Course Instructor

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MOSFET Current Voltage Characteristics

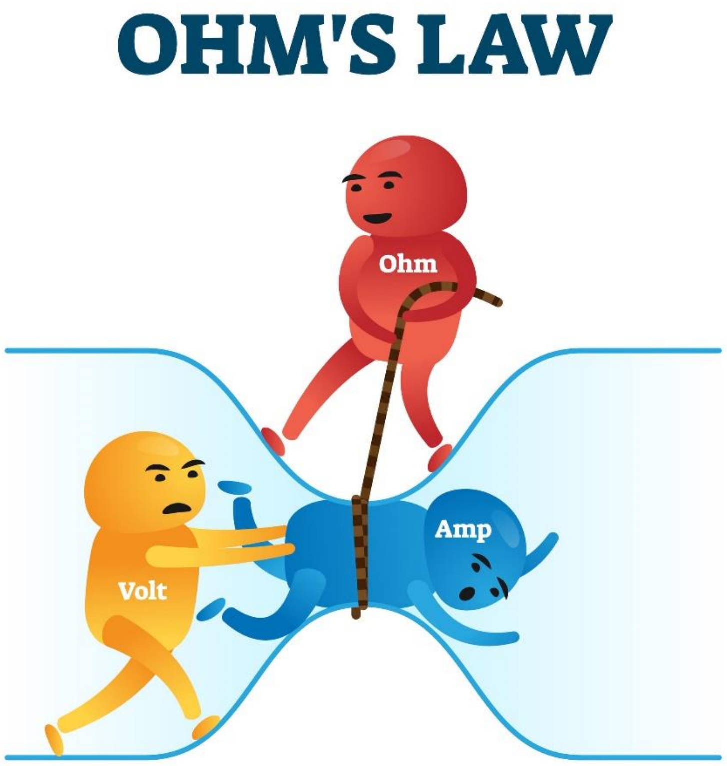
Modes of Operation

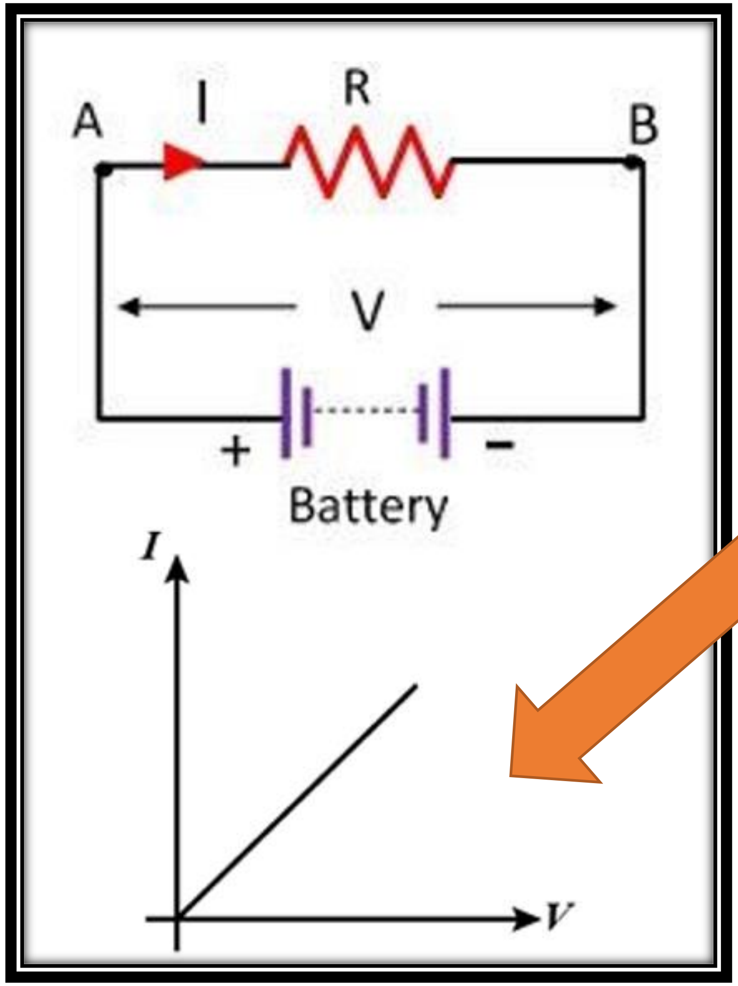
MOSFET Related Important Equations

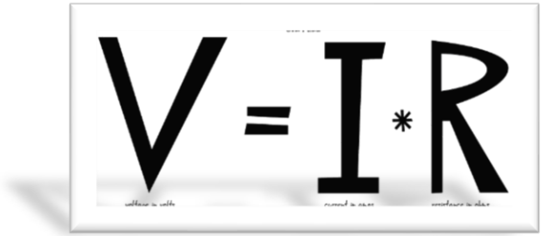
MOSFET Related Ckt Problem

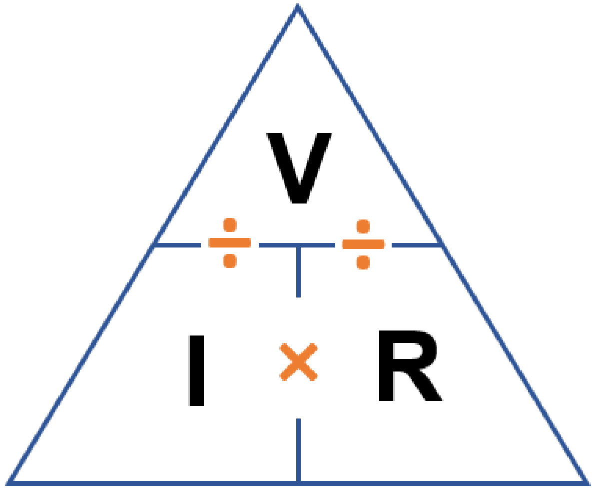
Video Link of this Lecture:

- Lecture-1: https://youtu.be/7CrDQtUQbwA
- Lecture-2: https://youtu.be/DSuMV-5ANr8
- Lecture-3: https://youtu.be/JE-UHlML3jw


OHM'S LAW
Ohm
Amp
Volt


A
I
R
B
V
+
-
Battery
I
V


V = I * R


V
÷
÷
I
×
R

$$\boxed{I_D = \frac{W}{L} \bullet \mu_n C_{ox} \left[V_{GS} - \frac{V_{DS}}{2} - V_T \right] \bullet V_{DS}}$$

$\boxed{L}$ $\boxed{\mu_n}$

$\boxed{V_{GS}}$ $\boxed{W}$ $\boxed{V_{DS}}$

$\boxed{V_T}$ $\boxed{I_D}$ $\boxed{C_{ox}}$

$$I_D = \frac{W}{L} \bullet \mu_n C_{ox} \left[V_{GS} - \frac{V_{DS}}{2} - V_T \right] \bullet V_{DS}$$

