Digital Electronics.

CHAPTER SIXTEEN

Metal Oxide Semiconductor Field Effect Transistors [MOSFET]

Introduction

MOSFET transistors have smaller size than BJT transistors 

MOSFET transistors have lower power consumption than that of BJT transistors 

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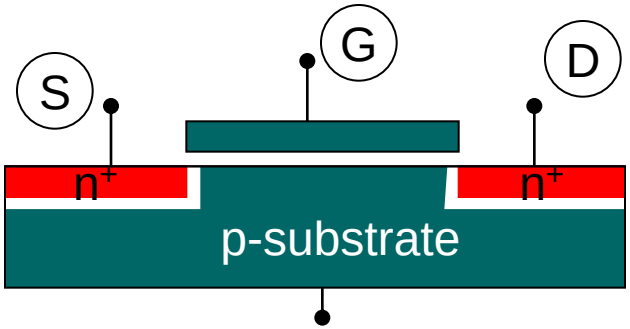
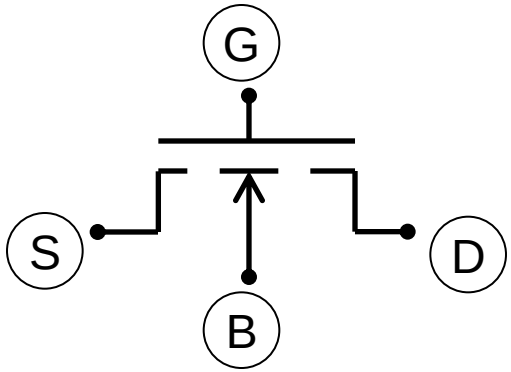
Types of MOSFETs

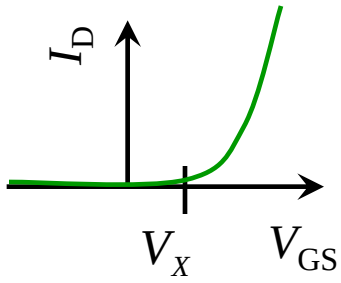
Enhancement (normally *OFF*)

NMOS

√ *faster (mobility of electrons is higher than of holes)*

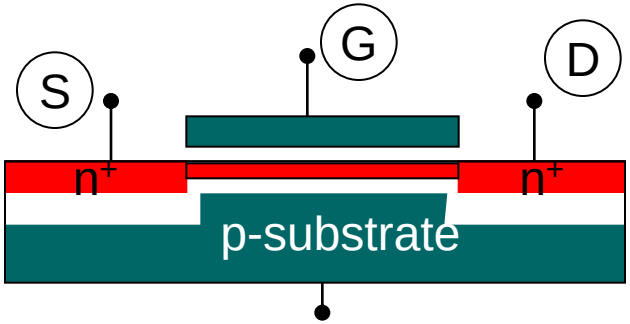


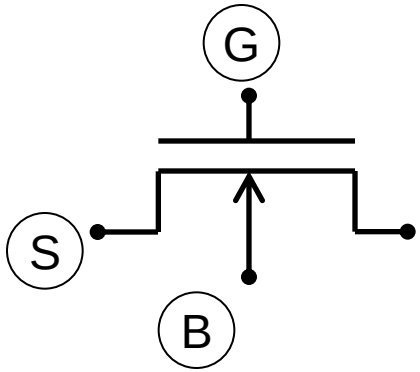


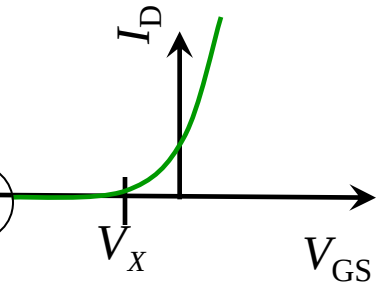


Depletion (normally *ON*)

