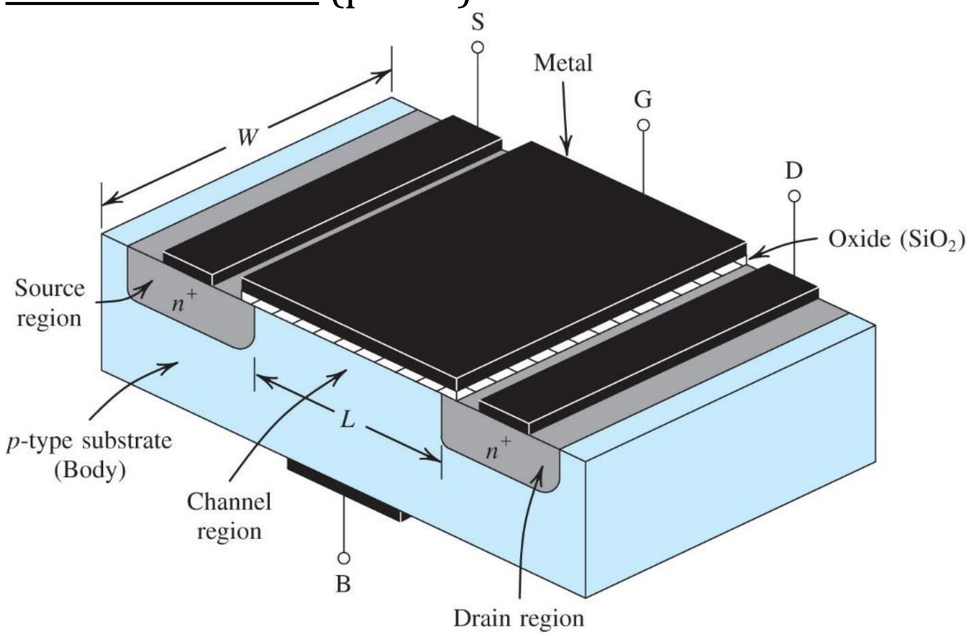
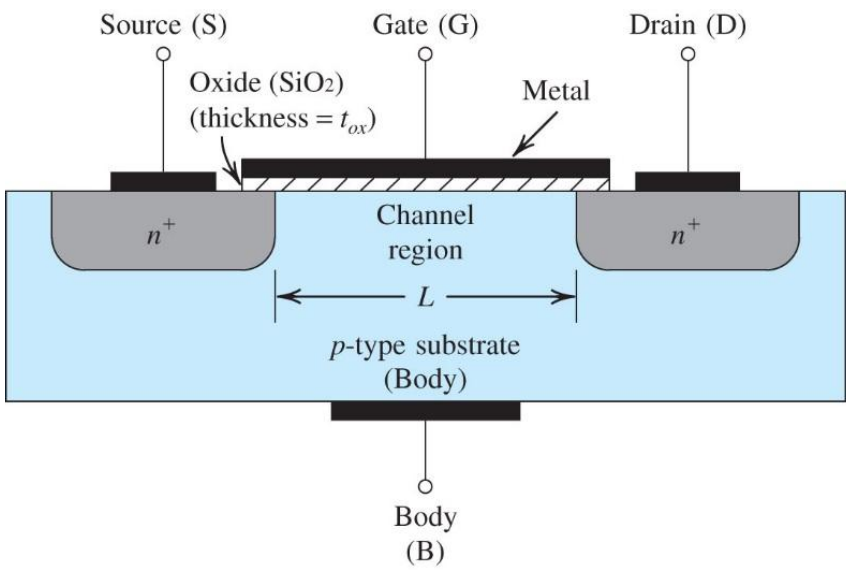
MOSFET TRANSISTOR SUMMARY

NMOS Transistor (p. 249):