$\boxed{V_{DS} < V_{GS} - V_T}$

linear or *triode*

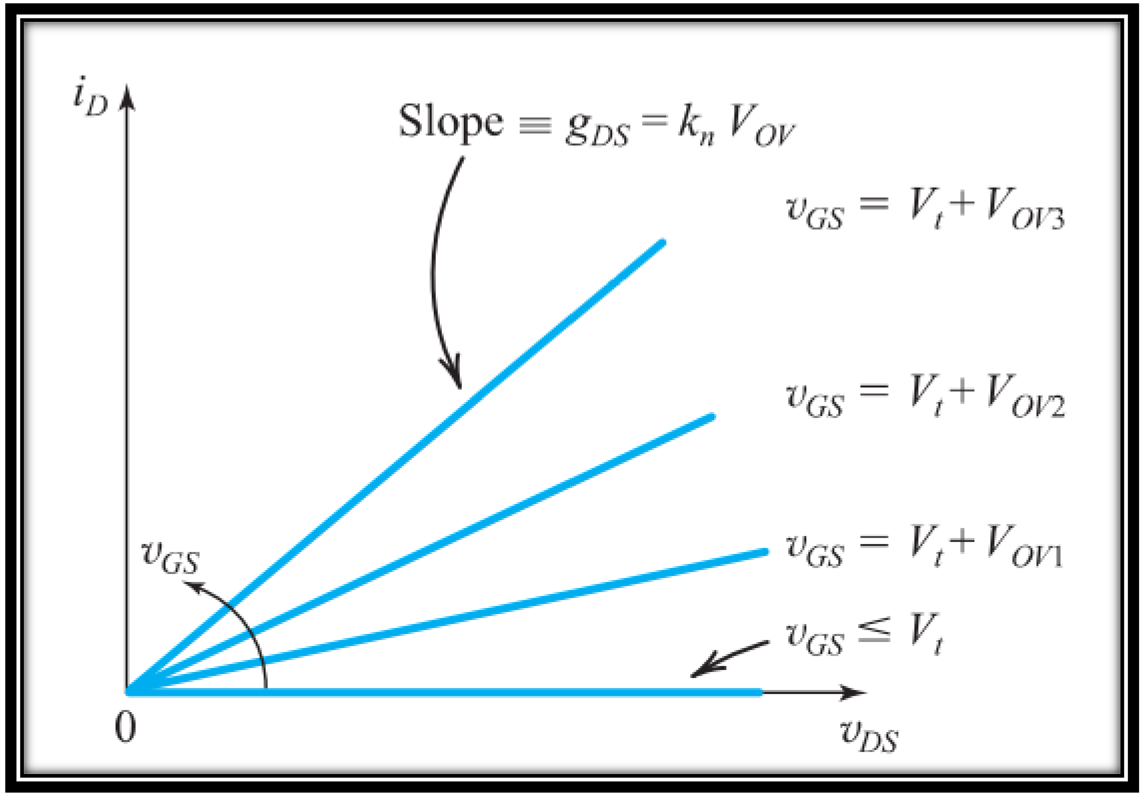
$\boxed{V_{DS} \geq V_{GS} - V_T}$

Saturation

v_{DS} is kept small

