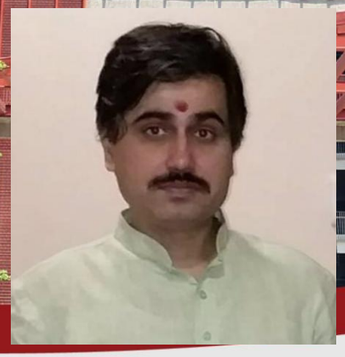
Analog Electronic Circuits
(UEC301)

By



Dr.Mayank Kumar Rai
Associate Professor,
ECED,TIET,Patiala

Thapar Institute of Engineering & Technology
(Deemed to be University)
Bhadson Road, Patiala, Punjab, Pin-147004
Contact No. : +91-175-2393201
Email : info@thapar.edu

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Subject: Analog Electronic Circuits (UEC301)

Faculty name: Dr. Mayank Kumar Rai (Associate Professor & Course Coordinator)

Topic of today's Lecture : ***Metal Oxide Semiconductor Field Effect Transistor (MOSFET)***

Key points

- ✓ **Difference between BJT and MOSFET**
- ✓ **MOSFET Types and symbols**
- ✓ **Basic Construction and operation of enhancement type NMOS**
- ✓ **Transfer Characteristics**

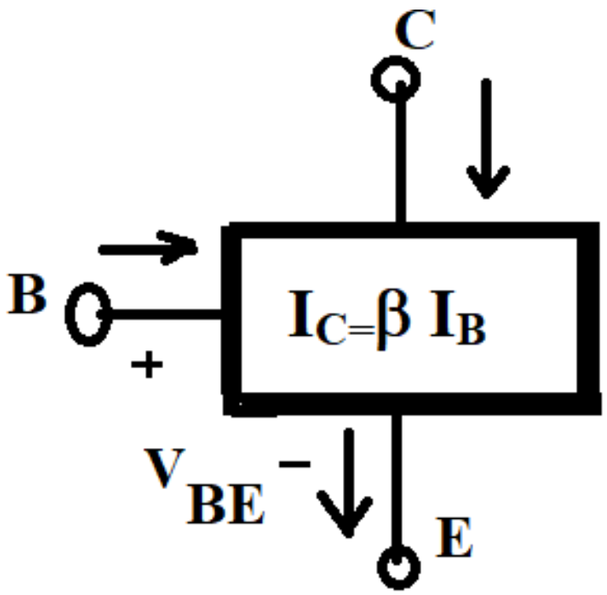
Contents of this lecture are based on the following books:

- *Jacob Milman & and C.C.Halkias,* ***"Integrated Electronics Analog and Digital Circuit and Systems"****Second Edition.*
- *Adel S. Sedra & K. C. Smith,* ***"MicroElectronic Circuits Theory and Application"*** *Fifth Edition.*
- *Robert L. Boylestad & L. Nashelsky,* ***"Electronic Devices and Circuit Theory"*** *Eleventh Edition.*

Difference between BJT and MOSFET

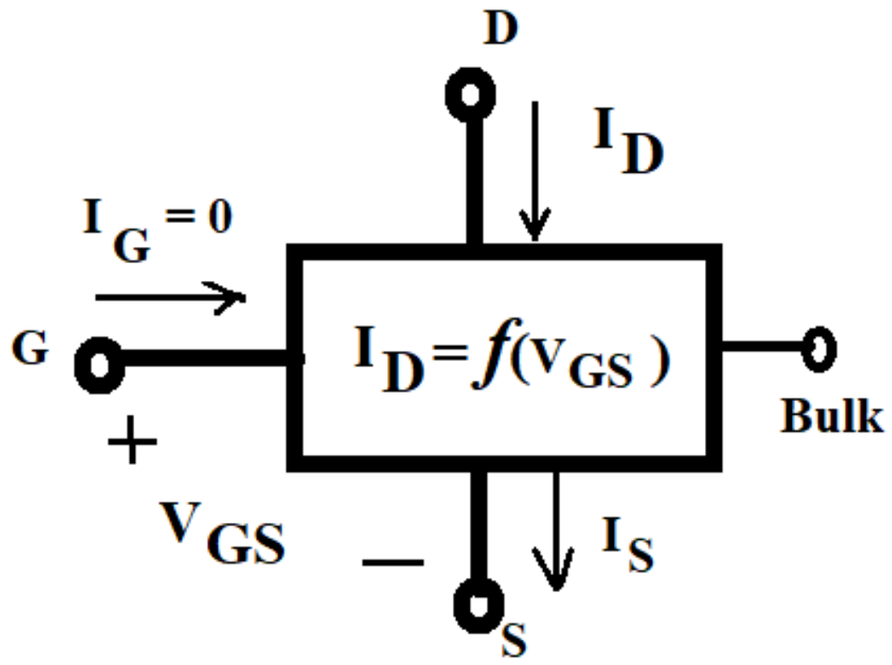
BJT

- Current Controlled current Device
- Input impedance is very small
- Bipolar
- Types: n-p-n and p-n-p



MOSFET

- Voltage controlled Current device
- Input impedance is very high
- Unipolar
- Types: Depletion and enhancement type



MOSFET Types and Symbols

- ✓**Depletion type**
  (n-channel and p-channel)
- ✓**Enhancement type**
  (n-channel and p-channel)

- ❖***n-channel depletion and p-channel depletion***
- ❖***n-channel enhancement mode and p-channel enhancement mode***

