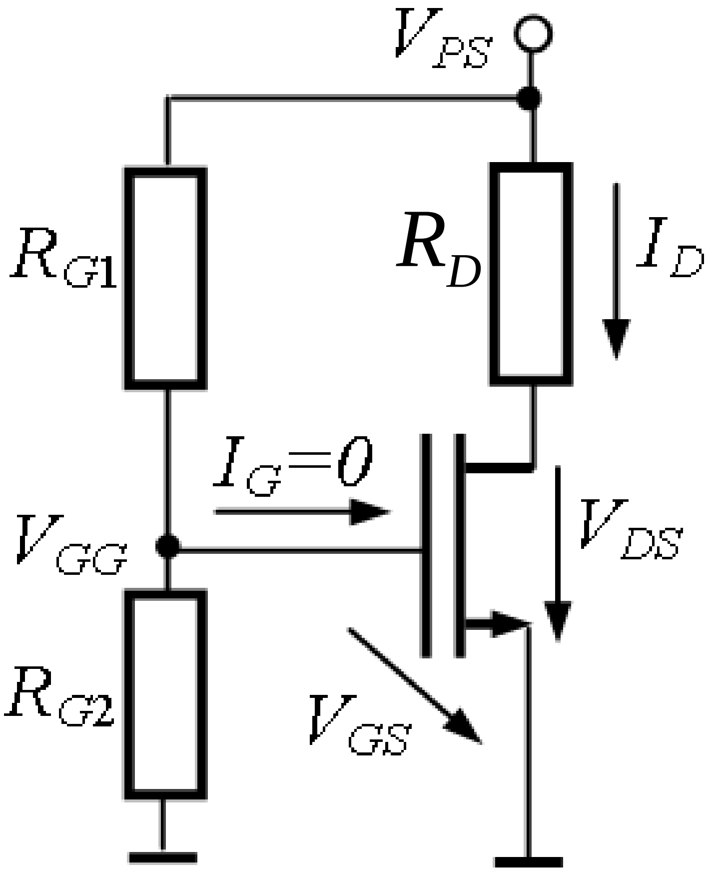
MOSFET BIASING

in active region a_F

MOSFET biasing

$Q(V_{DS}, I_D)$?

1st version – 3 resistors, single supply



$$V_{GS} = \frac{R_{G2}}{R_{G1} + R_{G2}} V_{PS}$$

$$I_D = \beta (V_{GS} - V_{Th})^2$$

$$V_{DS} = V_{PS} - R_D I_D$$

☺ very simple

☹ the current in the OP, I_D, depends on the transistor parameters, β and V_{Th}

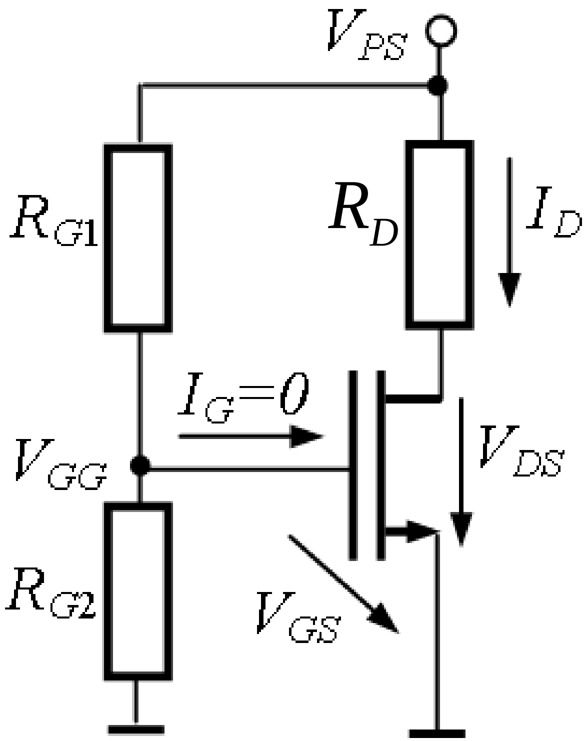
☹ cannot assure the stability of the quiescent point.