$$\boxed{V_{DS} << V_{GS} - V_T}$$

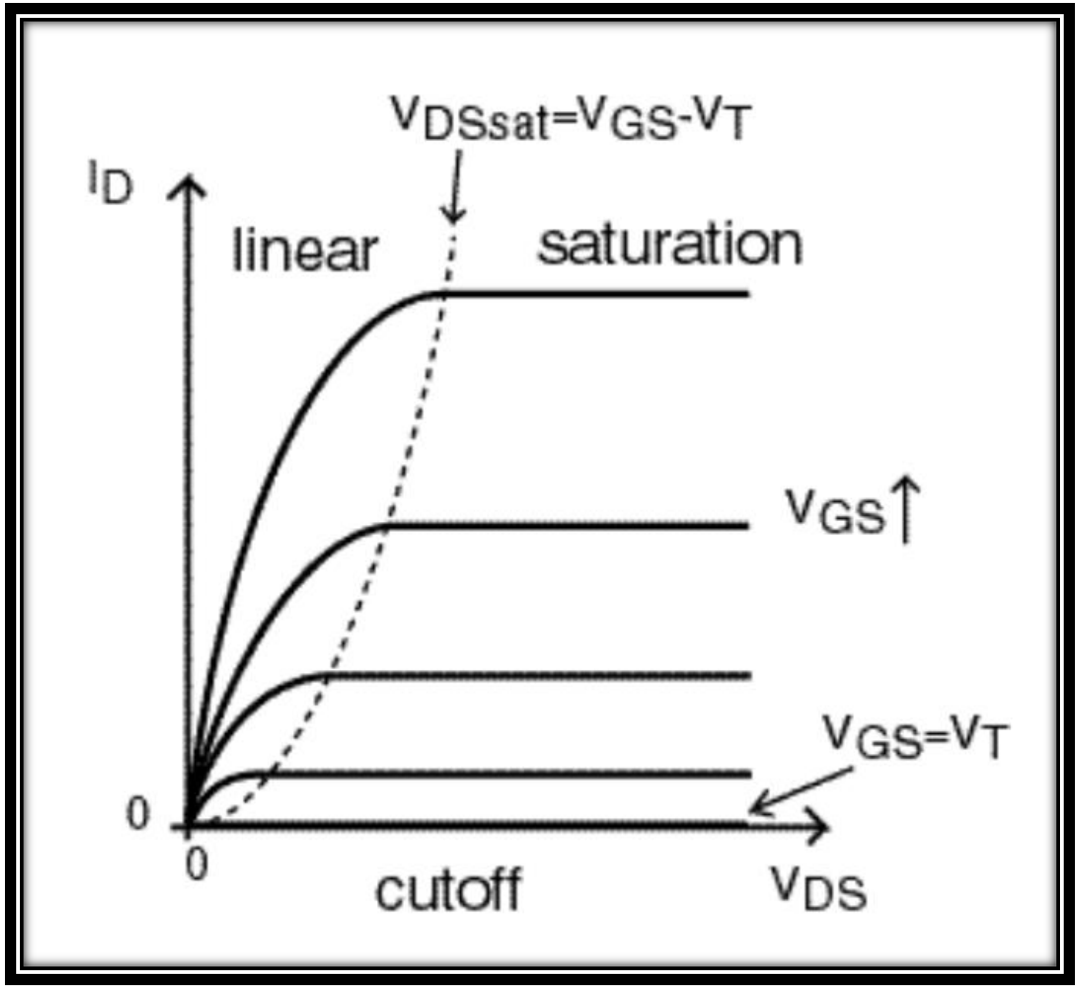
$$I_D = \frac{W}{L} \bullet \mu_n C_{ox} \left[V_{GS} - \frac{V_{DS}}{2} - V_T \right] \bullet V_{DS}$$