NMOS



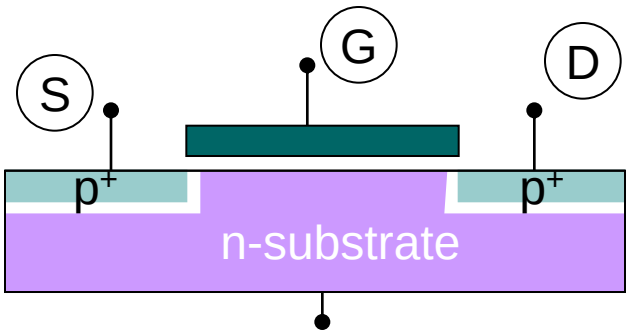


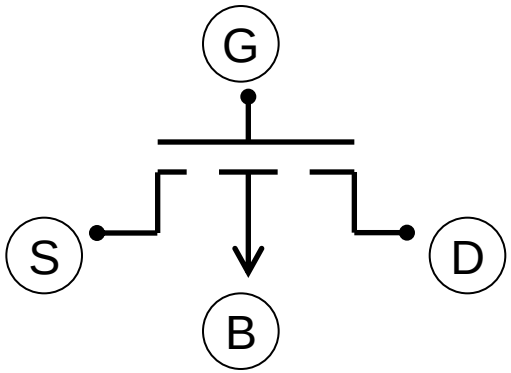


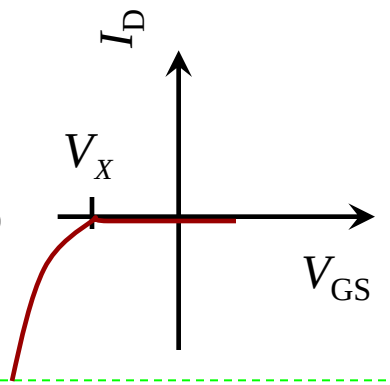
Types of MOSFETs

Enhancement (normally *OFF*)

PMOS







Depletion (normally *ON*)

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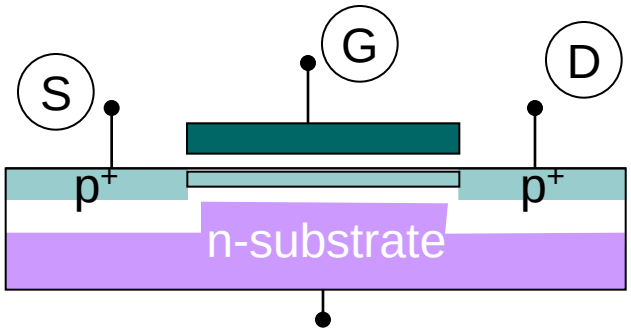