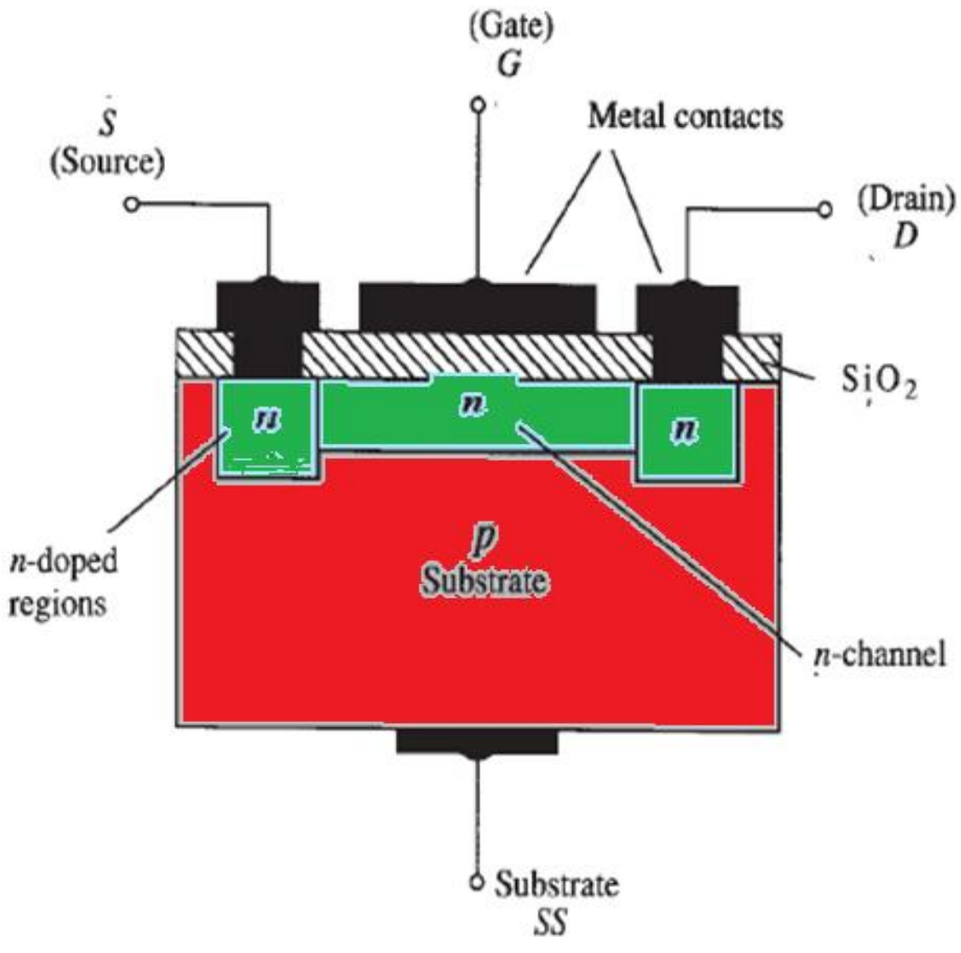


Figure 1 :The n- channel depletion type MOSFET.

