Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

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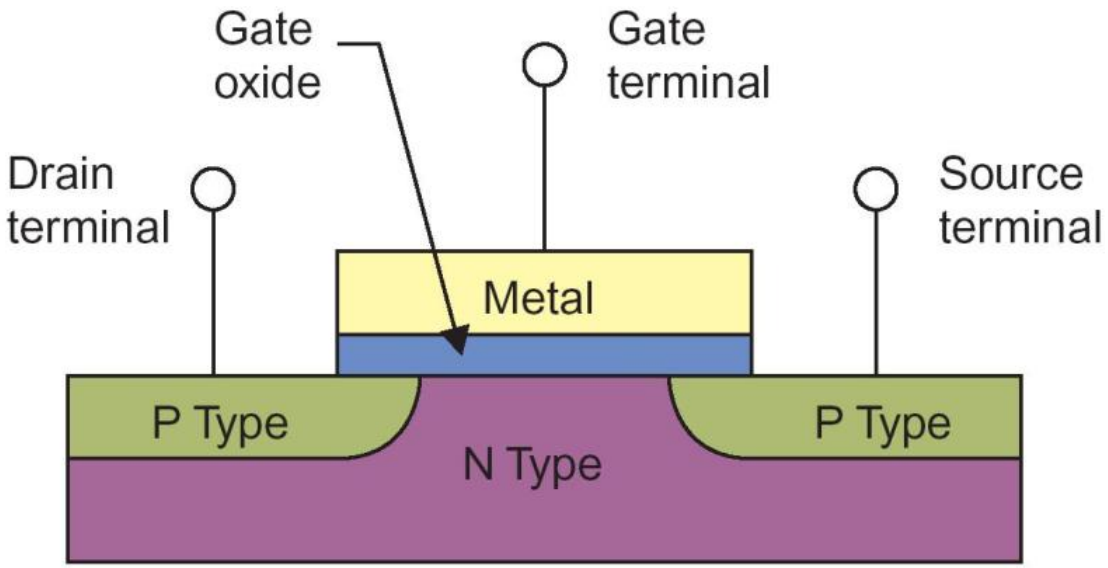
Introduction

- Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is another type of transistor mostly used in electronics world.
- Main different from BJT – there is no actual PN junction as the Pand N materials are insulated from each other. MOSFETs are static sensitive devices and must be handled by appropriate means.
- There are 2 types of MOSFET's:
- Depletion mode MOSFET (D-MOSFET)
  - Operates in Depletion mode when $V_{GS} \leq 0$
  - Operates in Enhancement mode like E-MOSFET when $V_{GS} > 0$
- Enhancement Mode MOSFET (E-MOSFET)
  - Operates in Enhancement mode
  - $I_{DSS} = 0$ until $V_{GS} > V_T$ (threshold voltage)

Basic Construction of MOSFET

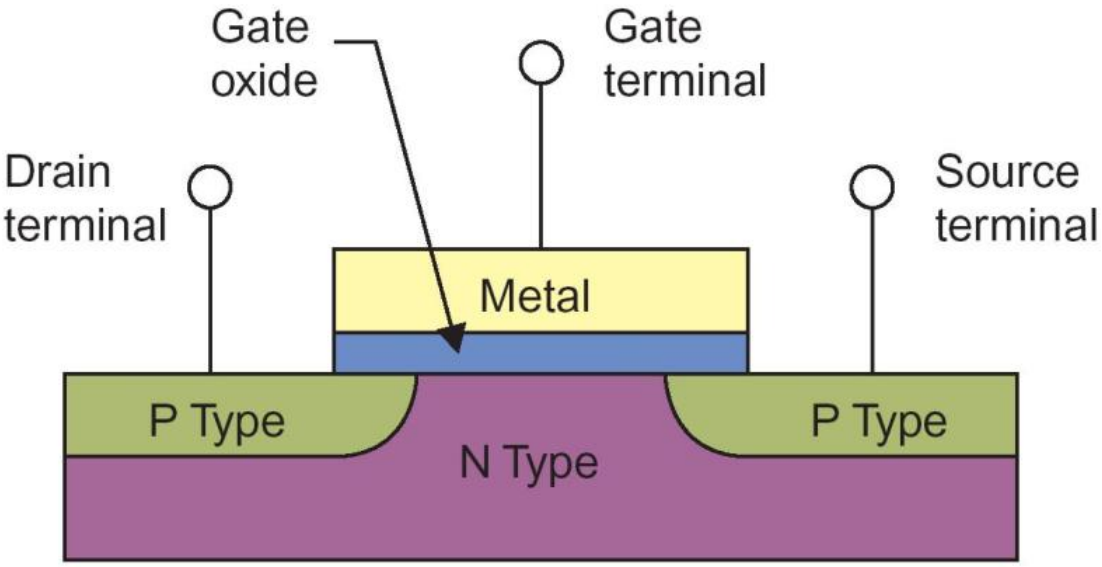
- MOSFET transistor have metal gates which are insulated from semiconductor by a layer of SiO_2 or other dielectric.
- The insulated gate prevented the current from applied gate voltage flowing through the gate.



