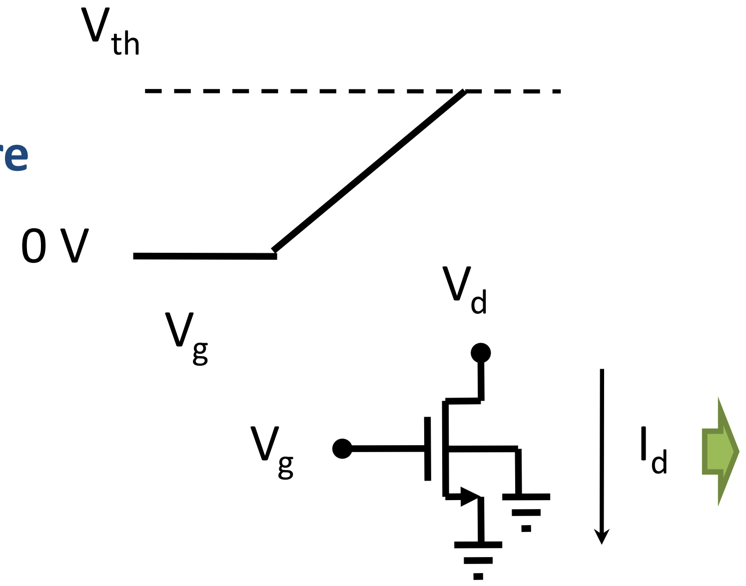
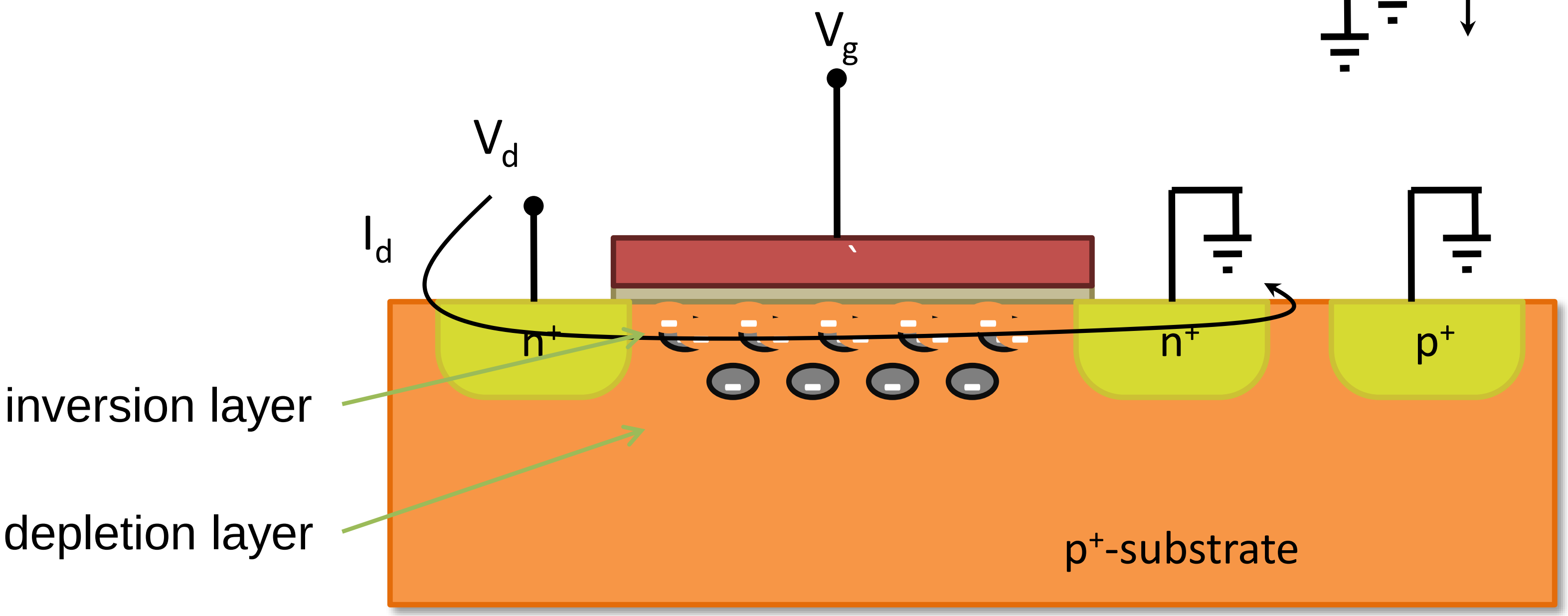
Last Lecture → MOS