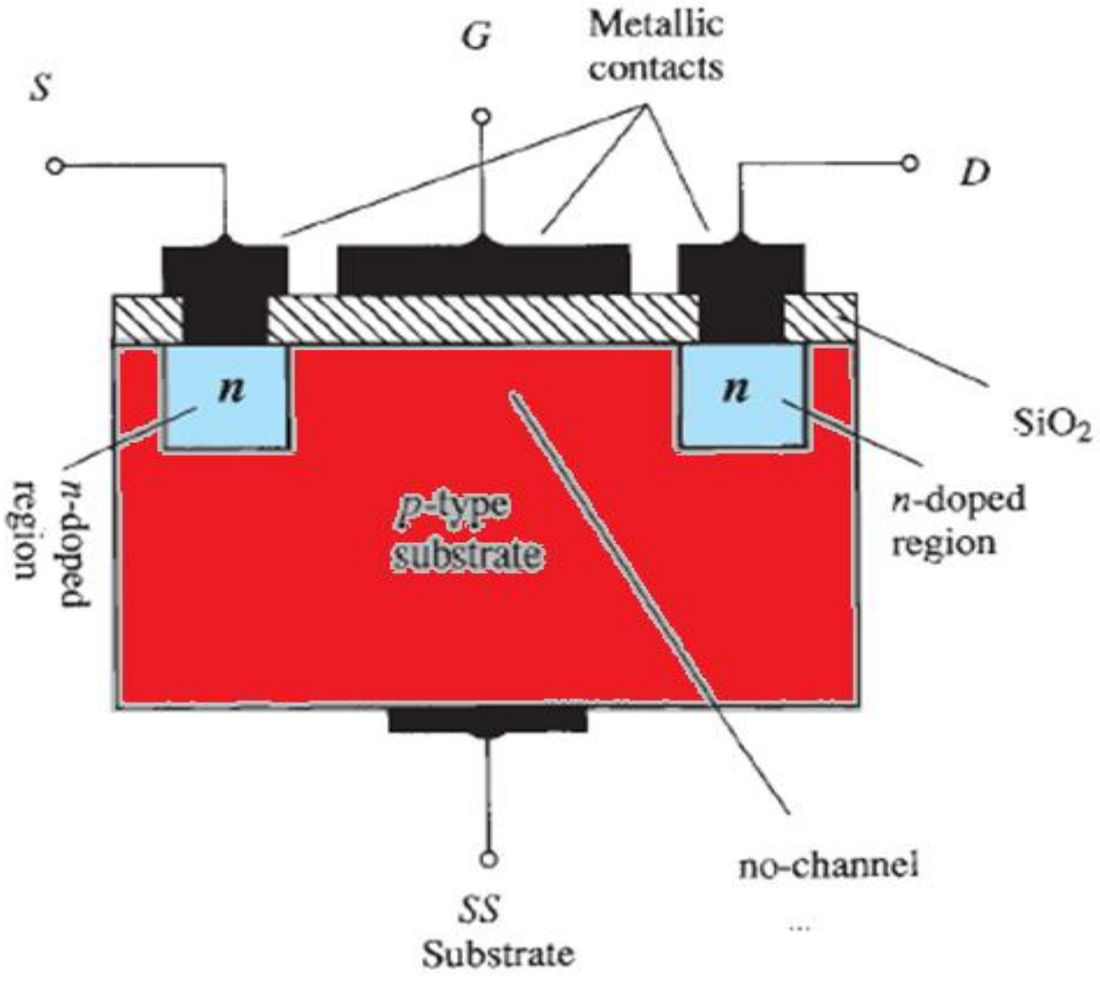
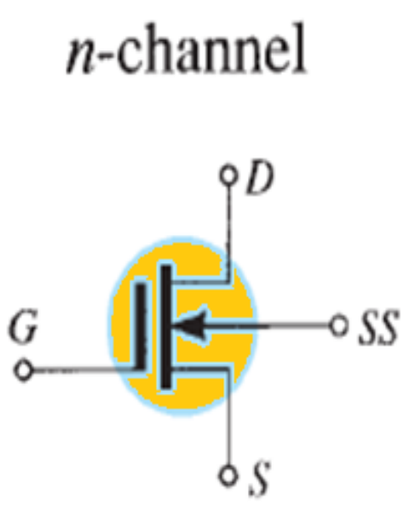
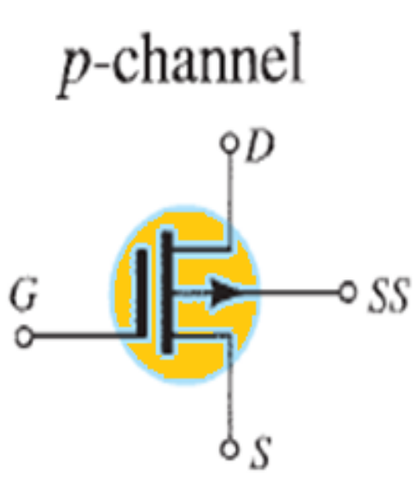
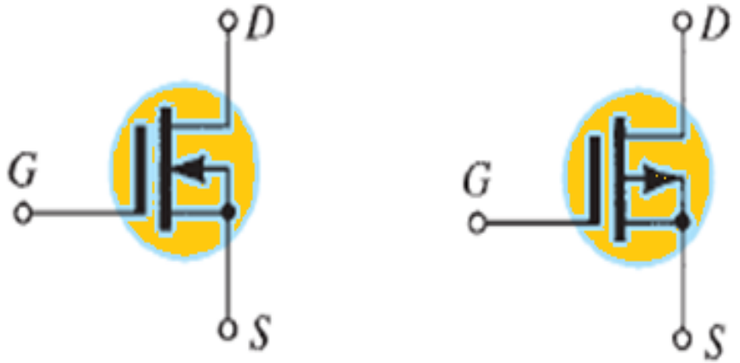


Figure 2 :The n- channel enhancement type MOSFET.

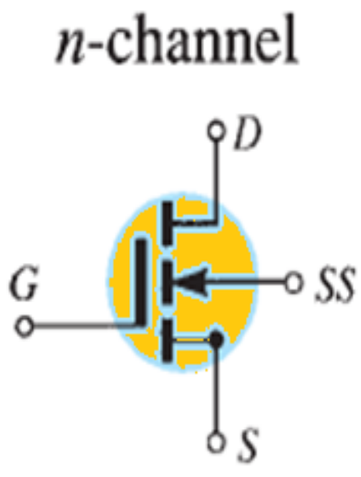
Symbols

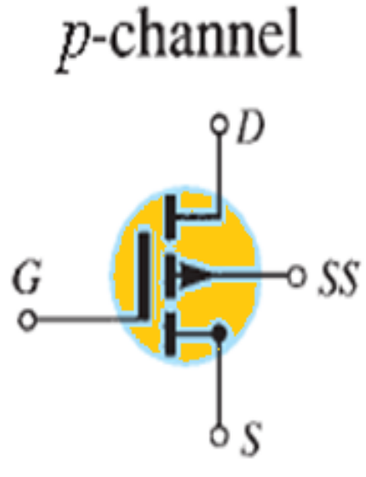


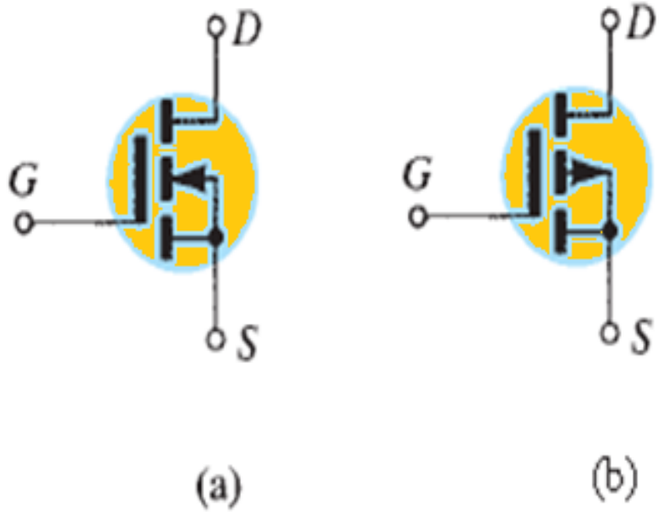




Symbols for : (a) n- channeldepletion type and (b) p-channel depletion type MOSFETs