- Metal terminal
- Oxide insulator
- Semiconductor material creating the source-drain channel

N and P channel of MOSFET

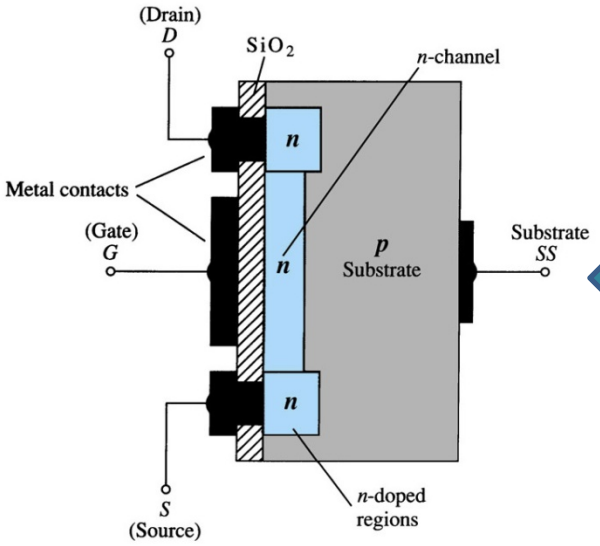
- If the MOSFET is an N-channel or N-MOSFET , then the source and drain are 'n+' regions and the body is a 'p' region.
- If the MOSFET is a p-channel or P-MOSFET , then the source and drain are 'p+' regions and the body is a 'n' region.



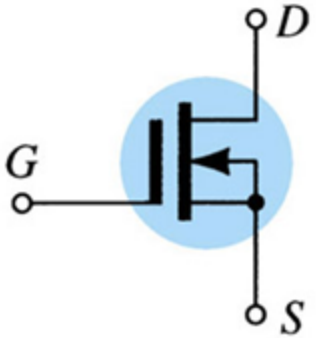
Depletion Mode MOSFET (D-MOSFET)

- Continues channel of N-type material between the source and the drain
- A voltage placed across the source and drain induce current flow.
- The gate, G is connected to metal eg: aluminum which is insulated from the channel by a thin layer of insulator eg: Silicon dioxide.
- The three layers led to the device name:
  (ii) Metal (ii) Oxide (iii) Semiconductor

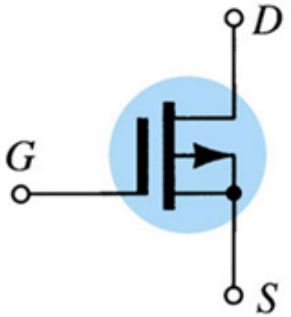
•Arrow pointing position indicate the MOSFET type (n or p)
• The line with arrow indicate connection between source and drain.