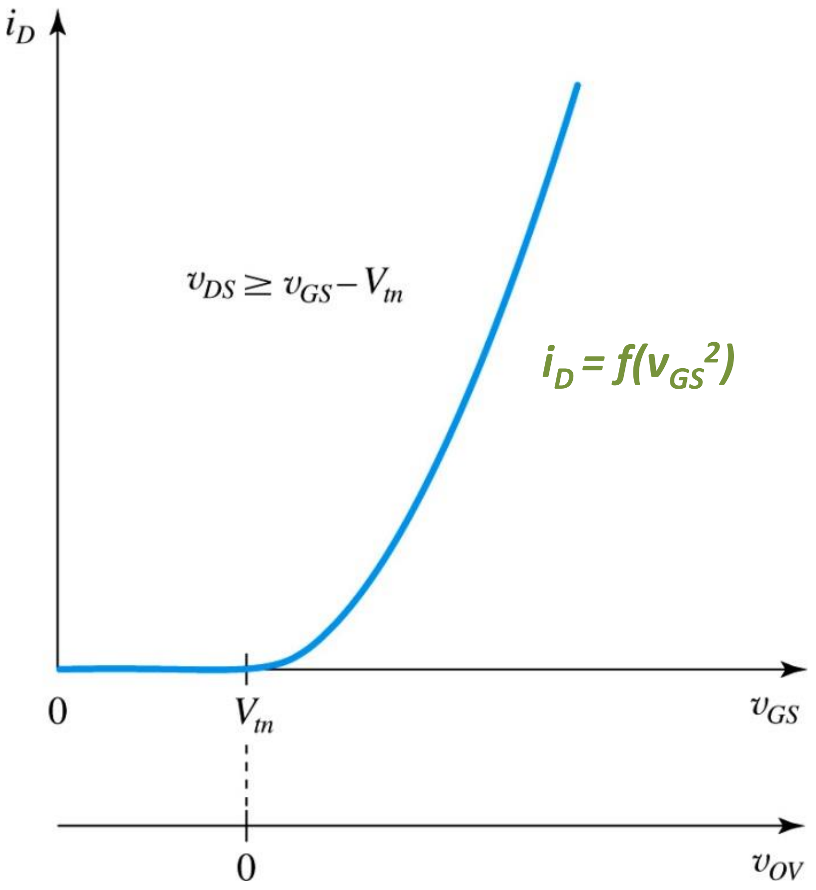
- **Two external voltage sources are required for biasing**
- **Three operation modes:**
  1) **Cut-Off**
  2) **Ohmic**
  3) **Saturation**

used for switching!

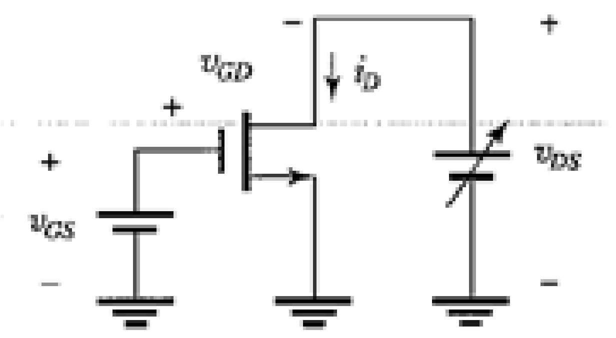
used for amplification!