Symbols for : (a) n-channel enhancment and (b) p-channel enhancement MOSFETs

Basic Construction of n-channel enhancement type MOSFET(NMOS)

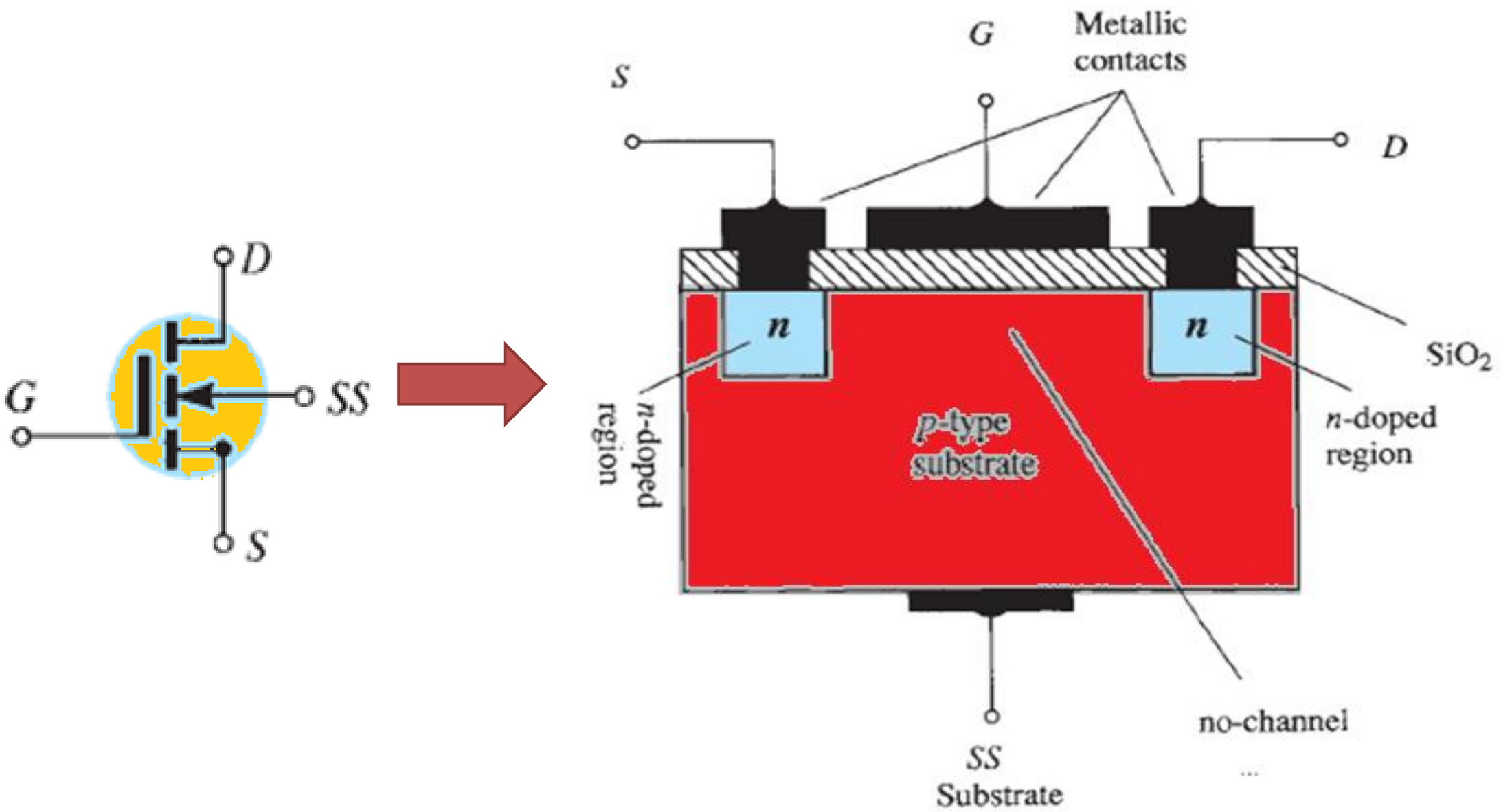


Figure 3 :The n- channel enhancement type MOSFET.

