# Field-Effect Transistors

=> Amplifiers & logic switches

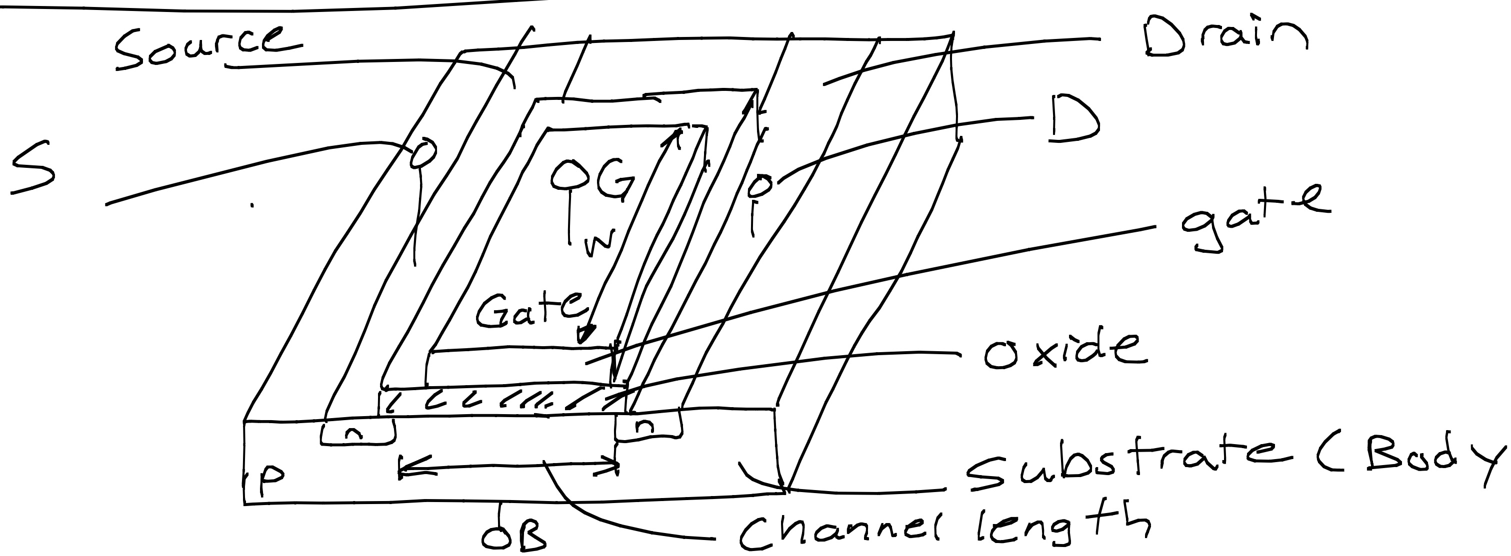
Main Types

=> Enhancement mode Metal-Oxide Semiconductor
Field-Effect Transistor (MOSFET)

=> Depletion mode MOSFET

=> Junction Field-Effect Transistor (JFET)