SYMBOL



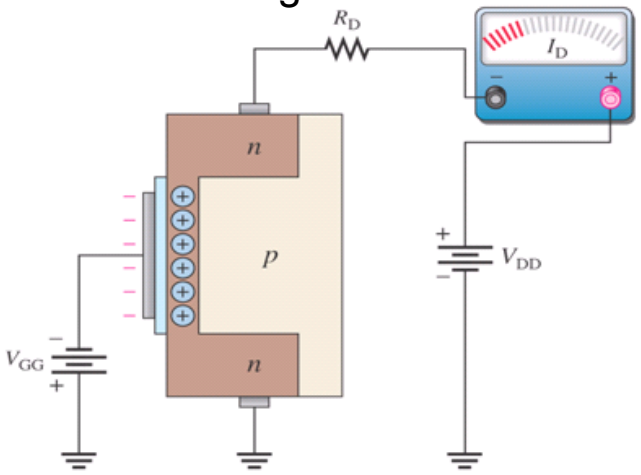
N-CHANNEL



P-CHANNEL

Depletion Mode D-MOSFET Biasing Operation

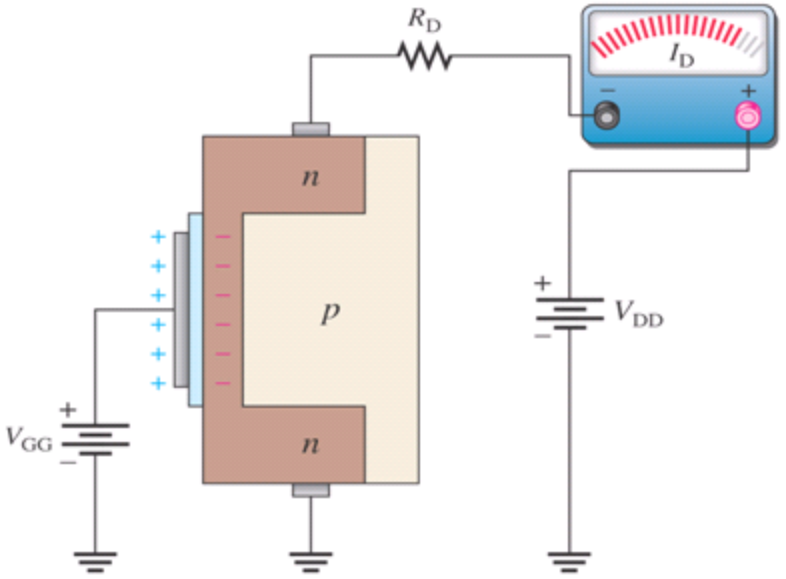
- The N-channel should be biased more positive than the source so current flow from drain to source.
- The gate terminal, V_{GG} is applied with negative bias voltage to from a depletion region.
- The –VGG will push the majority carrier inside the N channel and pull the holes inside the P-type substrate.
- Recombination will occur and cause the number of free electrons at the N channel to decrease. The channel conductivity is decreased
- Further increasing the negative voltage at the gate pushes even more electrons away, narrowing the channel and decreasing the current



(a) Depletion mode: V_{GS} negative and less than $V_{GS(off)}$

Enhancement Mode D-MOSFET Biasing Operation

- V_{GG} is applied with positive voltage.
- The +VGG will attract electrons from p-substrate to the n –channel repelled holes.
- The number of free electron at the N-channel increase and channel conductivity will also increase.

