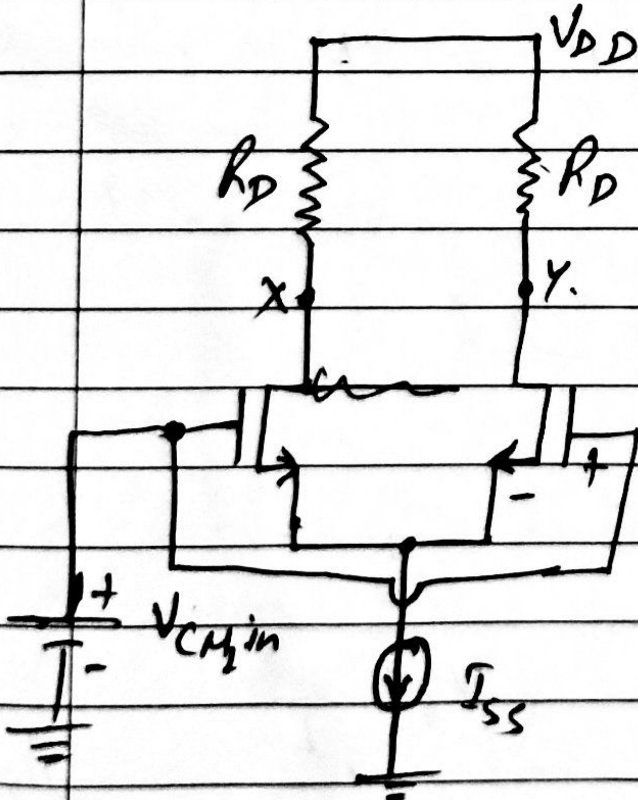
Additional Analysis of MOS Differential Pair :—

* Summary of the Results.



Now,

$V_X = V_{DD} - R_D I_{D1}$

$V_Y = V_{DD} - R_D I_{D2}$

$V_X - V_Y = -R_D [I_{D1} - I_{D2}]$

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

$V_{GS} = \sqrt{\frac{2 I_D}{\mu_n C_{ox} \frac{W}{L}}} + V_{th}$

$V_{GS1} = V_{GS2} = \sqrt{\frac{I_{SS}}{\mu_n C_{ox} \frac{W}{L}}} + V_{th}$

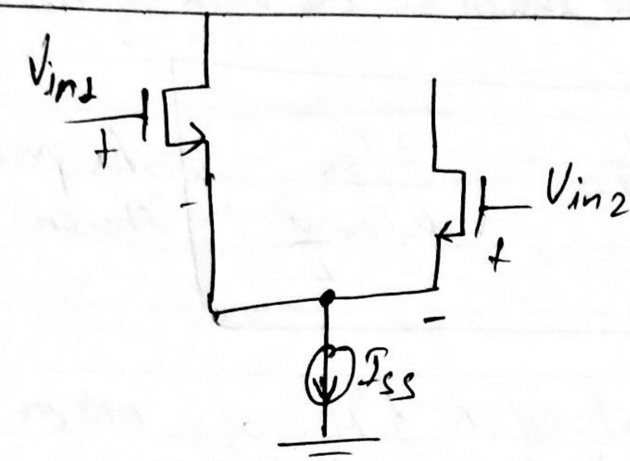
Now,

$V_{OV} = V_{GS1} - V_{th} = \sqrt{\frac{I_{SS}}{\mu_n C_{ox} \frac{W}{L}}}$

- Equilibrium Overdrive

Teacher's Signature: ____________

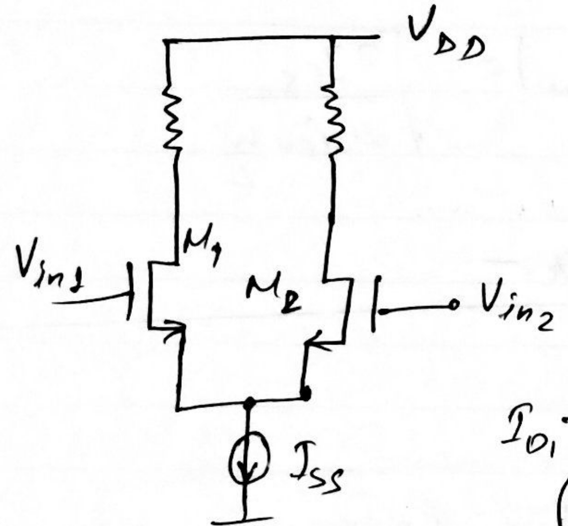
(2)