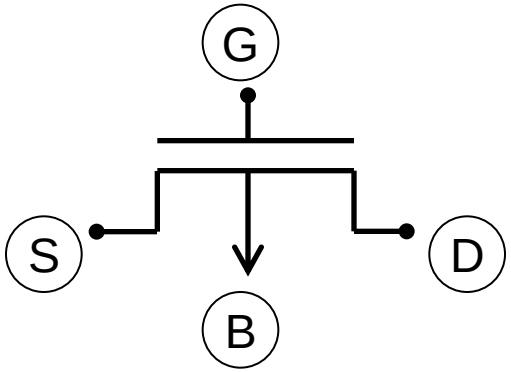

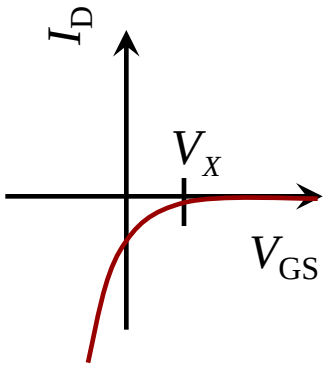

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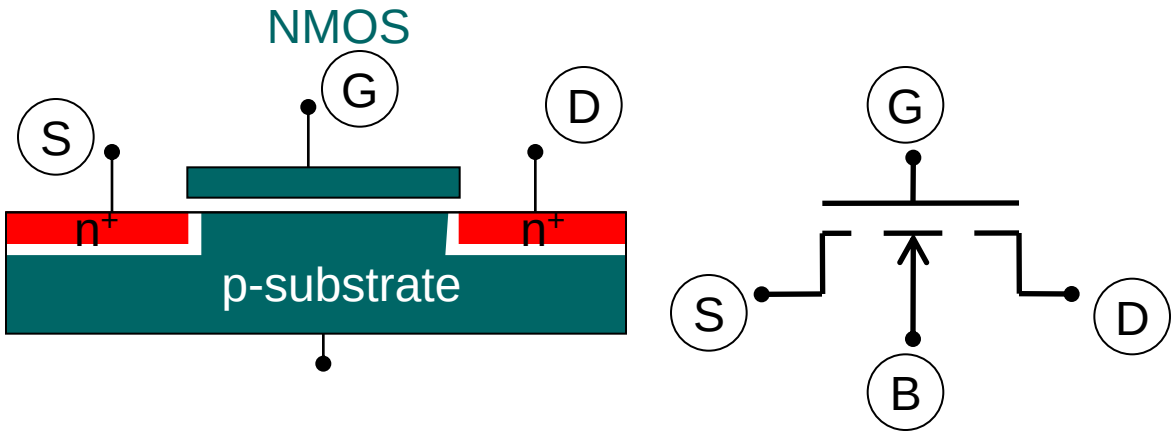
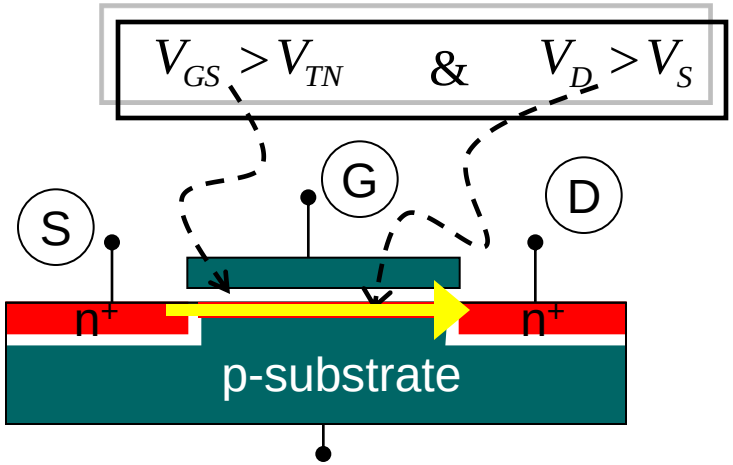
N- MOSFET

Enhancement (normally *OFF*)



The Drain-to-Source current (electrons are emitted from the source to the drain)
$I_{DS} > 0$



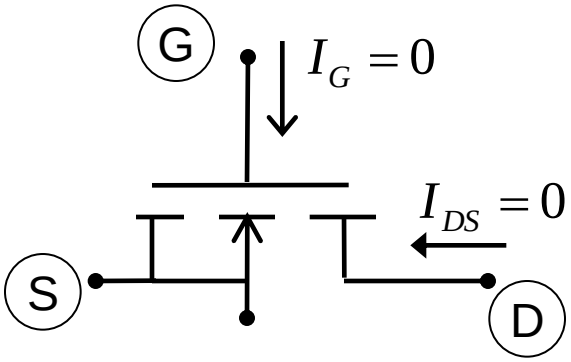
V_{TN} is the threshold voltage and defined as the minimum V_{GS} needed to create a channel between the source and the drain