Operation of n-channel enhancement type MOSFET(NMOS)

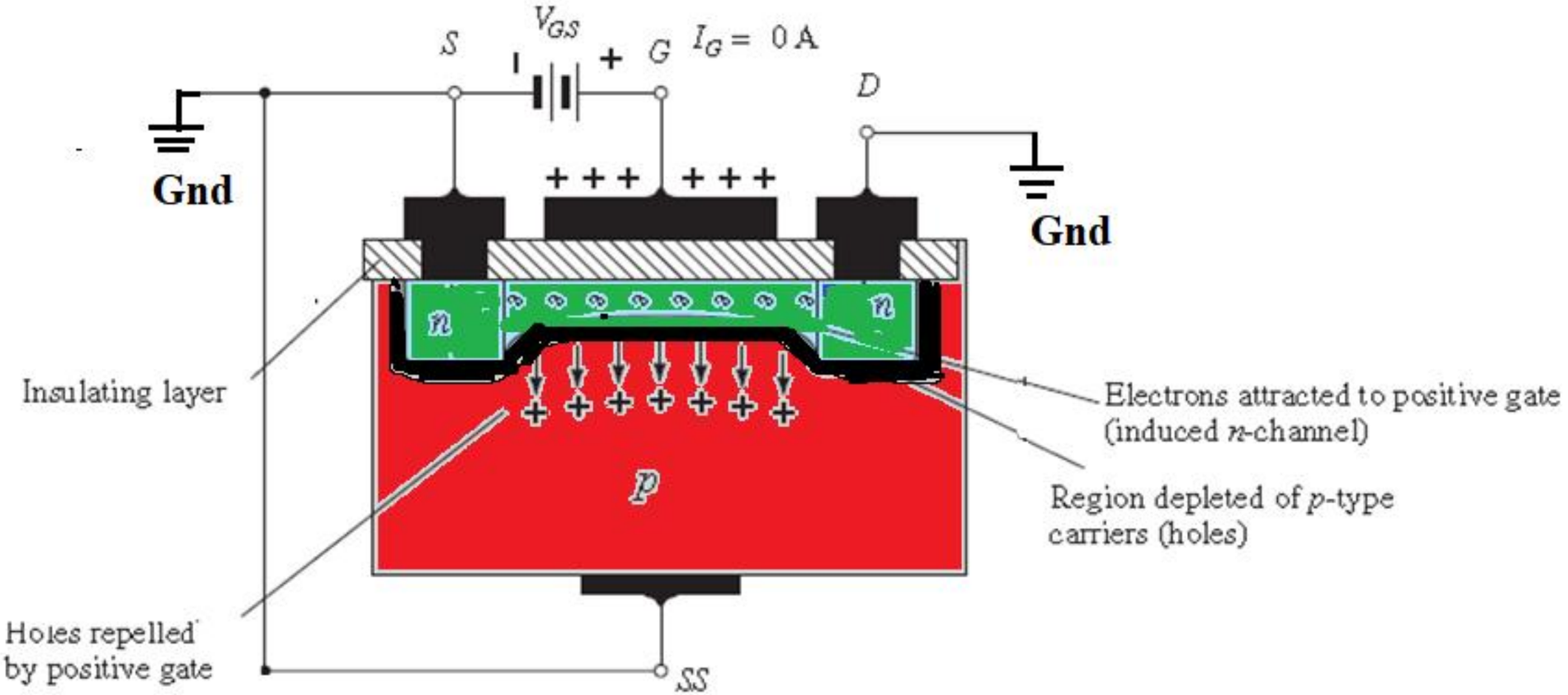


Figure 4: Channel formation in the n- channel enhancement type MOSFET.

Case-1

- ✓ $V_{GS}=V_{to}$ (threshold voltage) and $V_{DS}=0$
- ✓ $I_D=0$
- ✓ Causing an Inversion

(conducting Channel is formed between Source and Drain)

$$V_{to} = \Phi_{MS} + 2\Phi_F + \gamma\left(\sqrt{2\Phi_F}\right),$$

Where $\gamma = \left(\sqrt{2q\ N_{sub}\ \varepsilon_{si}}\right),$

$$\Phi_F = \frac{KT}{q} ln\left(\frac{N_{sub}}{n_i}\right),$$

and Φ_{MS} is the difference between the work functions of polysilicon gate and the silicon substrate