Min. $|V_{in1} - V_{in2}|$ necessary to turn off one side:

$$\sqrt{\frac{2 I_{SS}}{\mu_n C_{ox} \frac{W}{L}}}.$$

(3)



$$I_{D1} - I_{D2} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right)(V_{in1} - V_{in2}) \sqrt{\frac{4 I_{SS}}{\mu_n C_{ox} \frac{W}{L}} - (V_{in1} - V_{in2})^2}$$

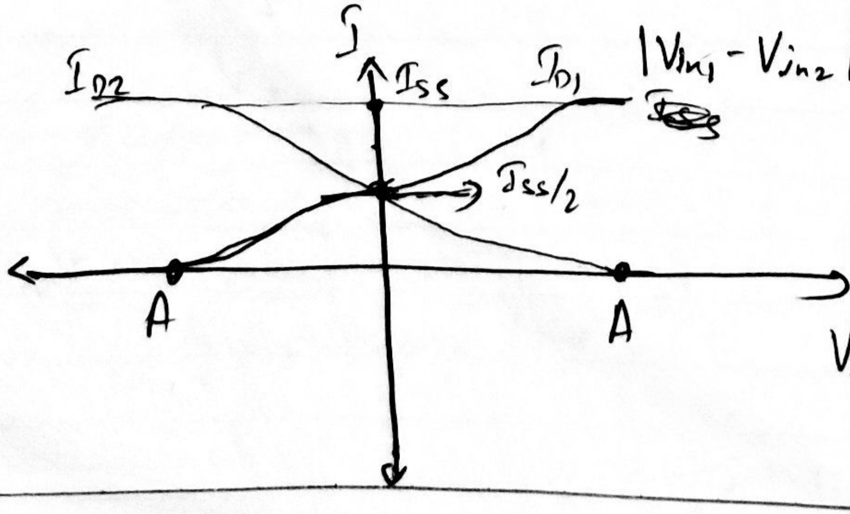
↳ Valid if M_1 & M_2 are ON or near turning OFF.

→ If $V_{GS} < V_{tn}$ of any transistor then it won't be valid.