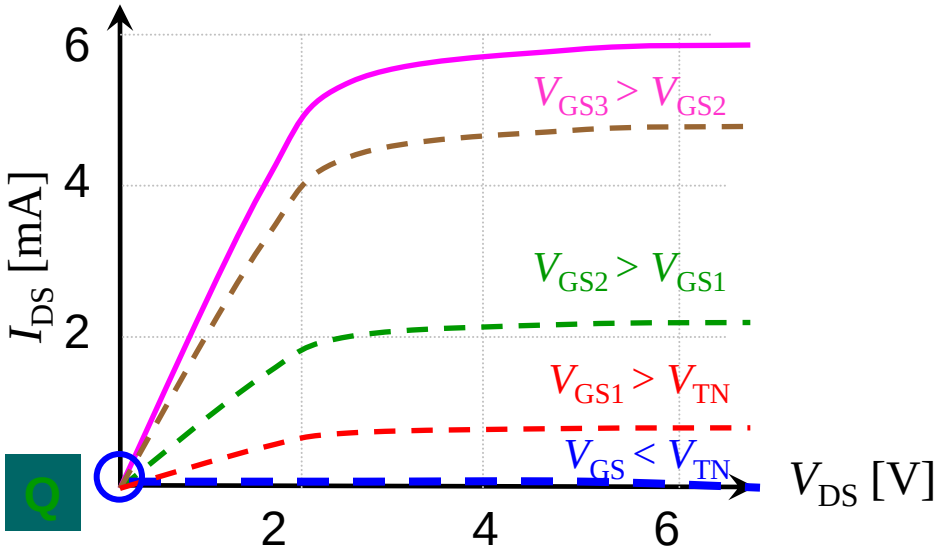
N- MOSFET (Modes of Operation)

There are three modes of operation of N-channel MOSFET (assuming the substrate and the source are connected)

1 Cut-Off Mode

$(V_{GS} < V_{TN})$





$I_{DS} = 0$

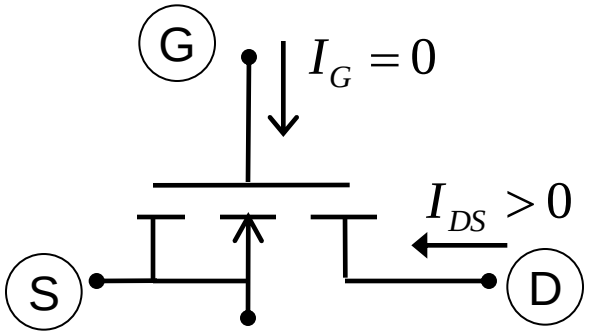
N- MOSFET (Modes of Operation)

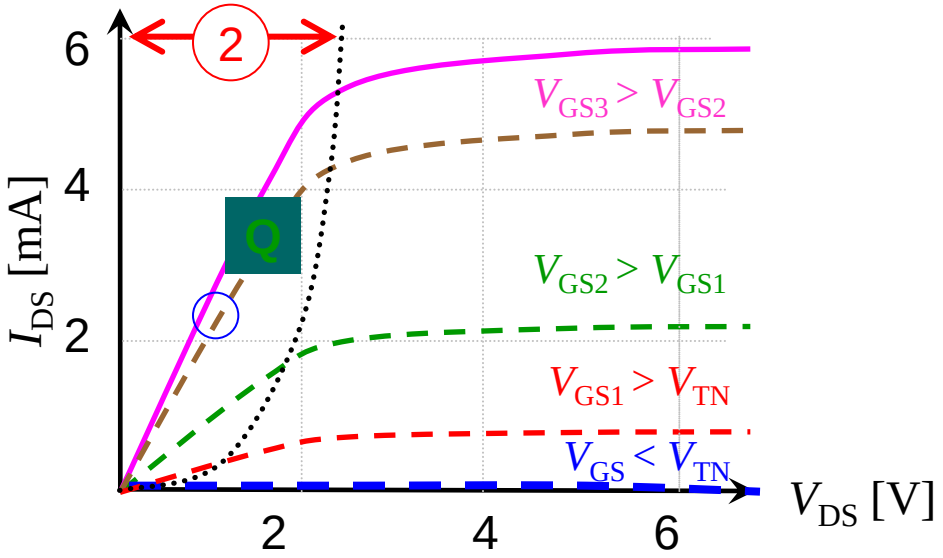
There are three modes of operation of N-channel MOSFET (assuming the substrate and the source are connected)