Problem 1

R_{G1}=7.6MΩ; R_{G2}=2.4MΩ; R_D=29.1KΩ; V_{PS}=5V

V_{Th} =0.8V; β =500μA/V².

OP **?**



$$V_{GS} = \frac{R_{G2}}{R_{G1}+R_{G2}} V_{PS} = \frac{2.4}{7.6+2.4} \cdot 5 = 1.2\text{V}$$

$$I_D = \beta (V_{GS} - V_{Th})^2 = 500 \cdot (1.2 - 0.8)^2 = 80\mu\text{A}$$

$$V_{DS} = V_{PS} - R_D I_D = 5 - 29.1 \cdot 0.08 = 2.67\text{V}$$

$$V_{DSsat} = V_{GS} - V_{Th} = 1.2 - 0.8 = 0.4\text{V}$$

$$V_{DS} > V_{DSsat} \text{ – the transistor is in } a_F$$

$$(V_{PS} + V_{DSsat})/2 = (5 + 0.4)/2 = 2.7\text{V} \approx V_{DS} = 2.67\text{V}$$

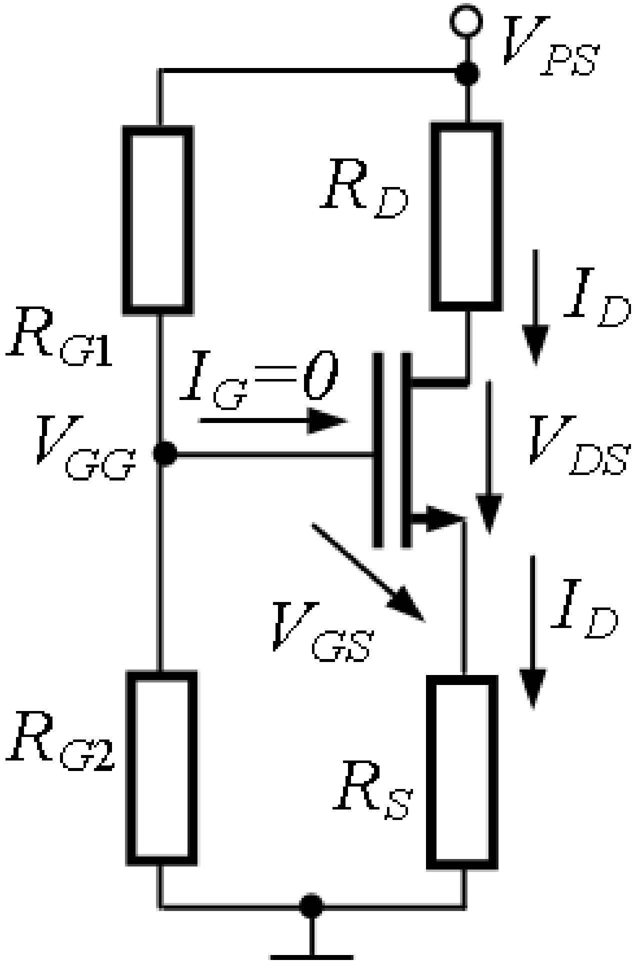
The transistor is biased in the middle of its active region

Q(2.67V, 80μA)

Resize the circuit to bias the transistor in the middle of its active region for I_{D1}=120μA