Case-2: $V_{GS} > V_{to}$ (threshold voltage) and small $V_{DS} > 0$

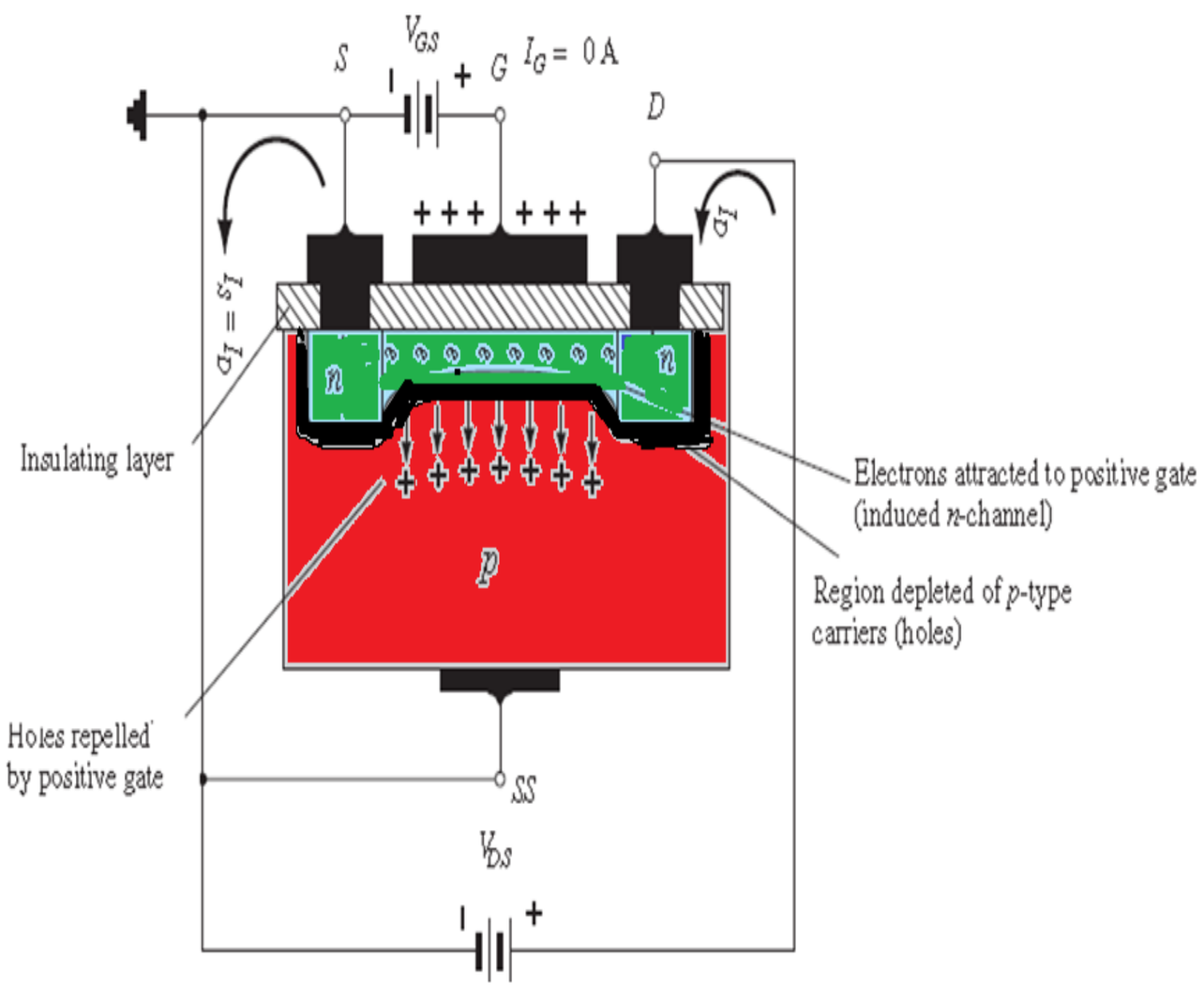


Figure 5: The n- channel enhancement type MOFET with external bias.

$$I_D = \mu_n C_{OX} \frac{W}{L}(V_{GS} - V_{to})V_{DS} - \frac{(V_{DS})^2}{2}$$

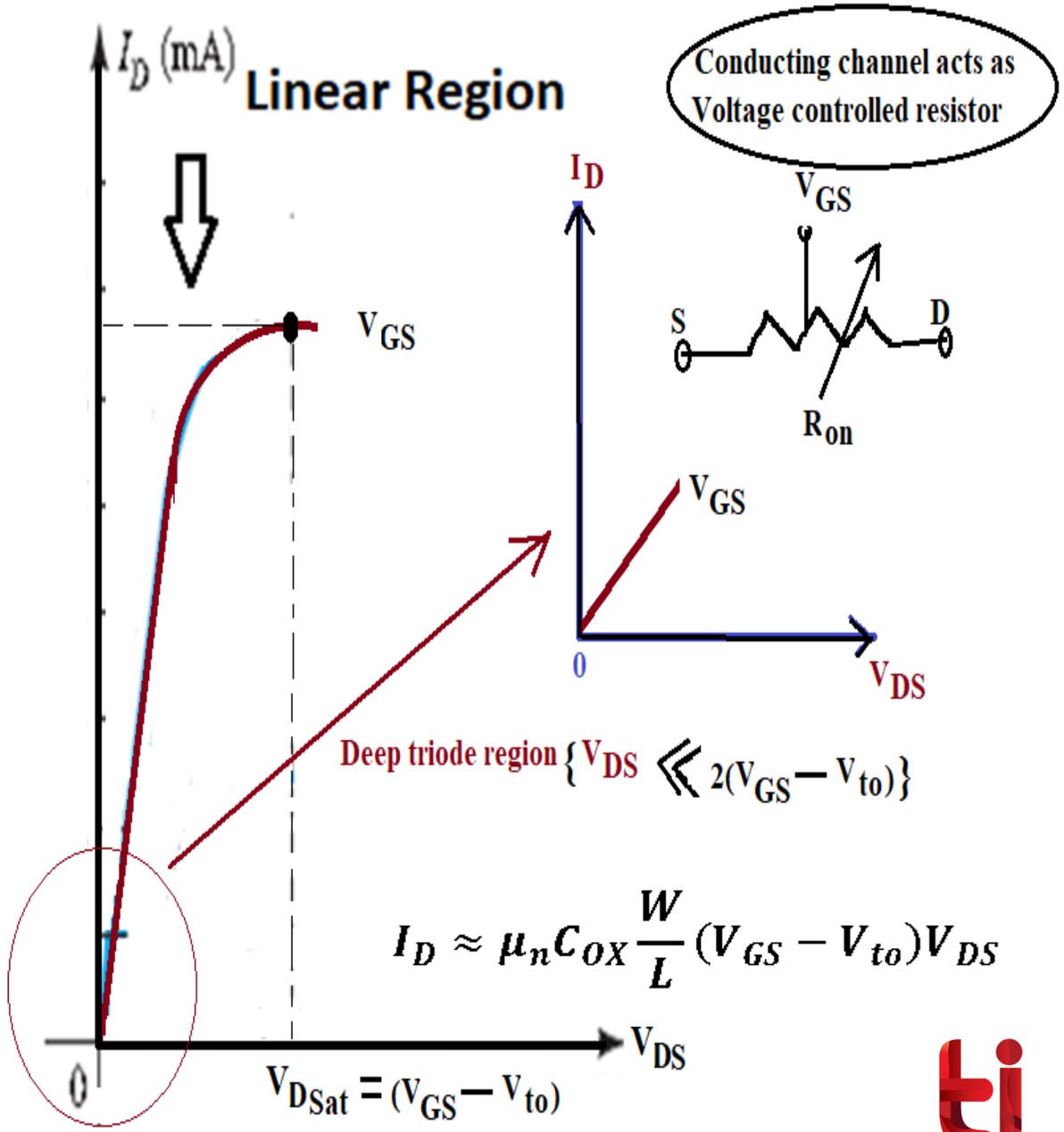


Figure 6: Linear operation of NMOS in deep triode region.