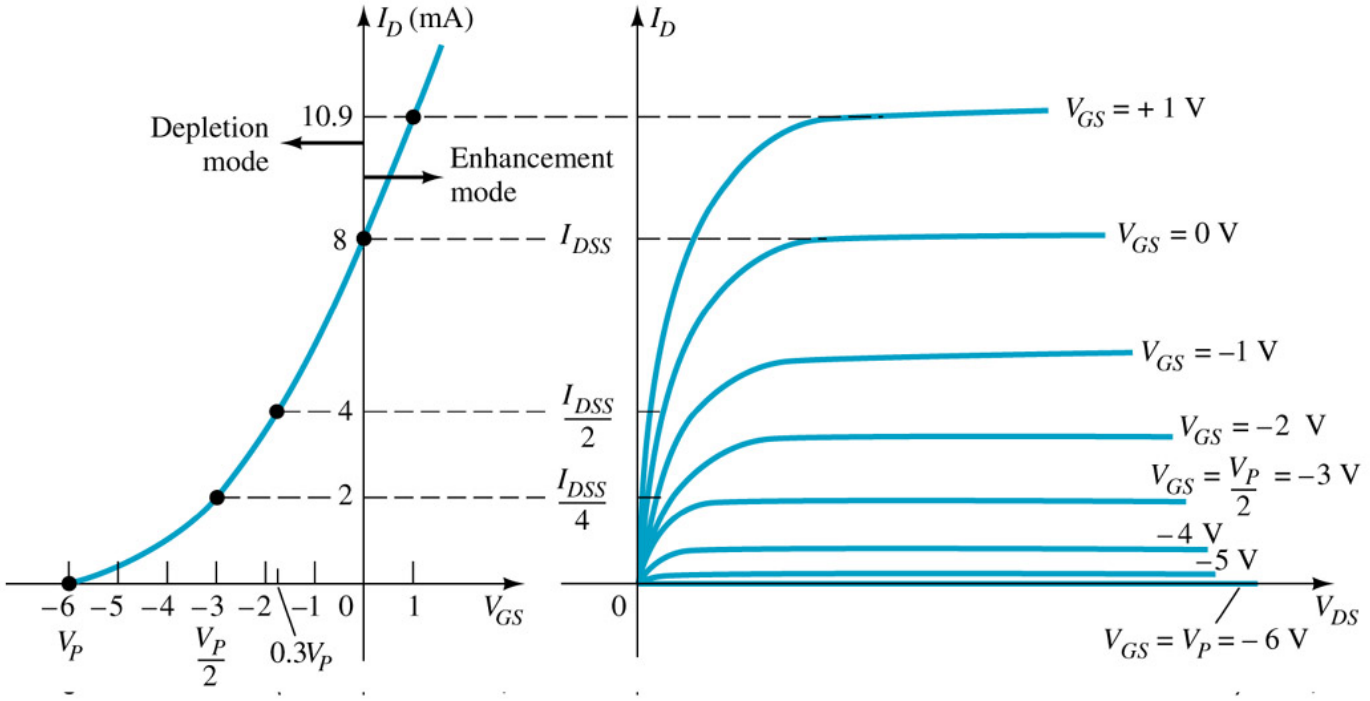


(b) Enhancement mode: V_{GS} positive

D-MOSFET CHARACTERISTIC (N-TYPE)

A D-MOSFET may be biased to operate in two modes:
the **Depletion** mode or the **Enhancement** mode

IF P-TYPE?

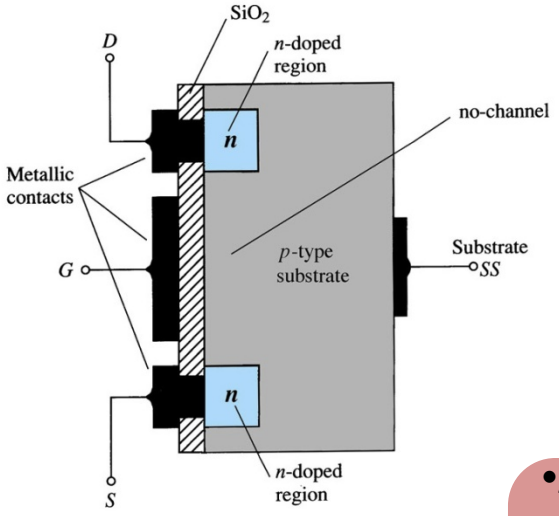


When $V_{GS} = 0V$, $I_D = I_{DSS}$
When $V_{GS} < 0V$, $I_D < I_{DSS}$
When $V_{GS} > 0V$, $I_D > I_{DSS}$

Enhancement MOSFET

Enhancement Mode MOSFET (E-MOSFET)

- The Drain (D) and Source (S) connect to the to n-doped regions
- These n-doped regions are not connected via an n-channel without an external voltage
- The Gate (G) connects to the p-doped substrate via a thin insulating layer of SiO_2



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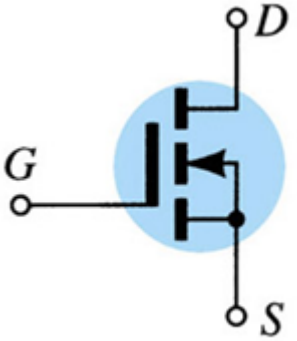
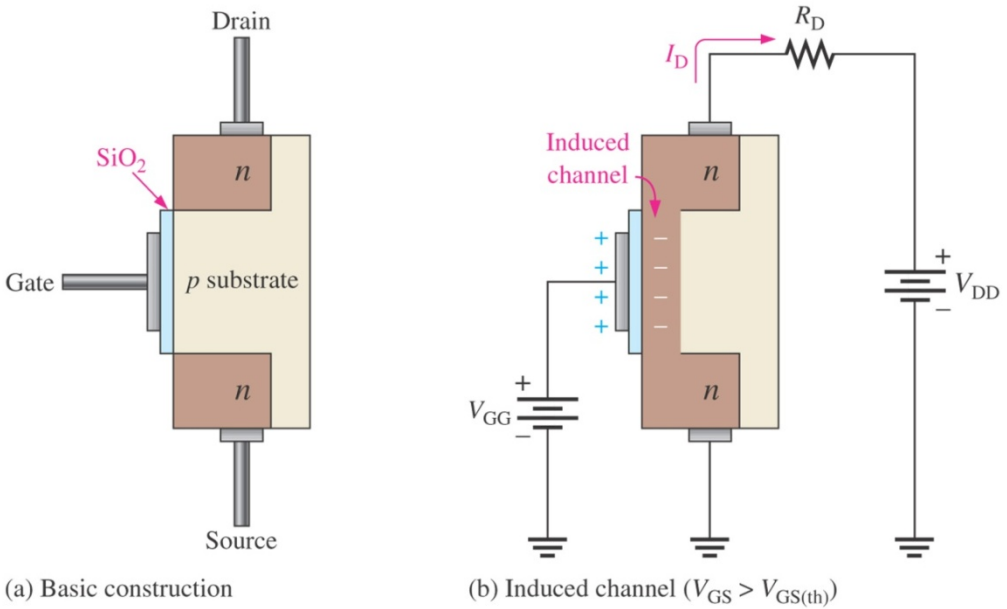


N-CHANNEL

•Arrow pointing position indicate the MOSFET type (n or p)
• The dotted line with arrow indicate connection between source and drain.

