MOS Characteristics II

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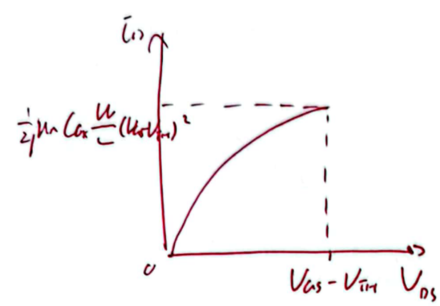
I/V Characteristics

Case I: $V_{DS} < V_{GS} - V_{TH}$

Last day we know the $I_D - V_{DS}$ relationship when $V_{DS} \leq V_{GS} - V_{TH}$.



The $I_D - V_{DS}$ relationship when $V_{DS} \leq V_{GS} - V_{TH}$

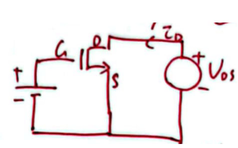
The drain current is:

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

We now assume that $V_{DS} * (V_{GS} - V_{TH}) >> \frac{1}{2}V_{DS}^2$, that is $V_{DS} << 2(V_{GS} - V_{TH})$.
we can get:

$$I_D \approx \mu * C_{ox}\frac{W}{L} * (V_{GS} - V_{TH}) * V_{DS}$$

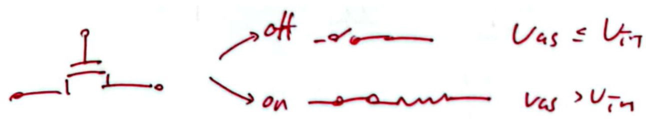
That is, V_{DS} is linearly related to I_D, shows us that **A MOSFET can act as a voltage-dependence resistor**. (if $V_{DS} << 2(V_{GS} - V_{TH})$)



$R_{on} = \frac{V_{DS}}{I_D} = \frac{1}{\mu C_{ox}\frac{W}{L}(V_{GS}-V_{TH})}$

R_{on} means the resistance when the MOS turns on.

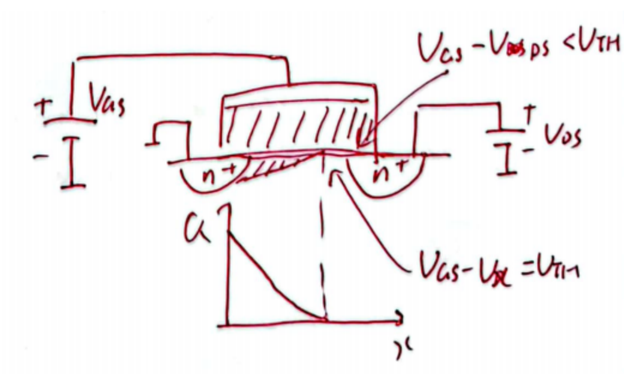
MOS Device as a Switch



MOS device as a switch

For example, it can use in a Bluetooth System, for both side have to determine to transmit or receive.

Case II: $V_{DS} > V_{GS} - V_{TH}$



Pinch-off

The potential difference between the upper and lower plates at the drain end is less than V_{TH}, leads to no electronics exit.

We call this phenomenon **pinch-off**.

Rederive I/V Equation

Relationship between I_D and V_{DS}

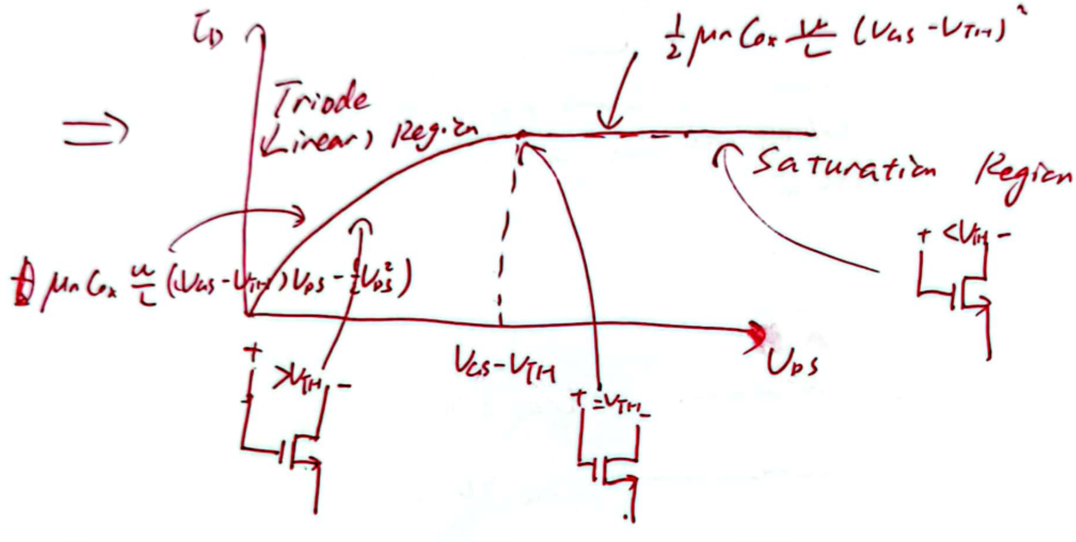
$$\int_0^L I_D dx = \mu_n * W * C_{ox} * \int_0^{V_{GS}-V_{TH}} (V_{GS} - V_{TH} - V(x))dV$$