2 Linear Mode

$$(V_{GS} \geq V_{TN})$$

$$V_{DS} \leq V_{GS} - V_{TN}$$





$$I_{DS} = \frac{K_n}{2}\left[2 \times (V_{GS} - V_{TN})V_{DS} - V_{DS}^2\right]$$

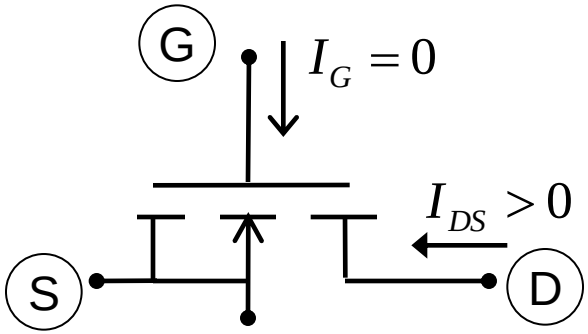
N- MOSFET (Modes of Operation)

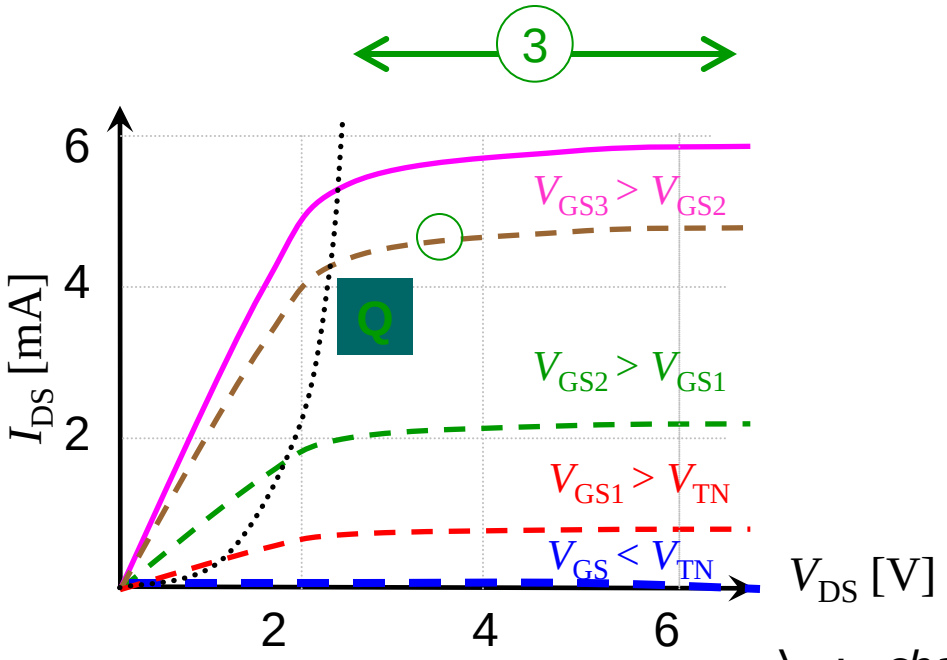
There are three modes of operation of N-channel MOSFET (assuming the substrate and the source are connected)