nMOS Operation → Saturation

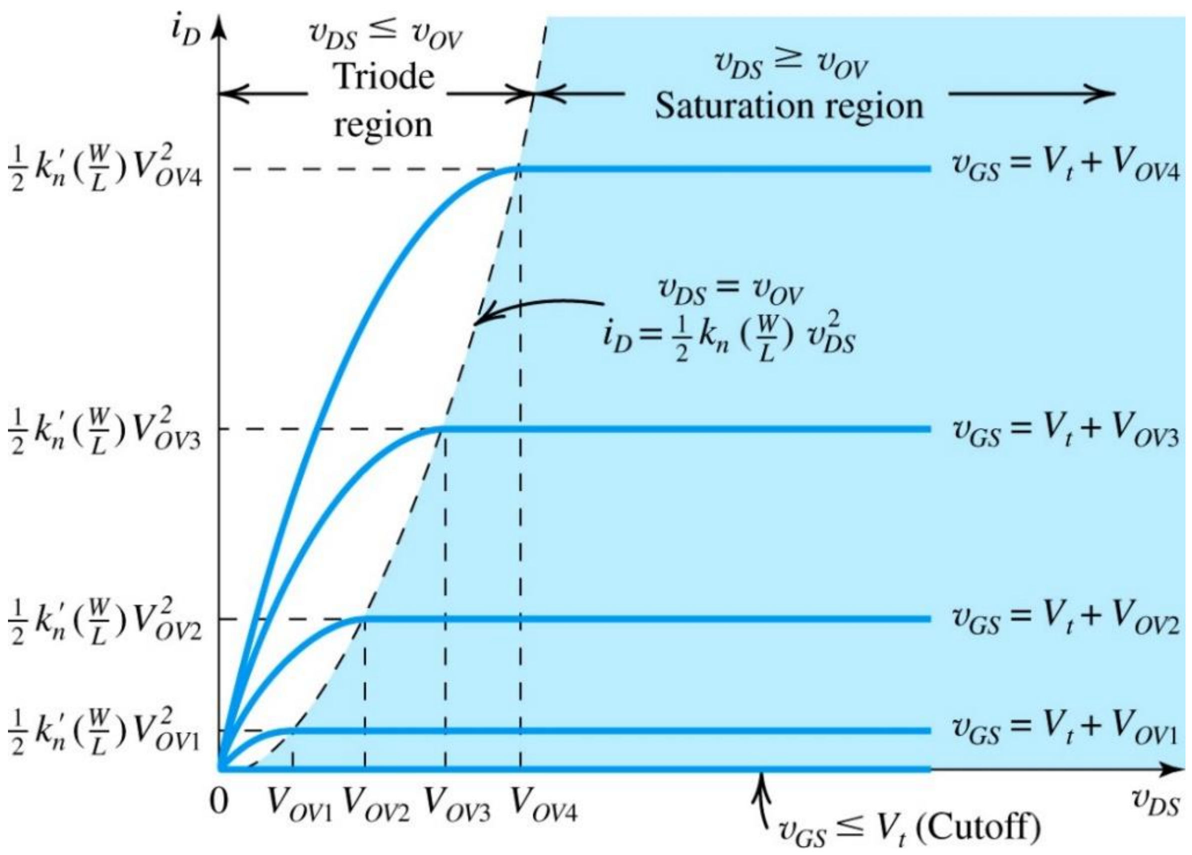


- $v_{GS} > v_{th}$
- $v_{DS} > v_{GS} - v_{th} = v_{ov}$
- $i_G = 0$

Over-drive Voltage

$$V_{ov} = V_{GS} - V_{th}$$

$i_D = f(v_{GS}, v_{DS})$



Channel Length Modulation Parameter [1/V]

K_n

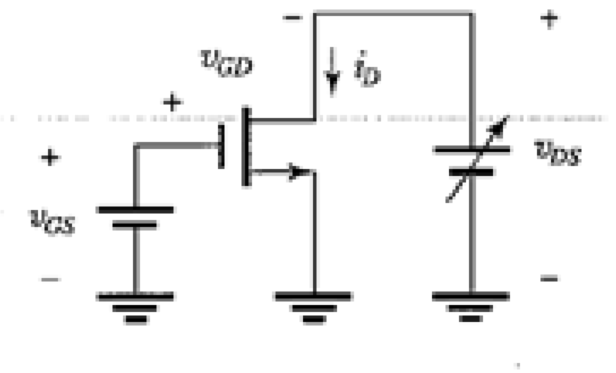
$$I_D = \frac{1}{2}k_n'\frac{W}{L}(V_{GS} - V_{th})^2(1 + \lambda V_{DS})$$

$$\approx \frac{1}{2}k_n'\frac{W}{L}(V_{GS} - V_{th})^2$$

Transconductance Parameter [A/V²]