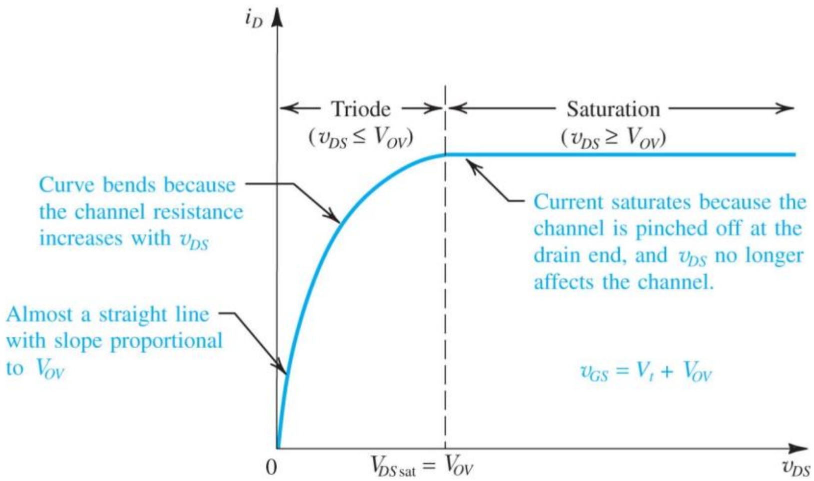
(a)

NMOS Cross-section (p. 249):



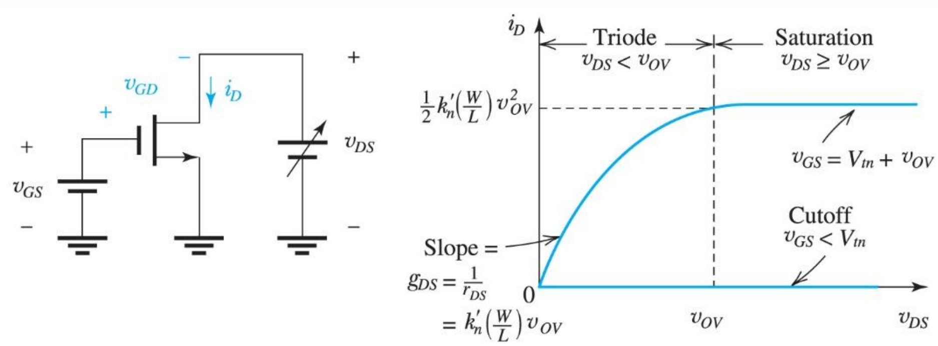
(b)

<u>MOSFET Operating Regions</u> (p. 258):



<u>MOSFET Equations</u> (p. 266):

Table 5.1 Regions of Operation of the Enhancement NMOS Transistor



- $v_{GS} < V_{tn}$: no channel; transistor in cutoff; $i_D = 0$
- $v_{GS} = V_{tn} + v_{OV}$: a channel is induced; transistor operates in the triode region or the saturation region depending on whether the channel is continuous or pinched off at the drain end;

Triode Region

Continuous channel, obtained by:

$$v_{GD} > V_{tn}$$

or equivalently:

$$v_{DS} < v_{OV}$$

Then,

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

or equivalently,

$$i_D = k_n'\left(\frac{W}{L}\right)\left(v_{OV} - \frac{1}{2}v_{DS}\right)v_{DS}$$

Saturation Region

Pinched-off channel, obtained by:

$$v_{GD} \le V_{tn}$$

or equivalently:

$$v_{DS} \ge v_{OV}$$

Then

$$i_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)(v_{GS} - V_{tn})^2$$

or equivalently,

$$i_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)v_{OV}^2$$

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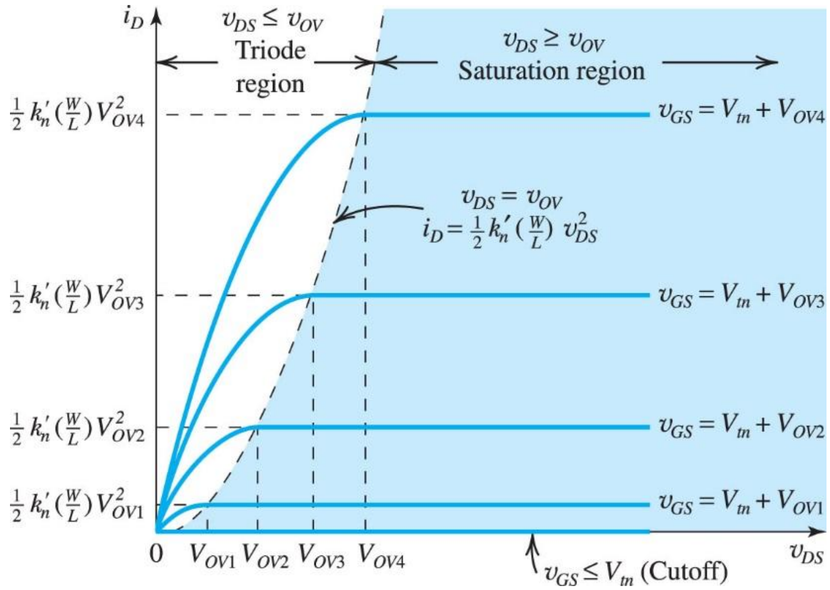

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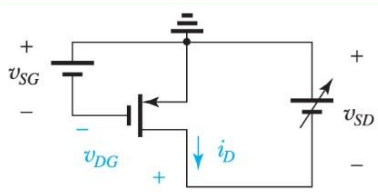
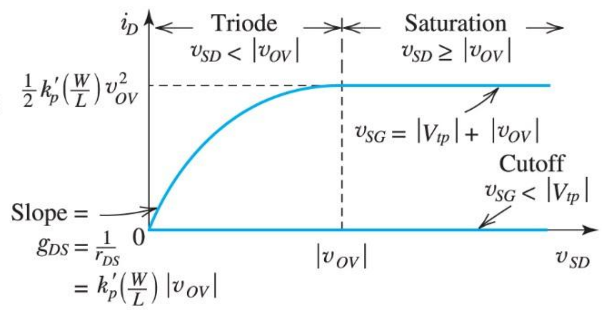
Table 5.2 Regions of Operation of the Enhancement PMOS Transistor





- $v_{SG} < |V_{tp}|$: no channel; transistor in cutoff; $i_D = 0$
- $v_{SG} = |V_{tp}| + |v_{OV}|$: a channel is induced; transistor operates in the triode region or in the saturation region depending on whether the channel is continuous or pinched off at the drain end;

Triode Region

Continuous channel, obtained by:

$$v_{DG} > |V_{tp}|$$

or equivalently

$$v_{SD} < |v_{OV}|$$

Then

$$i_D = k_p'\left(\frac{W}{L}\right)\left[(v_{SG} - |V_{tp}|)v_{SD} - \frac{1}{2}v_{SD}^2\right]$$

or equivalently

$$i_D = k_p'\left(\frac{W}{L}\right)\left(|v_{OV}| - \frac{1}{2}v_{SD}\right)v_{SD}$$

Saturation Region

Pinched-off channel, obtained by:

$$v_{DG} \le |V_{tp}|$$

or equivalently

$$v_{SD} \ge |v_{OV}|$$

Then

$$i_D = \frac{1}{2}k_p'\left(\frac{W}{L}\right)(v_{SG} - |V_{tp}|)^2$$

or equivalently

$$i_D = \frac{1}{2}k_p'\left(\frac{W}{L}\right)v_{OV}^2$$

Process transconductance parameter (p. 254):

$$k'_n = \mu_n C_{ox} \quad \text{(n-channel) or} \quad k'_p = \mu_p C_{ox} \quad \text{(p-channel)}$$