3 Saturation Mode

$$(V_{GS} \geq V_{TN})$$

$$V_{DS} \geq V_{GS} - V_{TN}$$





$$I_{DS} = \frac{K_n}{2}(V_{GS} - V_{TN})^2$$

$$I_{DS} = \frac{K_n}{2}(V_{GS} - V_{TN})^2(1 + \lambda V_{DS})$$

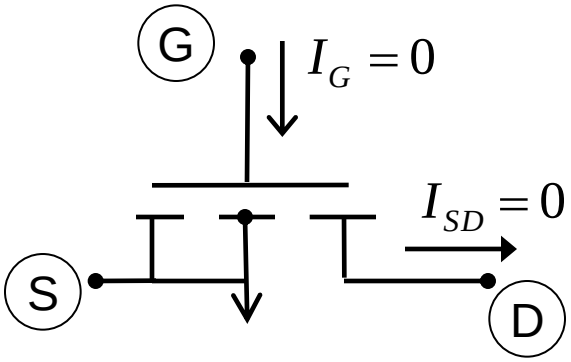
λ : *channel-length modulation parameter*

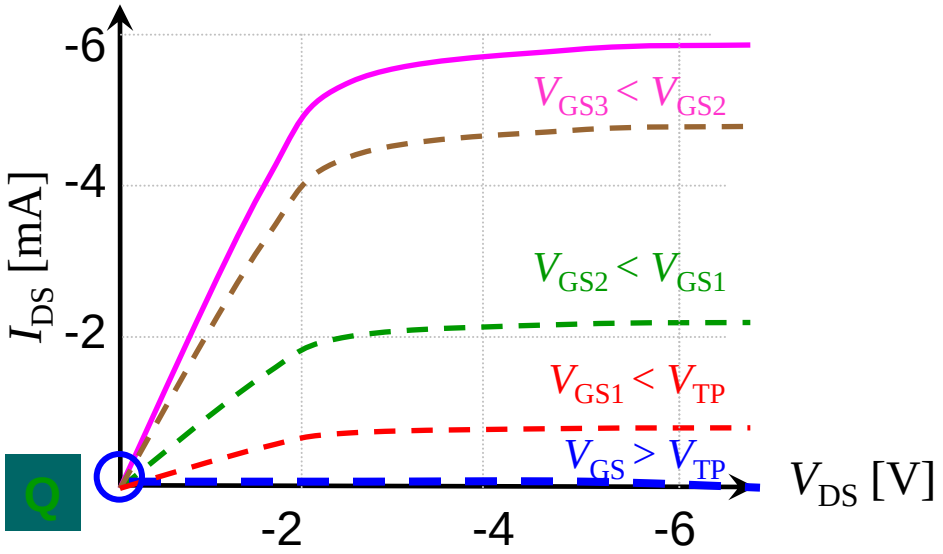
P- MOSFET (Modes of Operation)

There are three modes of operation of P-channel MOSFET (assuming the substrate and the source are connected)

1 Cut-Off Mode

$(V_{GS} > V_{TP})$ $V_{TP}^{(-)}$





$I_{SD} = 0$

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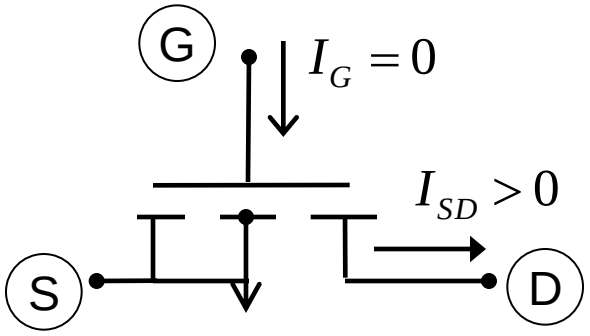
P- MOSFET (Modes of Operation)