Case-3: $V_{GS}>V_{to}$ and $V_{DS}=V_{DS}$

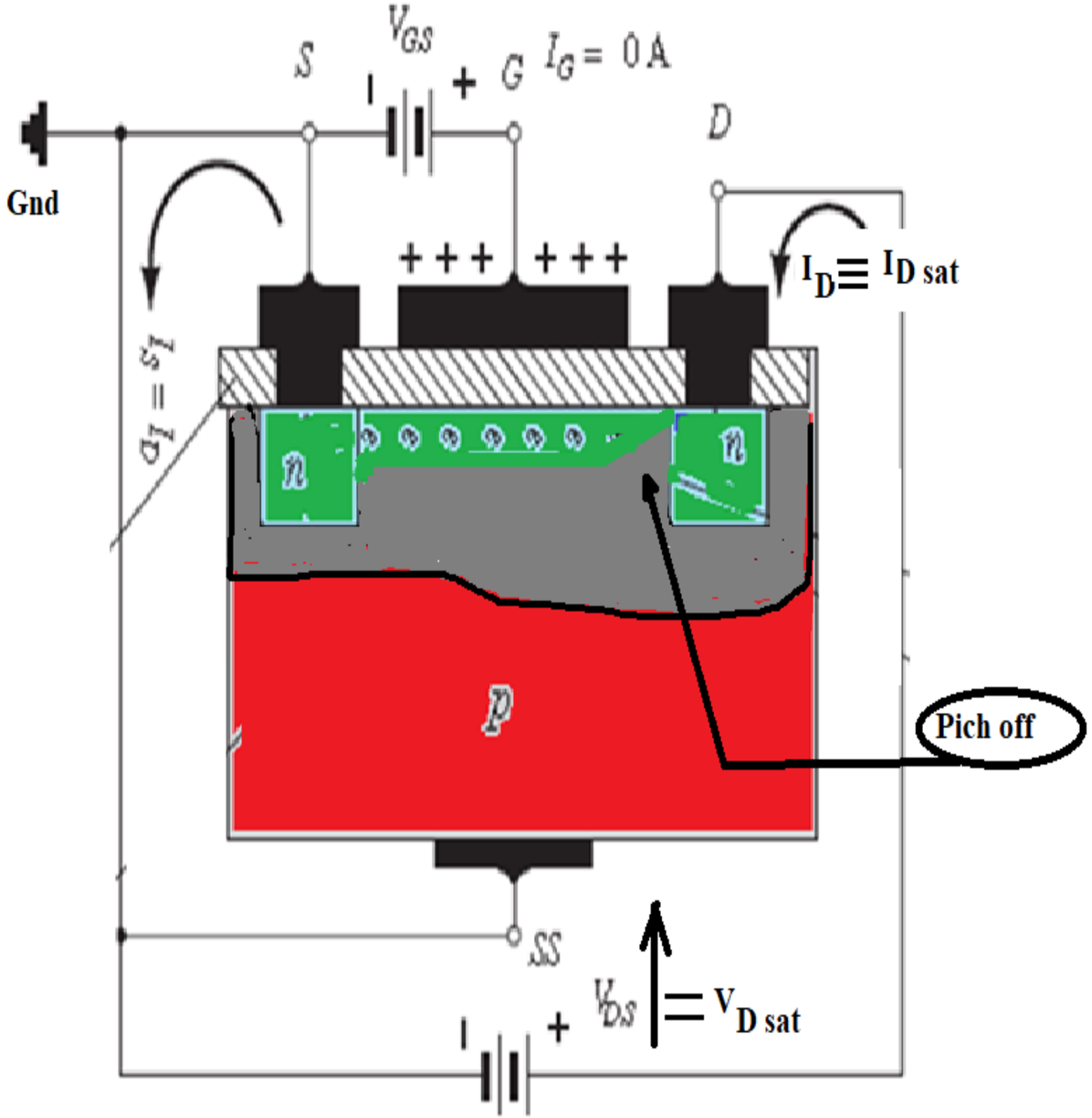


Figure7:The n- channel enhancement type MOSFET under pinch off condition.

