MOS Characteristics I

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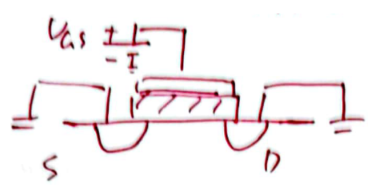
Behavour of Channel

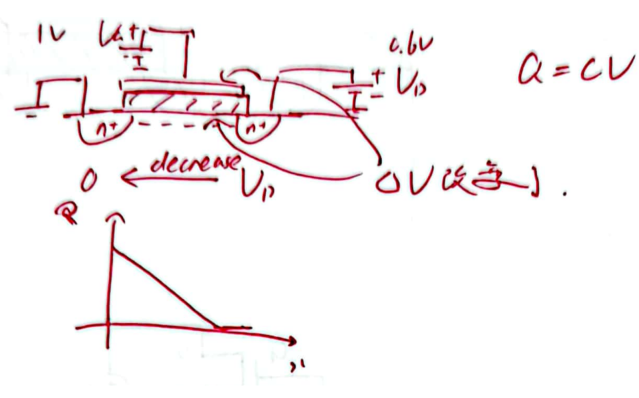
Case I: $V_{GS} > V_{TH}$**,** $V_D = V_S = 0$



$V_{GS} > V_{TH}$, $V_D = V_S = 0$

MOSFET turned on, but has no current.

Case II: $V_{GS} > V_{TH}$**,** $V_D > V_S = 0$

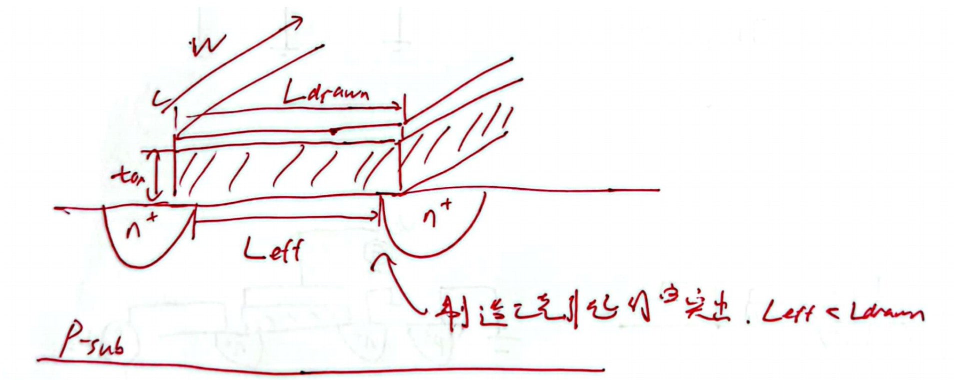


$V_{GS} > V_{TH}$, $V_D > V_S = 0$

When V_D is applied, A voltage drop occurs between the S and D, resulting in the voltage between the upper and lower plates not being equal to the V_G. It decreases from the D to the S.

With $Q = CV$, we can draw a Q-X relationship diagram. That indicates I_D is related to V_{DS}.

Dimensions of MOSFET



Dimensions of MOSFET

Affected by the manufacturing process, the n-type semiconductor and silicon dioxide oxide layers at both ends overlap a little. We call this length L_{eff}, and the length of the gate metal plate is called L_{drawn}.

Derivation of I/V Characteristic

Channel Charge Density

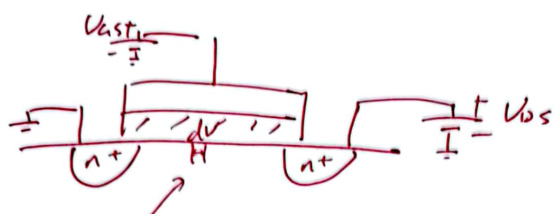
Case I: $V_{GS} > V_{TH}$, $V_D = V_S = 0$

$Q_{ch,total} = W * L_{eff} * C_{ox} * (V_{GS} - V_{TH})$
We call $V_{GS} - V_{TH}$ the overdrive voltage, C_{ox} the capper of unit area.
$Q_{ch,density} = W * C_{ox} * (V_{GS} - V_{TH})$

Case II: $V_{GS} > V_{TH}$, $V_D > V_S = 0$

$Q_{ch,density} = W * C_{ox} * (V_{GS} - V_{TH} - V(x))$
V is x-dependence, see the Behavour of Channel's Case II.

Drain Current



Calculate drain current

We just mentioned that if a voltage is applied to the drain, a current will be generated.
We know that $v = \mu_n E$, $E = -\frac{dV}{dx}$.
So we get $v = -\mu_n \frac{dV}{dx}$.
From $Q_{ch,density} = W * C_{ox} * (V_{GS} - V_{TH} - V(x))$,
Select a unit length, we get

$$I_D = -v * Q_{ch,density} = -[-\mu_n \frac{dV}{dx} * W * C_{ox} * (V_{GS} - V_{TH} - V(x))]$$

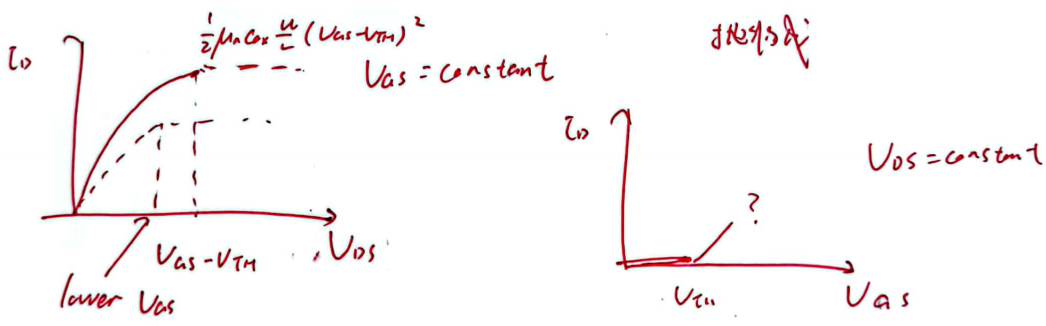
Note that I_D is a constant.
Move dx to the left and integrate both sides of the equation, we get

$$\int_0^L I_D dx = \mu_n * W * C_{ox} * \int_0^{V_{DS}} (V_{GS} - V_{TH} - V(x)) dV$$

L in these equations always refers to L_eff.
Simplify the equation, we get

$$I_D = \mu_n * C_{ox} * \frac{W}{L}[(V_{GS} - V_{TH}) * V_{DS} - \frac{1}{2}V_{DS}^2]$$

Pay attention $V_{GS} \geq V_{TH}$ here.
Then we can get their relationship curves.



The relationship between I_D, V_{DS} and V_{GS}

Now we haven't known how the I_D change if $V_{DS} > V_{GS} - V_{TH}$ or V_{GS} increases.

Link

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