## n-channel Enhancement Mode MOSFET

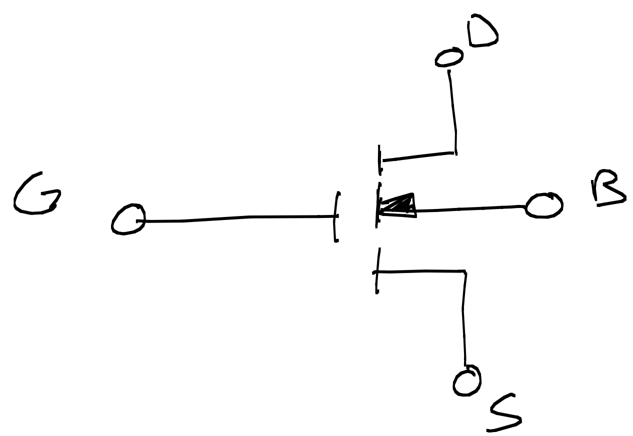


## Terminals

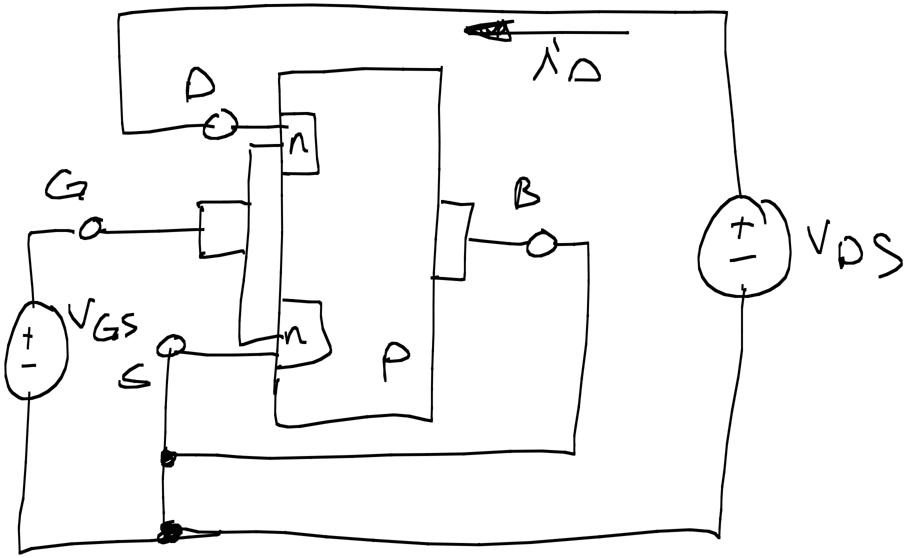
Source (S)
Gate (G)
Drain (D)
Body (B)

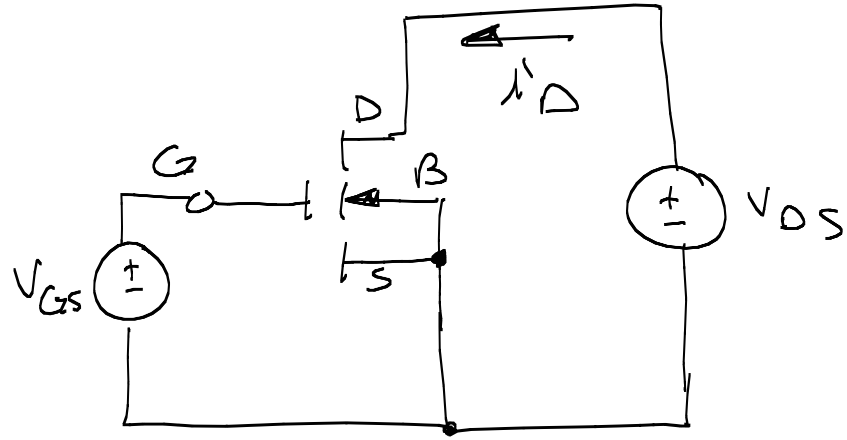
Channel Length => 0.2 to 10 $\mu m$
Width (W) => 0.05 to 0.1 $\mu m$
Oxide => Silicon dioxide
Gate => Use to be Aluminum
Now polysilicon

## Circuit Symbol




## Operation in the Cutoff Region




pn-junctions => Drain-Body, Source-Body

$v_{DS}$ => Causes the Drain-Body to go into Reverse Bias => $i_D = 0$ (Cutoff Region)