E-MOSFET Biasing Operation



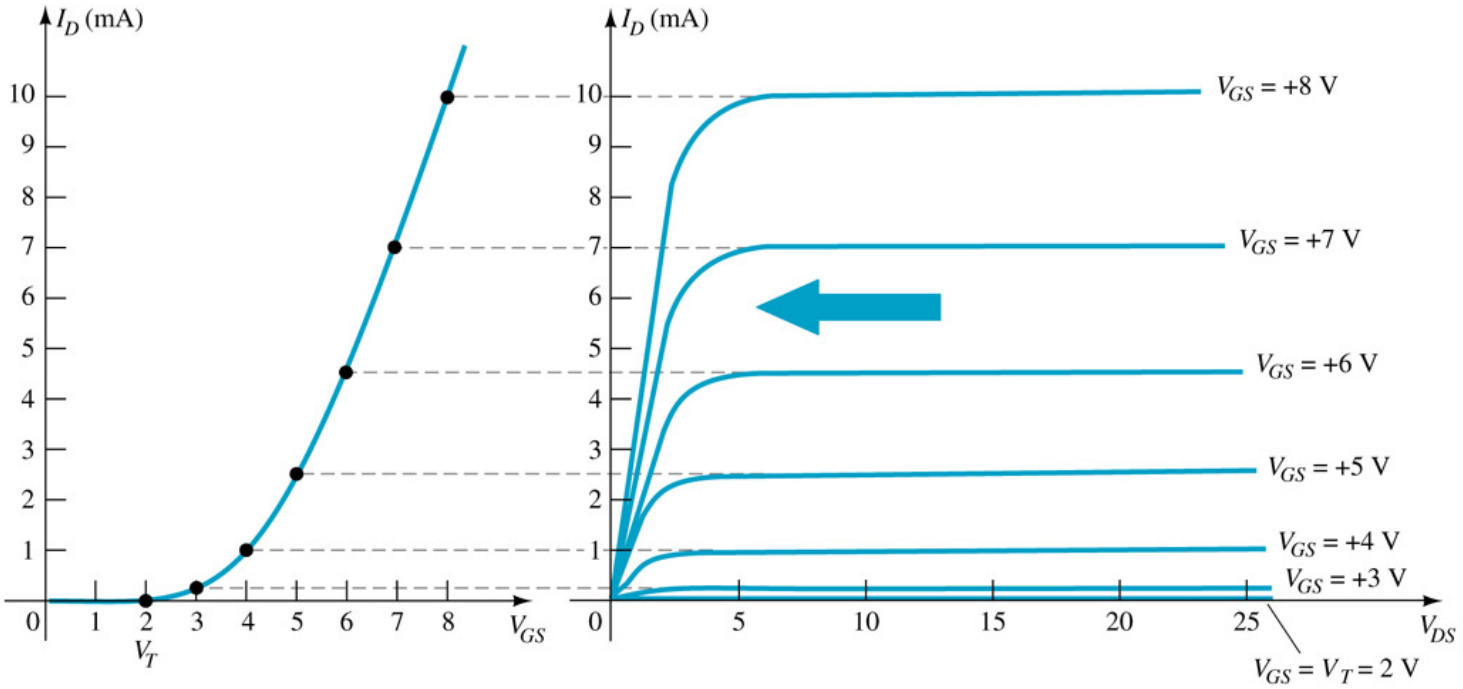
(a) Basic construction

(b) Induced channel ($V_{GS} > V_{GS(th)}$)

- When positive gate voltage is applied, the gate capacitance charges to the value of the gate to source voltage.
- The +VGG will attract electron and accumulate in the region near the surface of the SiO2
- The holes repelled by the positive voltage to the p-subtrate.
- As the magnitude of the bias increase, the concentration near the SiO2 surface increase thus induce the n-type material called n-inversion layer region to bridge the source and drain Current flow from source to drain.

N-Channel Enhancement Mode MOSFET

The Enhancement mode MOSFET only operates in the enhancement mode.



V_{GS} is always positive

$I_{DSS} = 0$ when $V_{GS} < V_T$

As V_{GS} increases above V_T, I_D increases

If V_{GS} is kept constant and V_{DS} is increased, then I_D saturates (I_{DSS})

The saturation level, V_{DSsat} is reached.

P-Channel Enhancement Mode MOSFET

The p-channel Enhancement mode MOSFET is similar to the n-channel except that the voltage polarities and current directions are reversed.