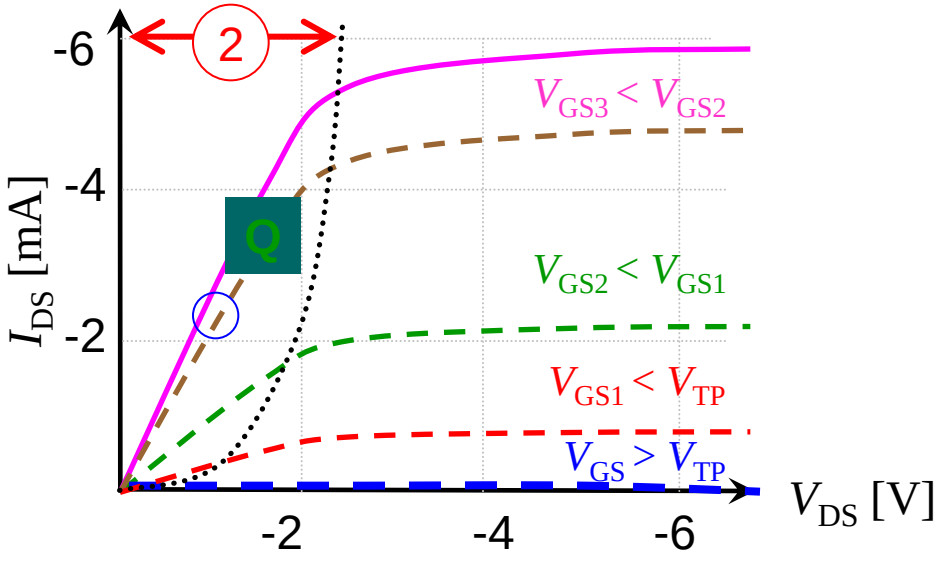
There are three modes of operation of P-channel MOSFET (assuming the substrate and the source are connected)

2 Linear Mode

$$(V_{GS} \le V_{TP})$$

$$V_{DS} \ge V_{GS} - V_{TP}$$





$$I_{SD} = \frac{K_p}{2}\left[2\times(V_{GS} - V_{TP})V_{DS} - V_{DS}^2\right] \text{ OR } I_{SD} = \frac{K_p}{2}\left[2\times(V_{SG} + V_{TP})V_{SD} - V_{SD}^2\right]$$

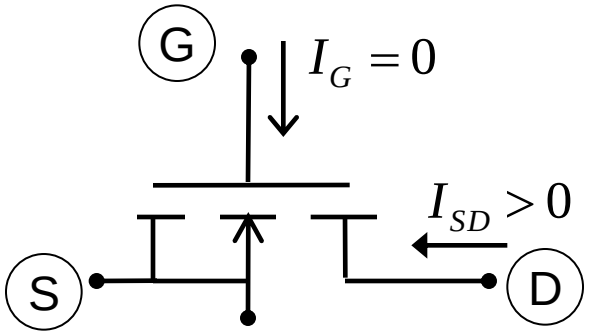
P- MOSFET (Modes of Operation)

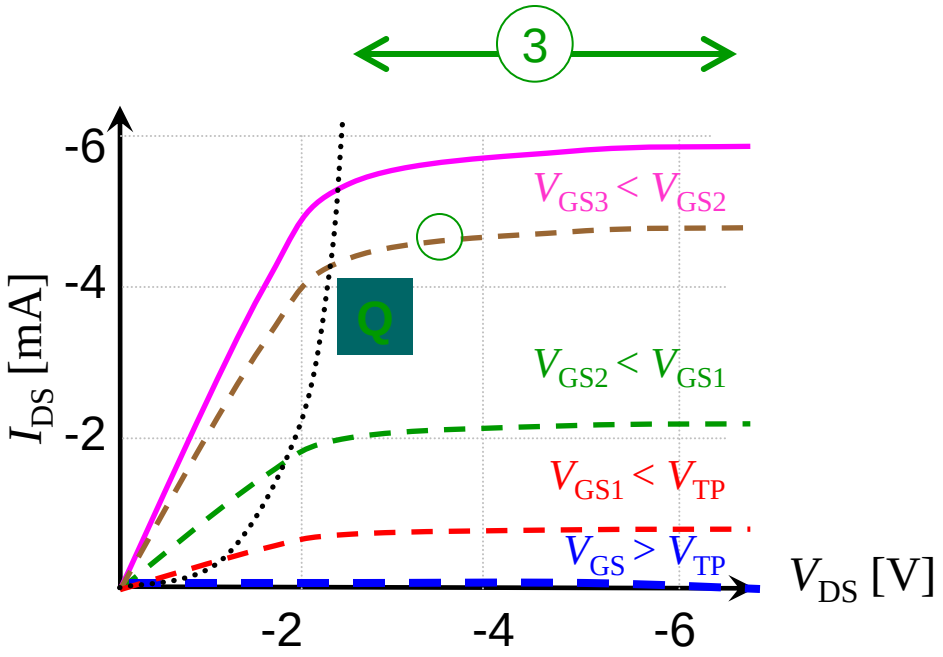
There are three modes of operation of P-channel MOSFET (assuming the substrate and the source are connected)