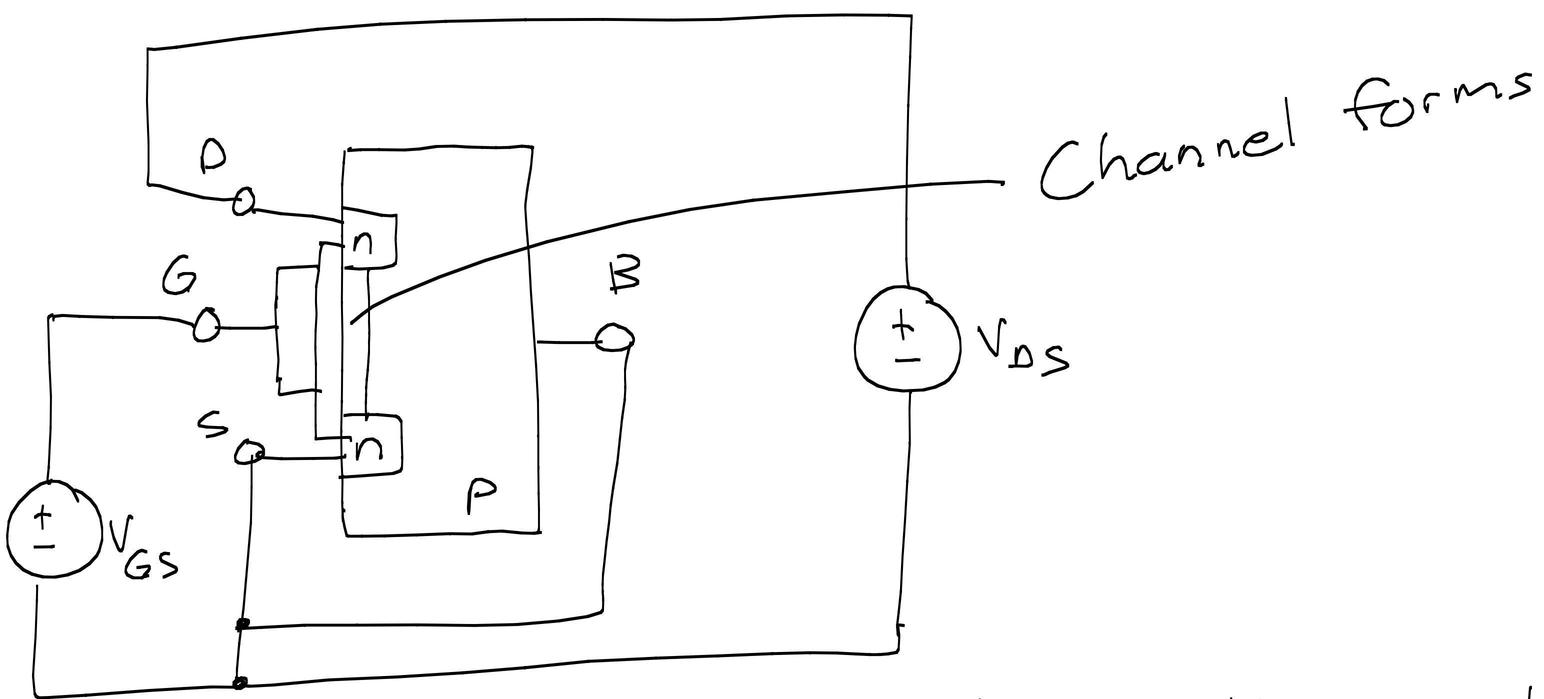
The device will remain in cutoff until $v_{GS}$ reaches a voltage called the threshold voltage. $V_{to}$

$$i_D = 0 \quad \text{for} \quad v_{GS} \le V_{to}$$

Cutoff

# Triode Region

$V_{GS}$ exceeds the threshold voltage




As $V_{GS}$ increases => Electric Field => n-type channel is formed between the drain and the source

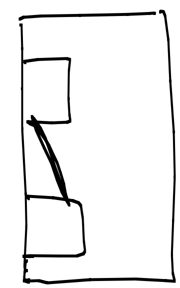
=> Current Flows into the drain, and out the source

=> Related the excess gate voltage

=> $V_{GS} - V_{to}$

=> As $v_{DS}$ increases, $i_D$ increases more slowly

=> Channel "pinches" down on the drain end



## Triode Region

$$V_{GS} > V_{to} \qquad V_{DS} < V_{GS} - V_{to}$$

$$i_D = K\left[2(V_{GS} - V_{to})V_{DS} - V_{DS}^2\right]$$

$$K = \left(\frac{W}{L}\right)\frac{KP}{2}$$

W = width of the gate

L = Channel length

$$KP = \mu_n C_{ox}$$

$\mu_n$ = surface mobility

$C_{ox}$ => Capacitance of the gate per unit area

For n-channel enhancement device

$$KP = 50\ \mu A/V^2$$

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Saturation Region

Channel goes to zero at the drain end

$V_{DS}$ => Increases => $i_D$ is constant

$$v_{GS} > V_{to} \qquad v_{DS} \geq v_{GS} - V_{to}$$

$$i_D = K\,(v_{GS} - V_{to})^2$$