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

$$I_D = \frac{W}{L} \bullet \mu_n C_{ox} \left[V_{GS} - \frac{V_{DS}}{2} - V_T \right] \bullet V_{DS}$$

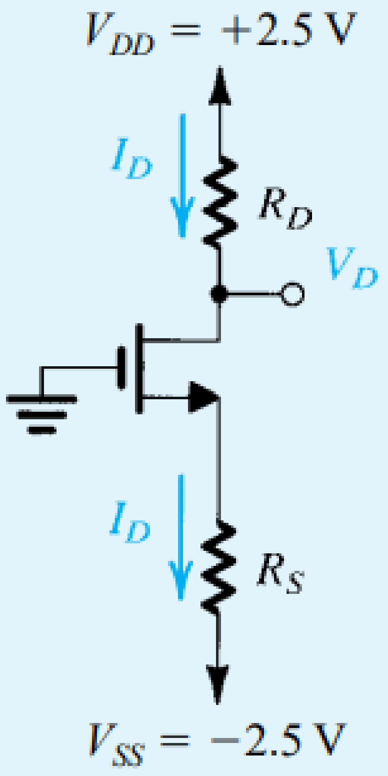
$$\boxed{I_{Dsat} = \frac{W}{2L} \mu_n C_{ox} (V_{GS} - V_T)^2}$$



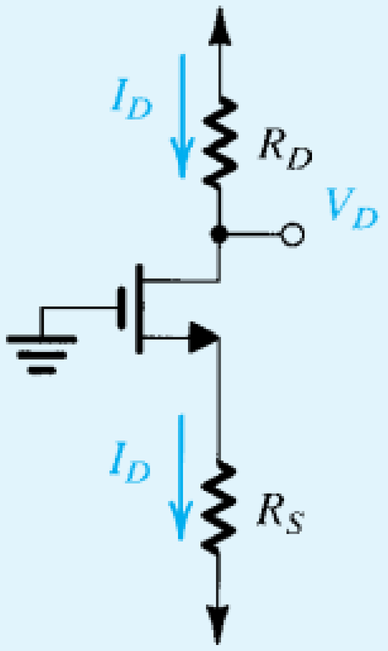
Operating mode	Voltages	
Cut-off	$V_{GS} < V_{th}$	
Linear	$V_{GS} > V_{th}$	$V_{DS} < V_{GS} - V_{th}$
Saturation	$V_{GS} > V_{th}$	$V_{DS} \geq V_{GS} - V_{th}$

Operating mode	Voltages		Drain current
Cut-off	$V_{GS} < V_{th}$		$I_{DS} = 0$
Linear	$V_{GS} > V_{th}$	$V_{DS} < V_{GS} - V_{th}$	$I_D = \frac{W}{L} \bullet \mu_n C_{ox} \left[V_{GS} - \frac{V_{DS}}{2} - V_T \right] \bullet V_{DS}$
Saturation	$V_{GS} > V_{th}$	$V_{DS} \geq V_{GS} - V_{th}$	$\boxed{I_{Dsat} = \frac{W}{2L} \mu_n C_{ox} (V_{GS} - V_T)^2}$

Design the circuit of Fig. 5.21, that is, determine the values of R_D and R_S, so that the transistor operates at $I_D = 0.4$ mA and $V_D = +0.5$ V. The NMOS transistor has $V_t = 0.7$ V, $\mu_n C_{ox} = 100\ \mu A/V^2$, $L = 1\ \mu m$, and $W = 32\ \mu m$.