MOSFET biasing

2nd version – 4 resistors, single supply



$$V_{GG} = \frac{R_{G2}}{R_{G1}+R_{G2}} V_{PS}$$

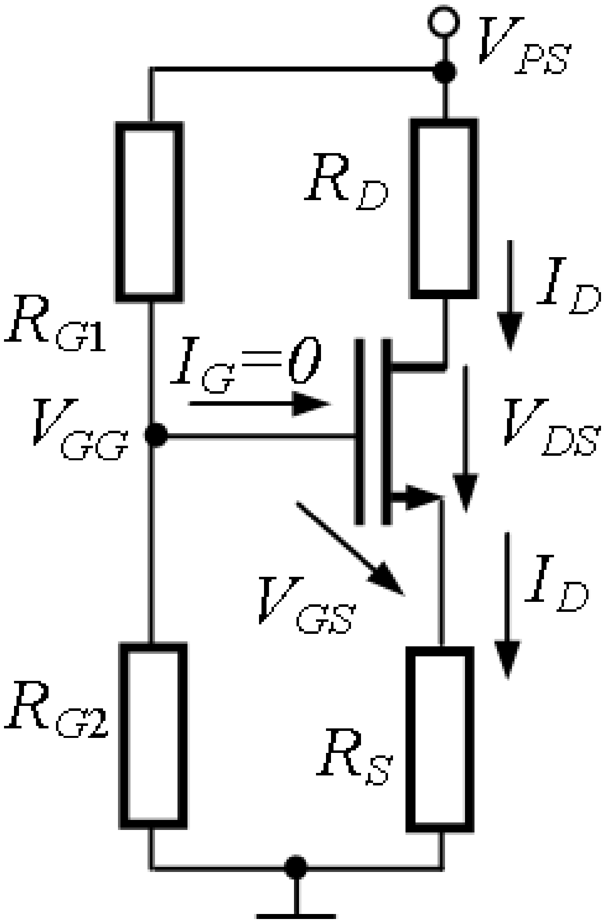
$$\begin{cases} V_{GS} = V_{GG} - R_S I_D \\ I_D = \beta (V_{GS} - V_{Th})^2 \end{cases}$$

- unknown: V_{GS} and I_D
- 2nd degree equations system.
- select the suitable I_D value

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

MOSFET biasing

2nd variant – 4 resistors, single supply - cont.



$$\begin{cases} V_{GS} = V_{GG} - R_S I_D \\ I_D = \beta (V_{GS} - V_{Th})^2 \end{cases}$$

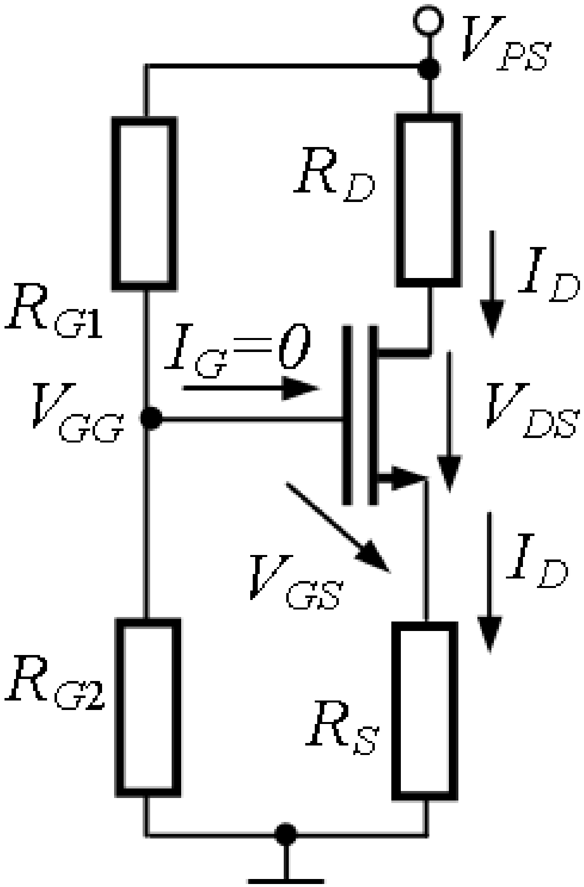
- V_{GS} depends also on the drain current I_D
- $\boldsymbol{I_D}\uparrow$, $R_S I_D\uparrow$, $V_{GS}\downarrow$, $\boldsymbol{I_D}\downarrow$ the circuit opposes to the variation tendency of I_D

• ***negative feedback*** **due to $\boldsymbol{R_S}$**

☺ *ensure the OP stability* for variation of certain parameters

☹ increases the complexity of computational relations

Problem 2



R_{G1}=3MΩ; R_{G2}=1MΩ;
R_D=3KΩ; R_S=1KΩ; V_{PS}=20V
V_{Th} =2V; β =0.5mA/V².