3 Saturation Mode

$$(V_{GS} < V_{TP})$$

$$V_{DS} \leq V_{GS} - V_{TP}$$





$$I_{SD} = \frac{K_P}{2}(V_{GS} - V_{TP})^2 \quad \text{OR} \quad I_{SD} = \frac{K_P}{2}(V_{SG} + V_{TP})^2$$

Example

Determine the drain current of an NMOS transistor assuming $K_n=20\mu A/V^2$, $V_{TN}=1V$, $\lambda=0$, and $V_{GS}=3V$

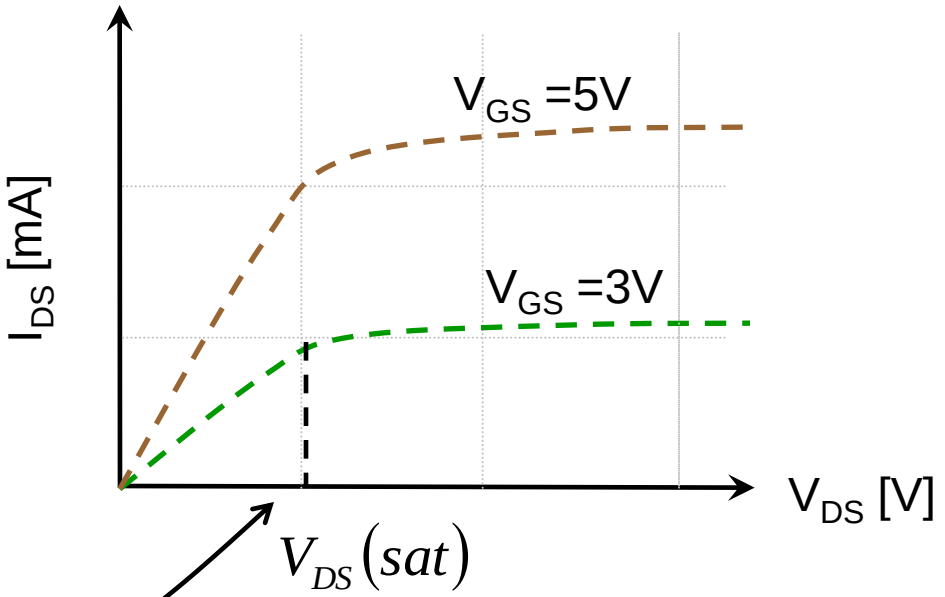
Solution

$$I_{DS}(sat)=\frac{K_n}{2}(V_{GS}-V_{TN})^2(1+\lambda V_{DS})$$

$$I_{DS}(sat)=\frac{20\times10^{-6}}{2}(3-1)^2(1+0\times V_{DS})$$

$$I_{DS}(sat)=40\mu A$$

$$V_{DS}(sat)=V_{GS}-V_{TN}=2V$$



Skip the MOSFET capacitances (sec. 6.7) and the fabrication processes of MOSFET devices