Design the circuit of Fig. 5.21, that is, determine the values of R_D and R_S, so that the transistor operates at $I_D = 0.4$ mA and $V_D = +0.5$ V. The NMOS transistor has $V_t = 0.7$ V, $\mu_n C_{ox} = 100\ \mu\text{A/V}^2$, $L = 1\ \mu$m, and $W = 32\ \mu$m.



$$R_D = \frac{V_{DD} - V_D}{I_D} = \frac{2.5 - 0.5}{0.4} = 5\ \text{k}\Omega$$

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_{OV}^2$$

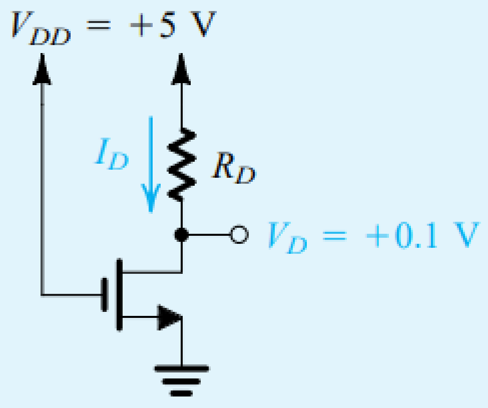
$$400 = \frac{1}{2} \times 100 \times \frac{32}{1} V_{OV}^2$$

$$V_{OV} = 0.5\ \text{V}$$

$$V_{GS} = V_t + V_{OV} = 0.7 + 0.5 = 1.2\ \text{V}$$

$$R_S = \frac{V_S - V_{SS}}{I_D} = \frac{-1.2 \quad (\ 2.5)}{0.4} = 3.25\ \text{k}\Omega$$

Design the circuit in Fig. 5.23 to establish a drain voltage of 0.1 V. What is the effective resistance between drain and source at this operating point? Let $V_{tn} = 1$ V and $k_n'(W/L) = 1\ \text{mA/V}^2$.



Solution

Since the drain voltage is lower than the gate voltage by 4.9 V and $V_{tn} = 1$ V, the MOSFET is operating in the triode region. Thus the current I_D is given by

$$I_D = k_n' \frac{W}{L}\left[(V_{GS} - V_{tn})V_{DS} - \frac{1}{2}V_{DS}^2\right]$$

$$I_D = 1 \times \left[(5-1)\times 0.1 - \frac{1}{2}\times 0.01\right]$$

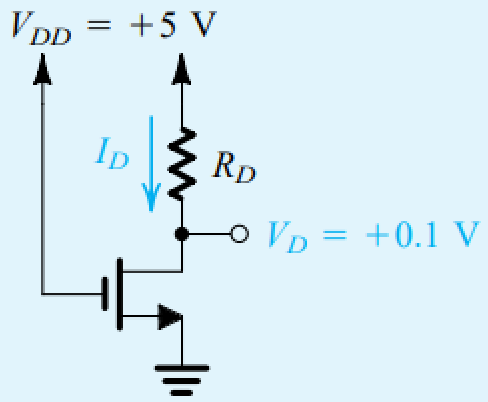
$$= 0.395\ \text{mA}$$

The required value for R_D can be found as follows:

$$R_D = \frac{V_{DD} - V_D}{I_D}$$

$$= \frac{5-0.1}{0.395} = 12.4\ \text{k}\Omega$$

Design the circuit in Fig. 5.23 to establish a drain voltage of 0.1 V. What is the effective resistance between drain and source at this operating point? Let $V_{tn} = 1$ V and $k_n'(W/L) = 1$ mA/V^2.



D5.9 For the circuit in Fig. E5.9, find the value of R that results in $V_D = 0.8$ V. The MOSFET has $V_{tn} = 0.5$ V, $\mu_n C_{ox} = 0.4$ mA/V^2, $W/L = \dfrac{0.72\ \mu\text{m}}{0.18\ \mu\text{m}}$, and $\lambda = 0$.

Ans. 13.9 kΩ

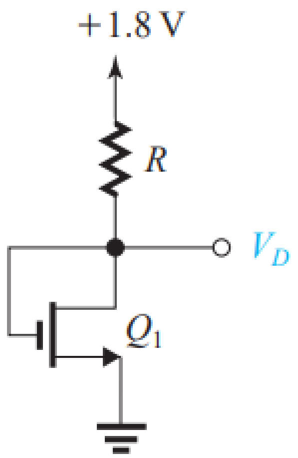


Figure E5.9

Thank You