

IE Assignment (Bonus)

$$V_{Th} = 1V$$

$$k_n = 20 \times 10^{-3} A/V^2$$

$$V_{DD} = 15V$$

$$V_{SS} = -15V$$

We can clearly observe that the given circuit is a current mirror circuit and hence if M₃ and M₄ are in saturation,

$$I_{ref} = I_{D4} = 5mA$$

$$R = \frac{V_{DD} - V_{D3}}{I_{ref}}$$

$$\begin{aligned} V_{D3} &= V_{DS3} + V_{S3} \\ &= V_{DS3} + V_{P1} \end{aligned}$$

$$\begin{aligned} \text{KVL: } -V_{DD} + I_{ref}R + V_{DS3} \\ + V_{DS1} &= -V_{SS} \end{aligned}$$

$$\rightarrow I_{ref}R + V_{DS3} + V_{DS1} = 30$$

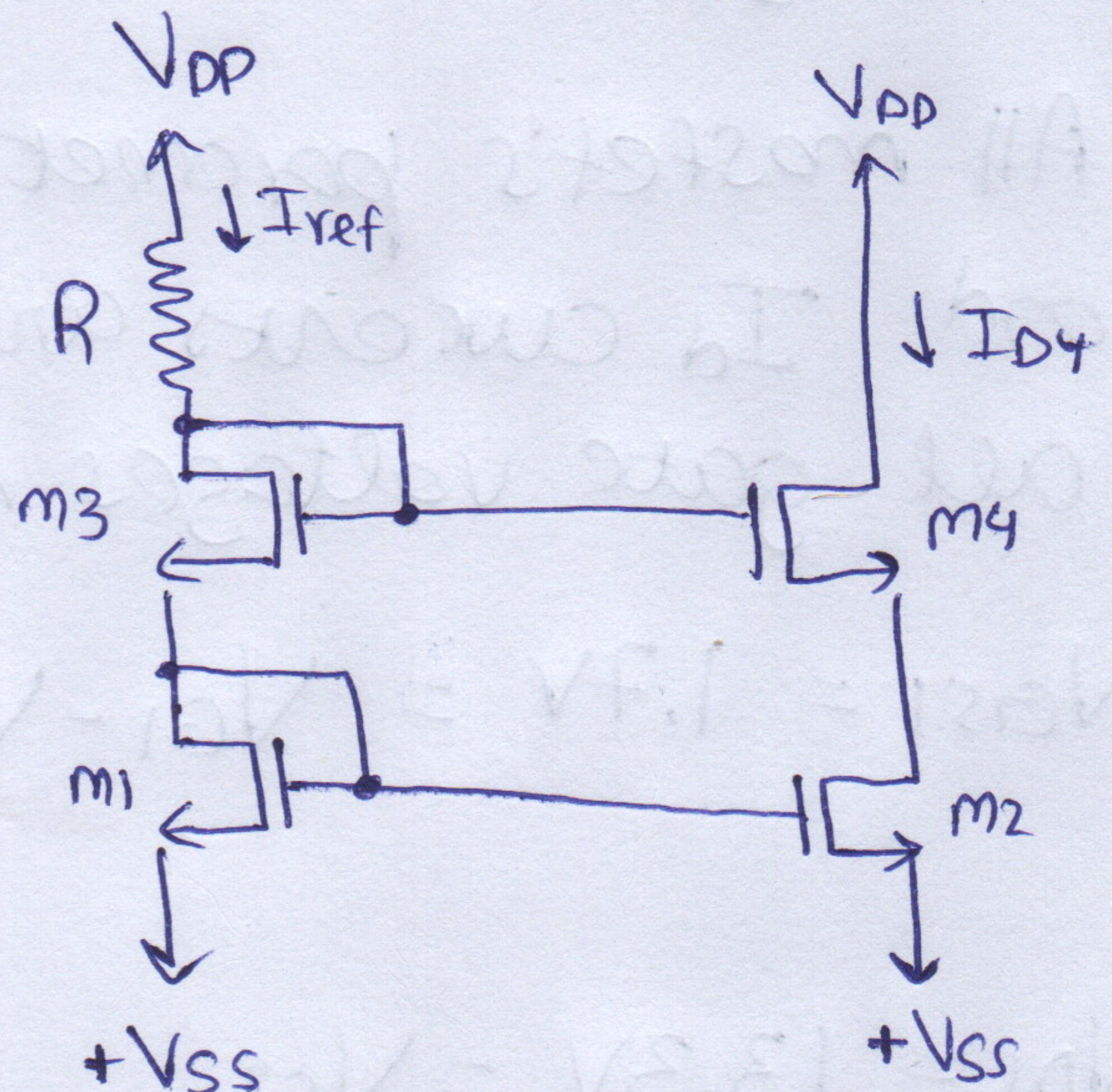
$$I_{ref} = I_{D4} = \frac{1}{2} \mu_n C_o x W \left(V_{GS4} - 1 \right)^2$$

$$\text{We know } V_{GS4} = V_{DS3}$$

$$V_{S1} = -15V$$

$$V_{S3} = V_{D1} = V_{DS1} + V_{S1}$$

$$\begin{aligned} V_{D3} &= V_{DS3} + V_{S3} = V_{DS3} + V_{D1} \\ &= V_{GS4} + V_{DS1} + V_{S1} \\ &= 1.7 + V_{GS2} + (-15) \\ &= 1.7V \end{aligned}$$



$$\text{KVL: } -V_{DD} + V_{DS4} + V_{DS2} + V_{SS} = 0$$

$$V_{DS4} + V_{DS2} = 30$$

We know $I_{D4} = I_{S4}$ because gate current = 0 and $I_{S4} = I_{D2}$
So, $V_{DS4} = V_{DS2}$

$$V_{DS4} = 15V \Rightarrow V_{DS2} = 15V$$

$$\Rightarrow 5mA = \frac{1}{2} \times 20 \times 10^{-3} (V_{GS4} - 1)^2$$

$$\Rightarrow \frac{1}{2} = (V_{GS4} - 1)^2$$

$$\Rightarrow 2(V_{GS4}^2 + 1 - 2V_{GS4}) = 1$$

$$\Rightarrow 2V_{GS4}^2 - 4V_{GS4} + 1 = 0$$

$$\Rightarrow V_{GS4} = \frac{1.7V \text{ or } 0.29V}{\text{because } V_{GS} > V_T}$$

$$V_{D3} = 1.7V$$

So $R = \frac{15 - 1.7}{5m} = 2.66k\Omega \times \left\{ \begin{array}{l} \text{wrong} \\ \text{calculation:} \\ \text{I forgot one} \\ (1.7V) \text{ in the} \\ \text{equation on the} \\ \text{previous page} \end{array} \right\}$

Re-Analysis:

All mosfet's parameters are same
and I_d currents are same and hence
all gate voltages must be same

$$\begin{aligned} V_{GS1} &= 1.7V = V_{G1} - V_{S1} = V_{G1} - (-IS) \\ &= V_{D1} + IS \end{aligned}$$

$$V_{D1} = 13.3V = V_{S3}$$

$$V_{GS3} = V_{DS3} = 1.7V = V_{D3} - V_{S3}$$

$$V_{D3} = 1.7 + 13.3 = 15V$$

$$-V_{DD} + I_{Ref} \cdot R + V_{DS3} + V_{PS1} + V_{SS} = 0$$

$$I_{ref} \cdot R + V_{DS3} + V_{PS1} = 30$$

$$R = \left(\frac{30 - 3.4}{5} \right) k = \left(\frac{26.6}{5} \right) k = \boxed{5.32k\Omega}$$