If $V_{in1} - V_{in2} = 0 \rightarrow I_{D1} = I_{D2}$

→ Validity of the eqn only if:-

$$|V_{in1} - V_{in2}| \le \sqrt{\frac{2 I_{SS}}{\mu_n C_{ox} \frac{W}{L}}}.$$



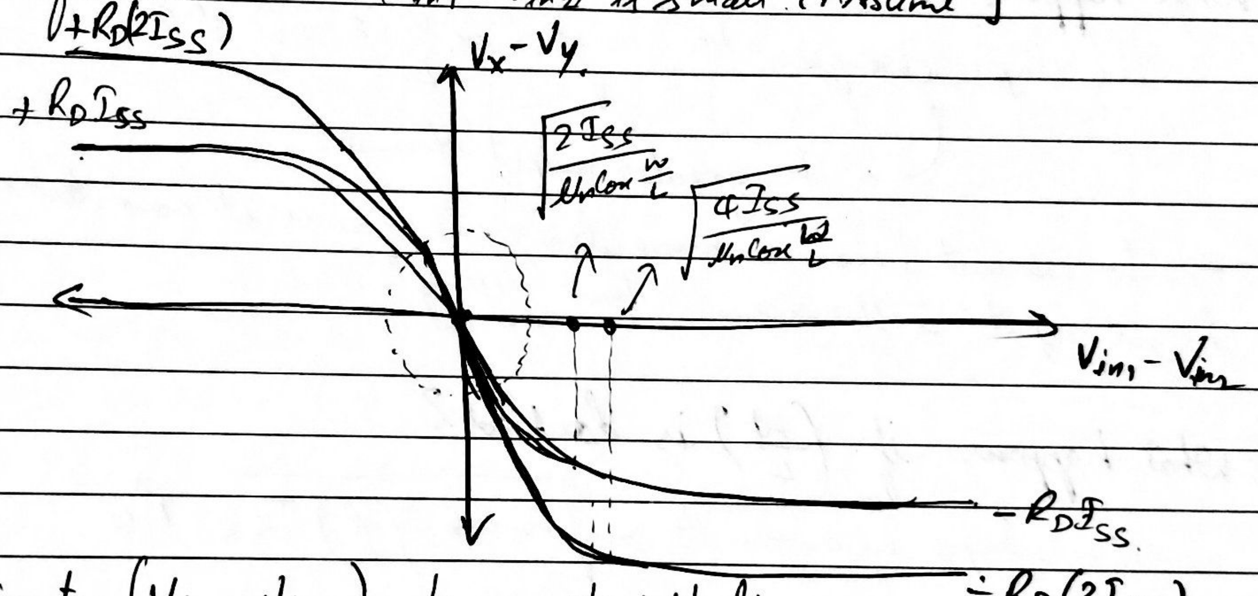
(A)

$V_{in1} - V_{in2}$ } If $V_{in1} - V_{in2} = \pm \sqrt{\frac{2 I_{SS}}{\mu_n C_{ox} \frac{W}{L}}}$

④ Minimum $|V_{in_1} - V_{in_2}|$ to turn off one side $= \sqrt{2} \times$ Equilibrium overdrive voltage.

⑤ $$V_x - V_y = -\frac{R_D}{2} \mu_n C_{ox}\left(\frac{W}{L}\right)(V_{in_1} - V_{in_2})\sqrt{\frac{4I_{SS}}{\mu_n C_{ox}\frac{W}{L}} - (V_{in_1} - V_{in_2})^2}$$

Lets focus on when $(V_{in_1} - V_{in_2})$ is small [Assume]



Approximate $(V_{in_1} - V_{in_2})$ by straight line :-

If $\boxed{(V_{in_1} - V_{in_2})^2 << \frac{4\, I_{SS}}{\mu_n C_{ox}\frac{W}{L}}}$

So,
$$V_x - V_y = -\frac{R_D}{2} \mu_n C_{ox}\left(\frac{W}{L}\right)(V_{in_1} - V_{in_2})\sqrt{\frac{4I_{SS}}{\mu_n C_{ox}\frac{W}{L}}}$$

~~very small~~

$$\simeq -\frac{R_D}{2} \mu_n C_{ox}\left(\frac{W}{L}\right)\sqrt{\frac{4I_{SS}}{\mu_n C_{ox}\frac{W}{L}}}\,[V_{in_1} - V_{in_2}]$$

$$\simeq -R_D\sqrt{\frac{I_{SS}\,\mu_n C_{ox}\frac{W}{L}}{\cancel{4}}} = -\sqrt{\mu_n C_{ox}\frac{W}{L} I_{SS}} \times R_D\,[V_{in_1} - V_{in_2}]$$

So,

$$\boxed{\text{slope} = -\sqrt{\mu_n C_{ox} \frac{W}{L} I_{SS}}\, R_D.}$$

↳ Will give gain of the circuit.

__Examples__

① What happens when ~~tail cur~~ tail current (I_{SS}) is doubled?

→ The slope changes to $-\sqrt{\mu_n C_{ox} \frac{W}{L} (2 I_{SS})}\, R_D$

↳ The greater output change.

→ The circuit becomes more linear because it can take are larger input difference without 'dying.'

__Quiz__

② What happens if $\left(\frac{W}{L}\right)$ is doubled?

→ The slope changes to $-\sqrt{\mu_n C_{ox}\, 2\left(\frac{W}{L}\right) I_{SS}}\, R_D$

→ But $R_D I_{SS}$ will remain same.

→ The circuit becomes less linear because it can take only a smaller input difference before it ~~dy~~ 'dies'