? *What is the OP* ?

$$V_{GG} = \frac{R_{G2}}{R_{G1}+R_{G2}} V_{PS} = \frac{1}{3+1} \cdot 20 = 5V$$

$$I_D = \beta (V_{GS} - V_{Th})^2 \qquad V_{GS} = V_{GG} - I_D R_S$$

I_D^2-8I_D+9=0; I_D in mA

→ I_{D1}=6.65mA and
→ I_{D2}=1.35mA

I_{D1} is not suitable; results V_{GS}<0

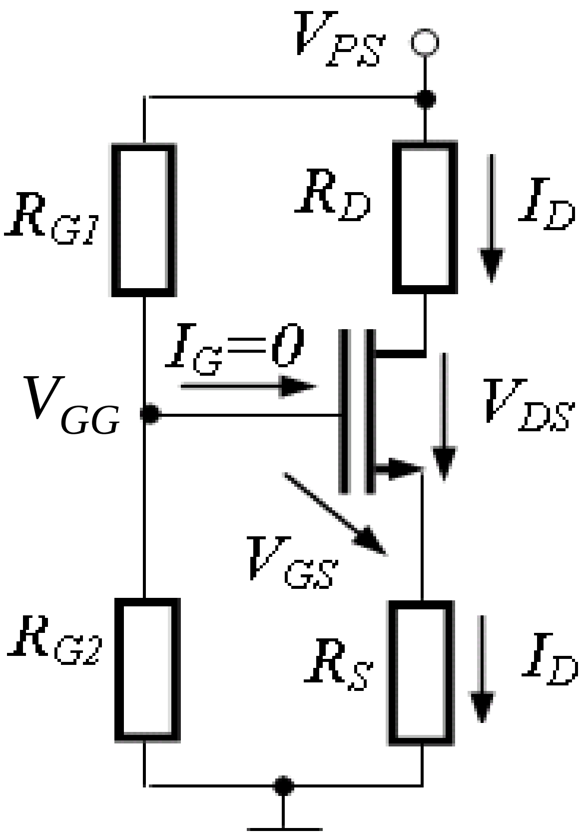
I_D=I_{D2}=1.35mA

$$V_{DS} = V_{PS} - I_D(R_D + R_S) = = 20 - 1.35(3+1) = 14.6V$$

Q(14.6V; 1.35mA)

V_D =? V_S =?

Problem 3



MOSFET: V_{Th} =2V; β =0.25mA/V^2; V_{PS}=20V

***?* Choose the resistances to obtain I_D=1mA in the OP**

$$I_D = \beta(V_{GS} - V_{Th})^2$$

$$V_{GS} = V_{Th} + \sqrt{\frac{I_D}{\beta}} = 2 + \sqrt{\frac{1}{0,25}} = 4\,\text{V}$$

$$V_{DSsat} = V_{GS} - V_{Th} = 2\text{V}$$

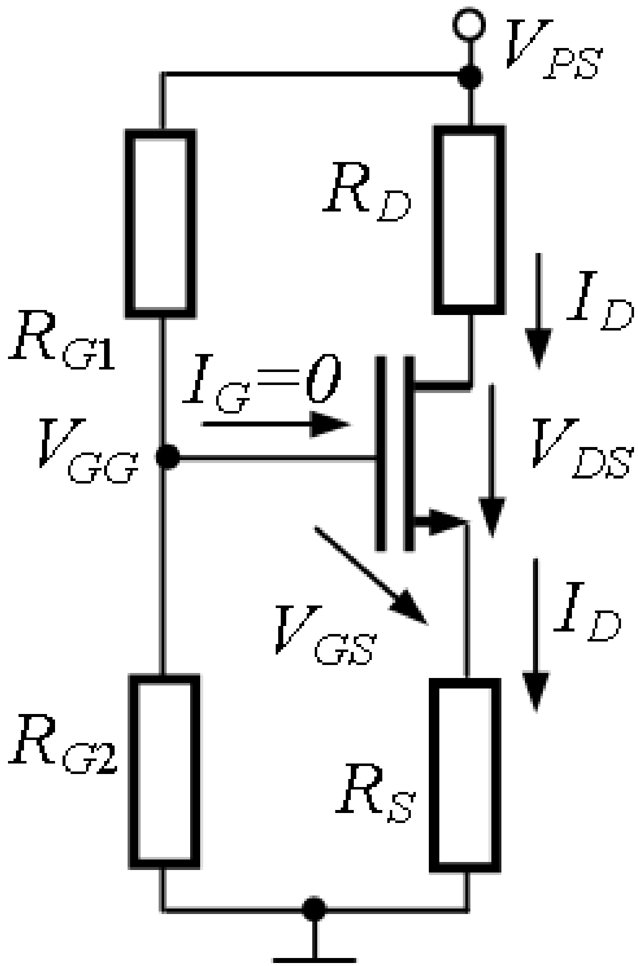
T- active region $V_{DS} \in (2\text{V}; 20\text{V})$.