For MOSFET transconductance parameter (p. 255):

$$k'_n(W/L) = \mu_n C_{ox}(W/L) = k_n \quad \text{(n-channel) and}$$

$$k'_p(W/L) = \mu_p C_{ox}(W/L) = k_p \quad \text{(p-channel).}$$

Overdrive Voltage V_{OV} (p. 251):
Defined at the triode-to-saturation point of MOSFET I-V curve where $v_{DS} = V_{OV}$ and $v_{GD} = V_t$ (note that V_t is either V_{tn} or V_{tp}) at channel pinch-off $V_{DS,sat} = V_{OV}$.

$$V_{OV} = V_{GS} - V_t \quad \text{or} \quad V_{GS} = V_{OV} + V_t$$

Transconductance g_m equations (p. 388):
There are three expressions which are useful for computing the transconductance parameter (depending upon the known MOSFET parameters at hand).

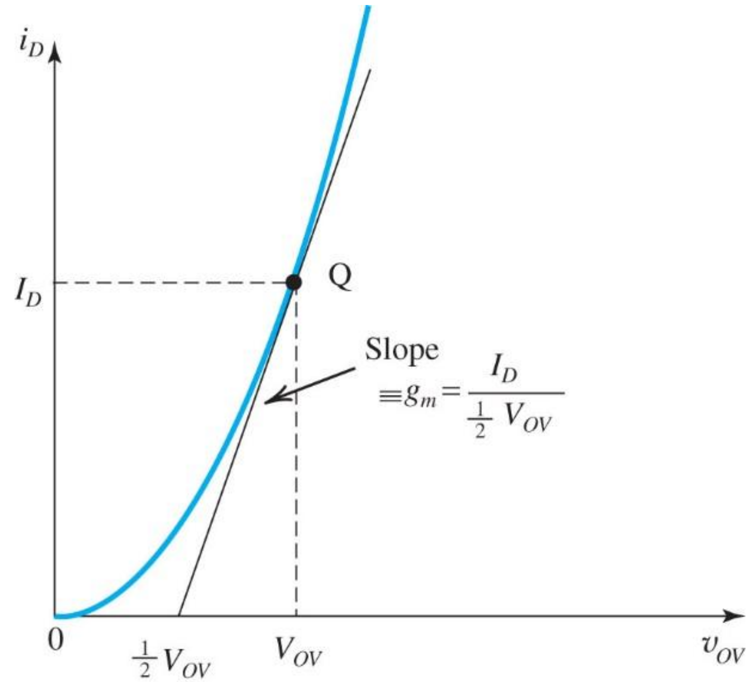
$$g_m = k'(W/L)(V_{GS} - V_t) = k'(W/L)V_{OV}$$

or $\quad g_m = [2k'(W/L)I_D]^{1/2}$,

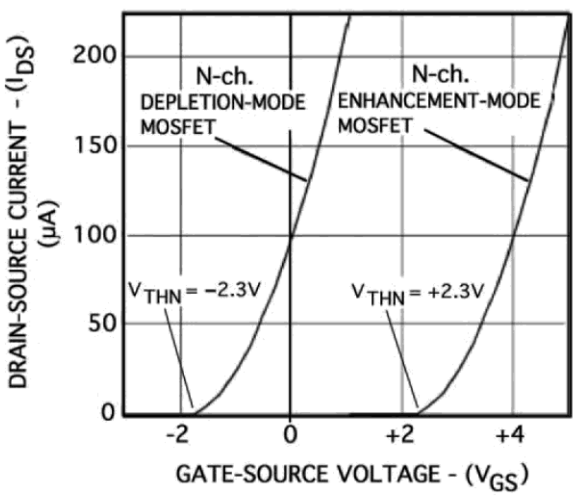
or $\quad g_m = [2I_D/V_{OV}]$

where k' represents either k'_n or k'_p, respectively, for n-channel or p=channel MOSFETs.

Graphical determination of transconductance g_m – Figure 7.14 on page 389:



<u>Enhancement-mode versus Depletion-mode MOSFETs</u>:



Comparing the transfer characteristics of Depletion-mode and Enhancement-mode N-channel devices.

Depletion-mode is also called “normally on,” and enhancement-mode is “normally off.”