Compare to the equation we derive last day, The upper limit of the integral on the right-hand side of the equation changes. For only $V_{GS} - V(x) > V_{TH}$ there exits Q.

$$I_D L = \frac{1}{2}\mu C_{ox} W (V_{GS} - V_{TH})^2$$

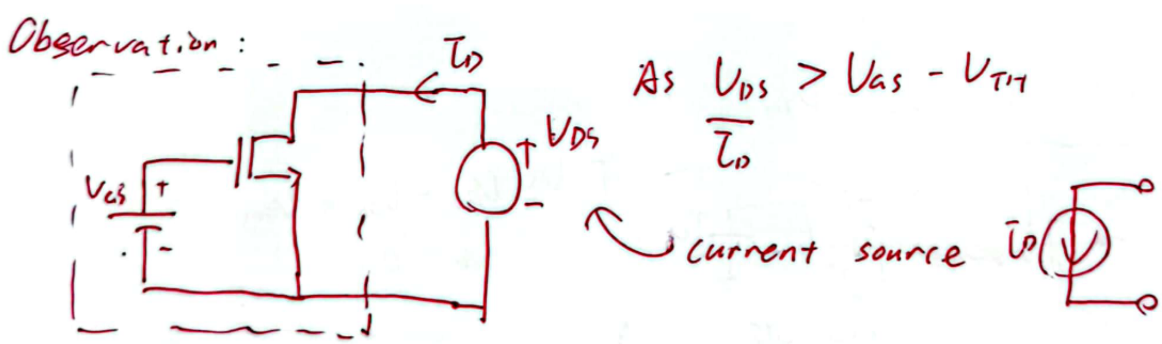
$$I_D = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS} - V_{TH})^2$$

Then we can draw the complete curve.



Relationship between I_D and V_{DS}

This also enlightens us that we only need to pay attention to the potential difference between the G and the D to judge the saturation region and the linear region. as the picture shows.



Current Source

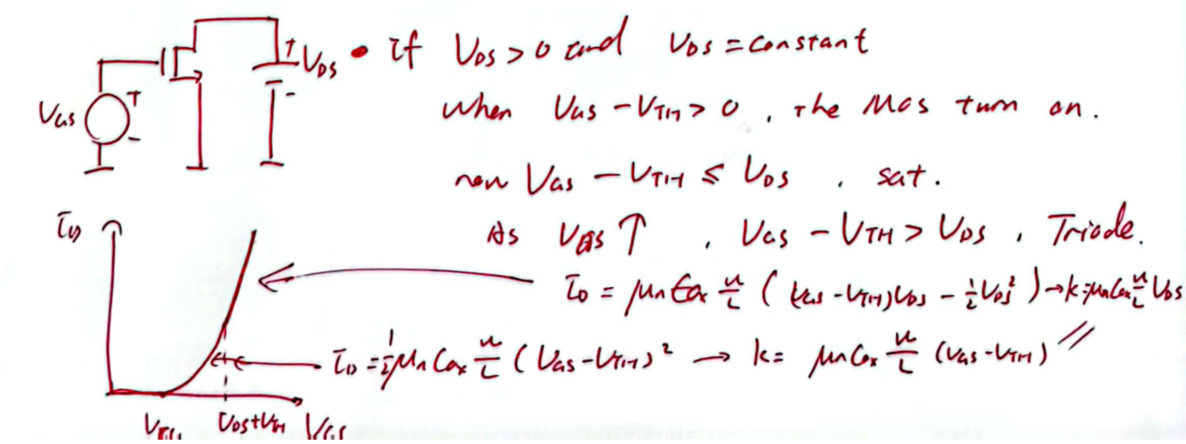
As $V_{DS} > V_{GS} - V_{TH}$, the I_D is a constant. We can use this to make a current source.

Relationship between I_D and V_{GS}

We can also derive the relationship between I_D and V_{GS}.

If $V_{DS} > 0$ and V_{DS} is a constant, when $V_{GS} > V_{TH} > 0$, the MOS turns on. now $V_{GS} - V_{TH} \le V_{DS}$, the MOS is in saturation zone.

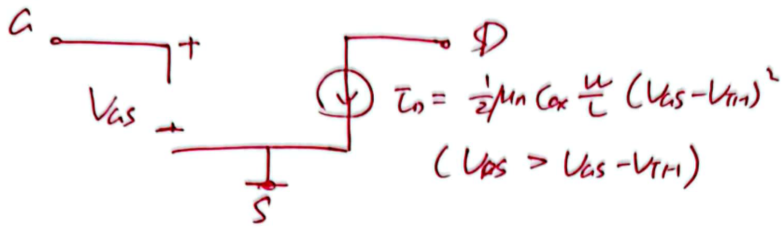
As V_{GS} becomes larger, $V_{GS} - V_{TH} > V_{DS}$, the MOS is in triode zone.



Relationship between I_D and V_{GS}

We can calculate for the curve, as I show in the picture.

Simple Model in Saturation Zone



Use the Saturation to Design a Current Source

Example

$\mu C_{ox} = 100\mu A/V^2$, $V_{TH} = 0.5V$, $\frac{W}{L} = \frac{5\mu m}{0.5\mu m}$
Design a 1mA current source.

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

we get $V_{GS} = 1.91V$.
Therefore, when $V_{DS} \geq 1.41V$, the MOS can be a current source with $I_D = 1mA$.

Link

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