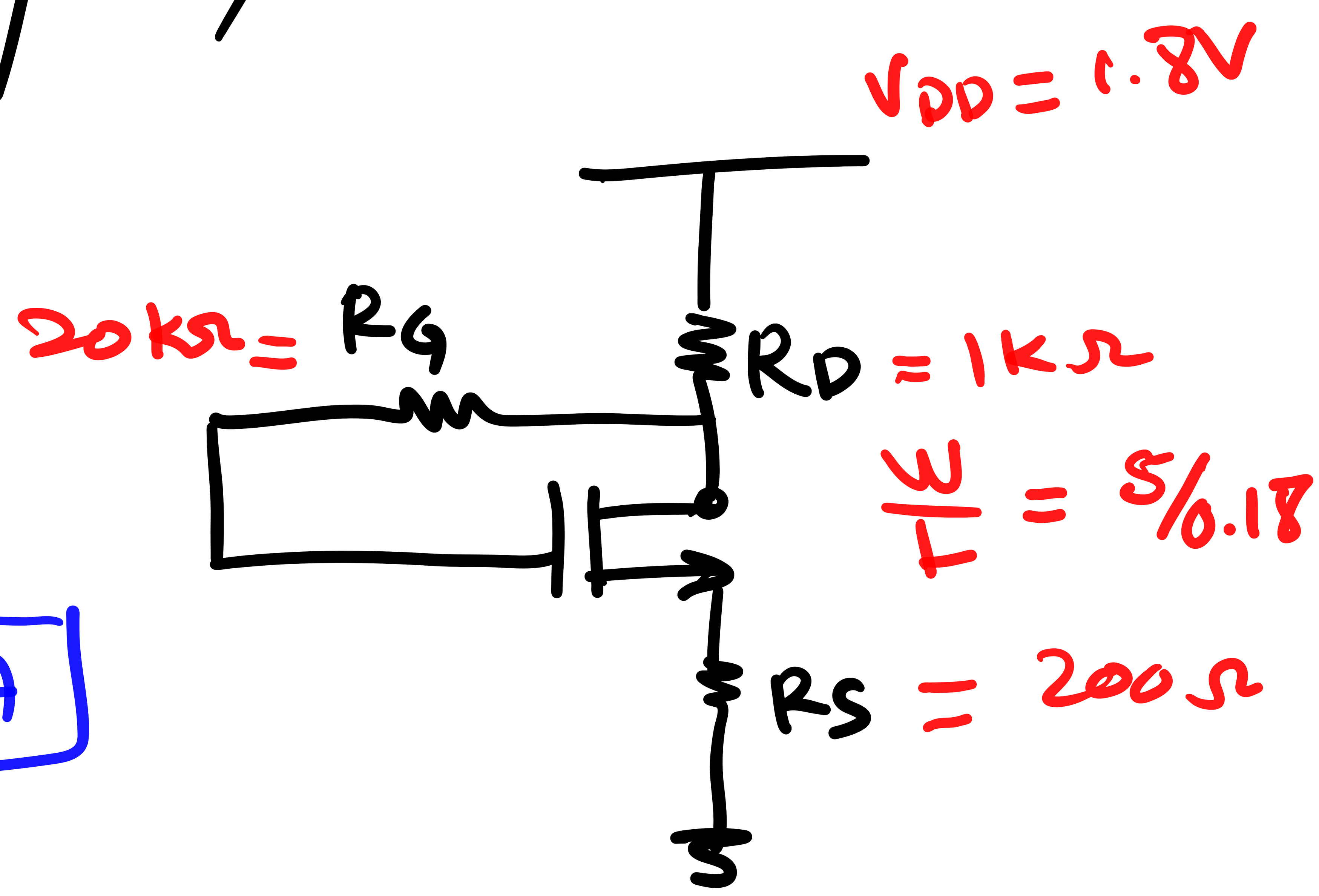
$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\left(V_{DD} - I_D(R_D + R_S) - V_{TH}\right)^2$$

$$\Rightarrow \boxed{(R_S + R_D)^2 \cdot I_D^2 - 2\left[(V_{DD} - V_{TH})(R_S + R_D) + \frac{1}{\mu_n C_{ox}\frac{W}{L}}\right] \cdot I_D + (V_{DD} - V_{TH})^2 = 0}$$

The above eq. will lead to two $I_D$ values a negative and a positive.

pick the positive value.

Ex: Calculate the drain current of $M_1$ in this cct. if $\mu_n C_{ox} = 100\,\mu A/V^2$, $V_{TH} = 0.4V$,




* Using the above eq for $I_D$

→ $\boxed{I_D = 556\,\mu A}$

* The other way to find $I_D$ is as follows:-

→ Lets find $I_D$ as $\frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_{ov}^2$

→ we need to find $V_{ov}$?

$$V_{GS} = V_{DD} - I_D(R_D + R_S) \Rightarrow V_{ov} = V_{GS} - V_{TH}$$

$$\Rightarrow V_{GS} = V_{ov} + V_{TH}$$

$$V_{ov} + V_{TH} = V_{DD} - I_D(R_D + R_S) \rightarrow$$

$$V_{ov} + V_{TH} = V_{DD} - \frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_{ov}^2 (R_D + R_S)$$

$$\frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_{ov}^2(R_D+R_S)+V_{OV}+(V_{TH}-V_{DD})=0$$

solve for $(V_{OV})$

$\rightarrow$ solving for $\boxed{V_{ov}=0.633V}$

$\Rightarrow$ $\boxed{V_{GS}=1.133\,V}$

$\rightarrow$ $I_D=\frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_{ov}^2=\boxed{556\,\mu A}$