$$k_n' = \mu_n C_{ox}$$

nMOS Operation → Ohmic



- $v_{GS} > V_{th}$
- $v_{DS} < v_{GS} - V_{th} = v_{ov}$
- $i_G = 0$

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

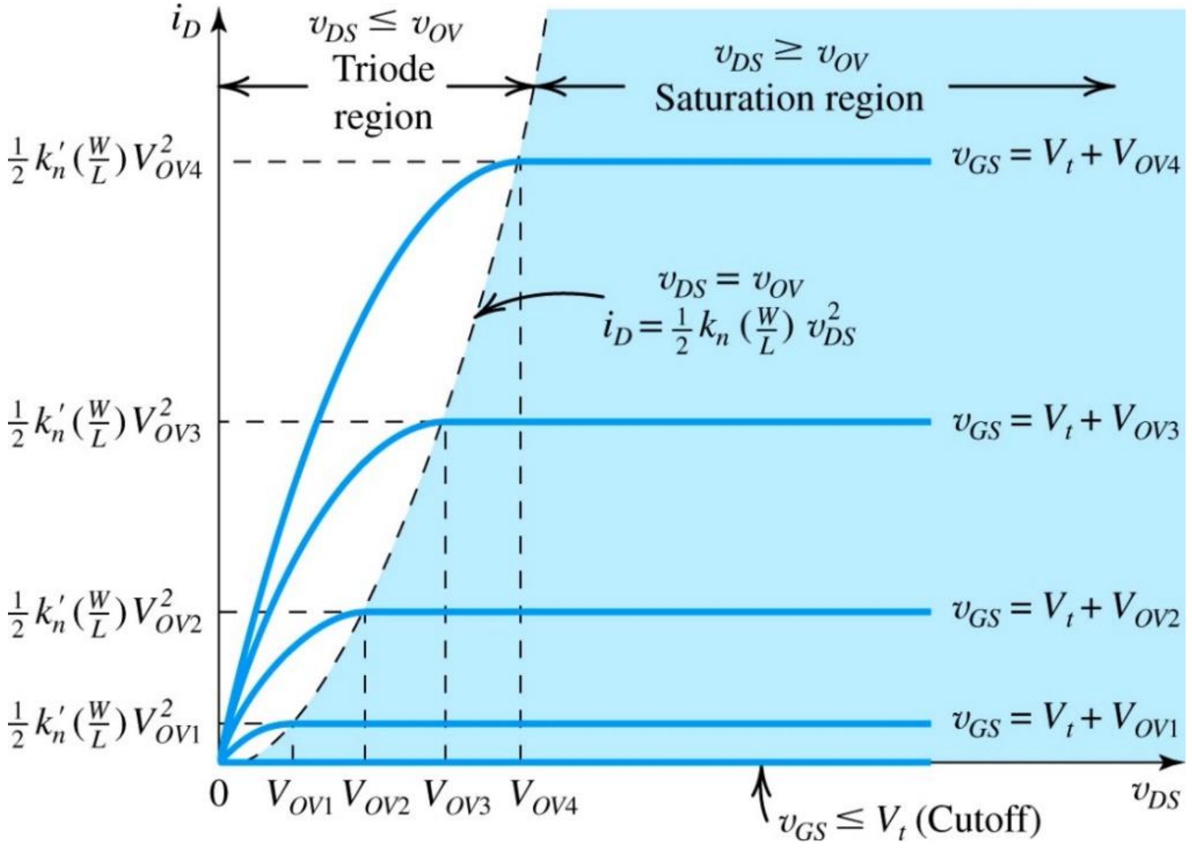
$$\approx k_n' \frac{W}{L}(V_{GS} - V_{th}) \cdot V_{DS}$$

$$r_{ds} = \frac{1}{k_n' \frac{W}{L}(V_{GS} - V_{th})}$$

Over-drive Voltage

$$V_{ov} = V_{GS} - V_{th}$$

$i_D = f(v_{GS}, v_{DS})$



Example 5.2

Consider an nMOS transistor fabricated in a 0.18µm process with L=0.18µm and W=2um. The process technology is specified to have C_{ox}=8.6fF/µm^2, μ_n=450cm^2/V·s, and V_{th}=0.5V.

a) Find V_{GS} and V_{DS} that result in the MOSFET operating at the edge of saturation with I_D=100 µ A.
b) If V_{GS} is kept constant, find V_{DS} that results in I_D=50µA.
c) To investigate the use of the MOSFET as a linear amplifier, let it be operating in saturation with V_{DS}=0.3V. Find the change in i_D resulting from v_{GS} changing from 0.7V by +0.01V and by -0.01V.

a) K_n=4.3mA
→ $V_{ov}=\sqrt{(2 \cdot I_D/K_n)}$=0.22mV
→ $V_{DS}=V_{ov}$=0.22mV
→ $V_{GS}=V_{th}+V_{ov}$=0.72mV.

Exercise 5.5

An n-channel MOSFET operating with V_{ov}=0.5V exhibits a linear resistance r_{DS}=1kΩ when v_{DS} is very small.

a) **What is the value of the device trans-conductance parameter K_n?**
b) **Assuming $\lambda = 0$, what is the value of the current I_D obtained when v_{DS} is increased to 0.5V? And to 1V?**
c) **Assuming an $\lambda = 0.1V^{-1}$, what is the value of the current I_D obtained when v_{DS} is increased to 0.5V? And to 1V?**