Q : Let's choose $V_{DS} = 7\text{V}$

($V_{DS} \sim 1/3\ V_{PS}$ for 3 elements in output loop: R_D, V_{DS}, and R_S)

$$V_{DS} = V_{PS} - (R_D + R_S) I_D \qquad R_D + R_S = \frac{V_{PS} - V_{DS}}{I_D} = \frac{20-7}{1} = 13\ \text{k}\Omega$$

Problem 3 – cont.



MOSFET: V_{Th} =2 V; β =0.25 mA/V^2

? Choose the resistances to obtain I_D=1 mA in the OP

R_D, R_S also sets the gain. For now we can consider $V_S = 7\text{V}$ across R_S :

$$R_S = \frac{V_S}{I_D} = \frac{7}{1} = 7\,\text{k}\Omega$$

$$R_D = 13 - 7 = 6\,\text{k}\Omega$$

$$V_{GG} = V_{GS} + V_S = 4 + 7 = 11\text{V}$$

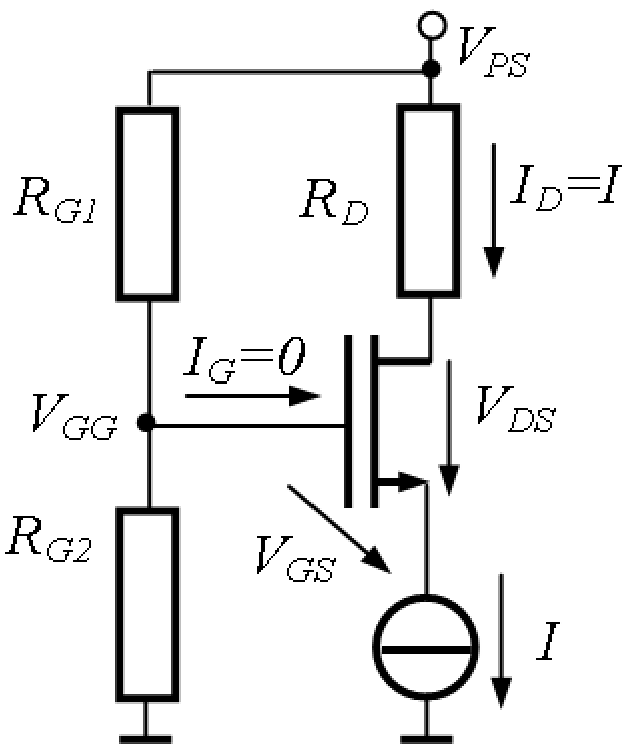
$$R_{G1} = 180\ \text{k}\Omega; \quad R_{G2} = 220\ \text{k}\Omega$$

MOSFET biasing

3rd version – current source, single /differential supply

- Usual in integrated circuits: biasing with *current sources*
- ***I_D independent of the transistor parameters***

single supply



$$I_D = I$$

$$V_{PS} = R_D I + V_{DS} - V_{GS} + V_{GG}$$

$$V_{DS} = V_{PS} - R_D I + V_{GS} - V_{GG}$$

Voltage across the current source:

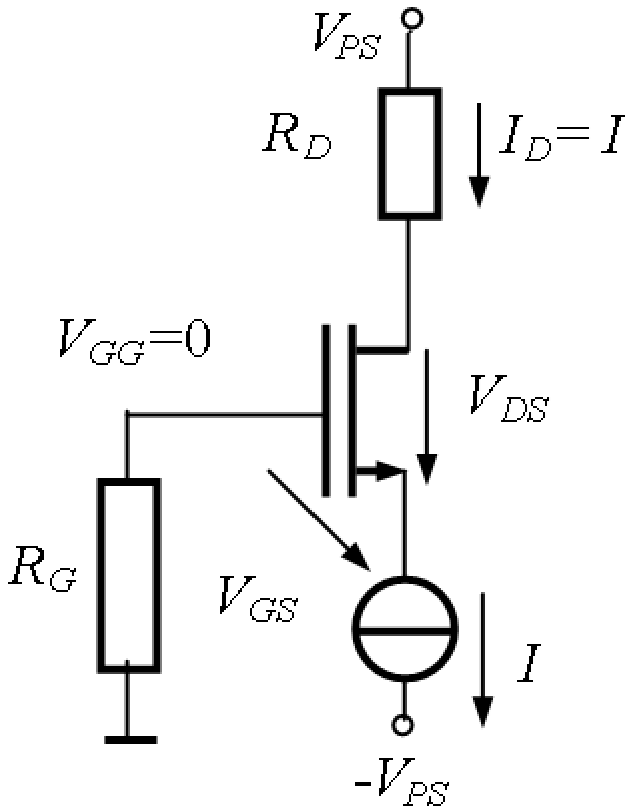
$V_{GG} - V_{GS}$

MOSFET biasing

3rd version – current source, single /differential supply

- Usual in integrated circuits: biasing with *current sources*
- ***I_D independent of the transistor parameters***

differential supply



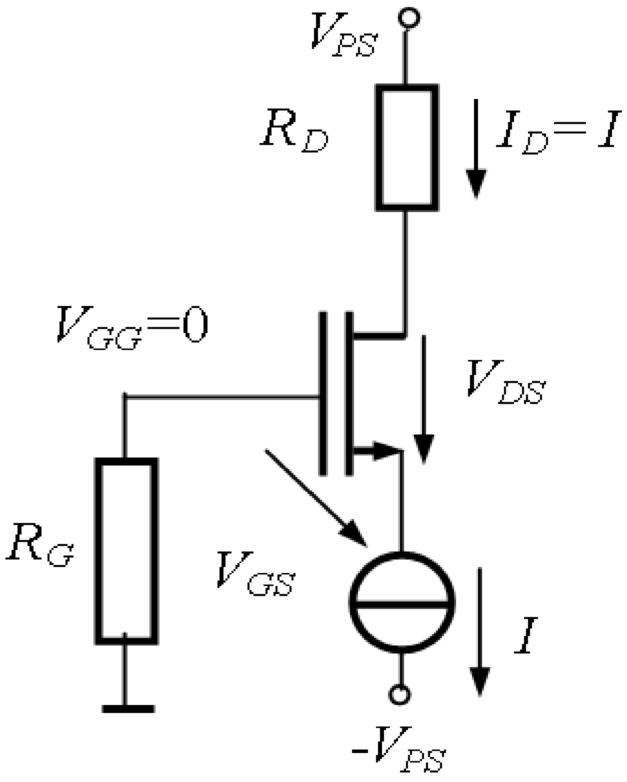
$$I_D = I$$

$$V_{PS} = R_D I + V_{DS} - V_{GS} + V_{GG}$$

$$V_{GG} = 0$$

$$V_{DS} = V_{PS} - R_D I + V_{GS}$$

Problem 4



$$\pm V_{PS} = \pm 12\text{V}$$

$$R_G = 500\ \text{k}\Omega,\ R_D = 4.7\,\text{k}\Omega,\ I = 1.6\,\text{mA}$$

$$k = 0.1\text{mA}/\text{V}^2, W/L = 2, V_{Th} = 0.5\,\text{V}$$

What is the OP?

What are the dc potentials in the terminals of the transistor?

What is the voltage drop across the dc biasing current source?