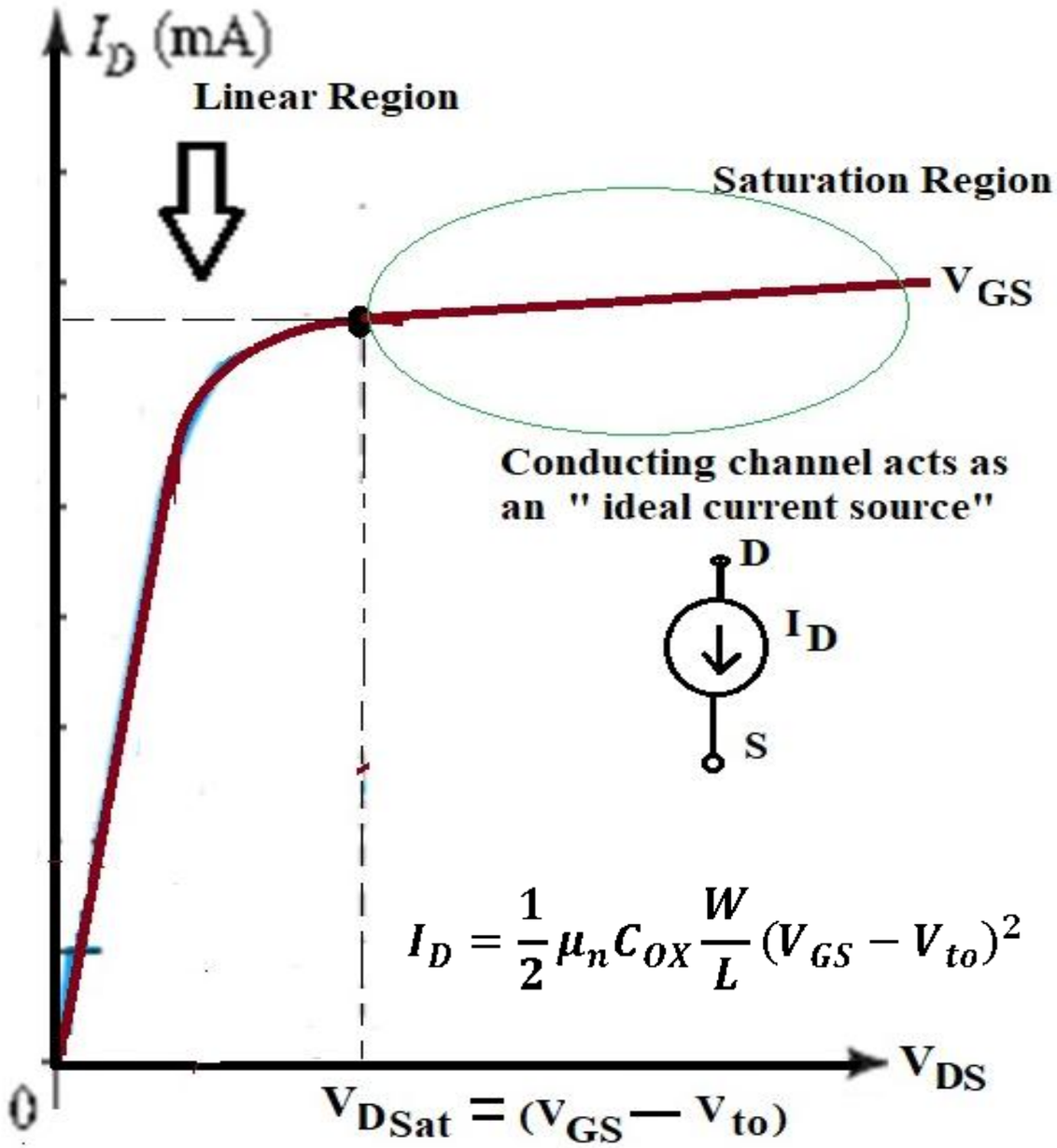


Figure 8: Operation of NMOS under Saturation region.

Case-4: $V_{GS} > V_{to}$ and $V_{DS} > V_{DS\ at}$

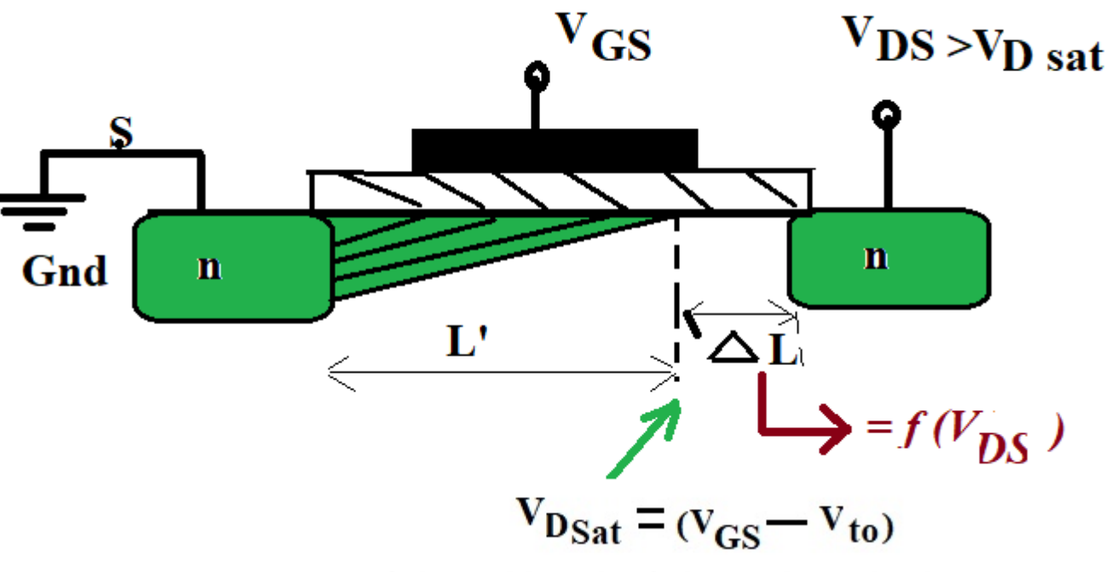
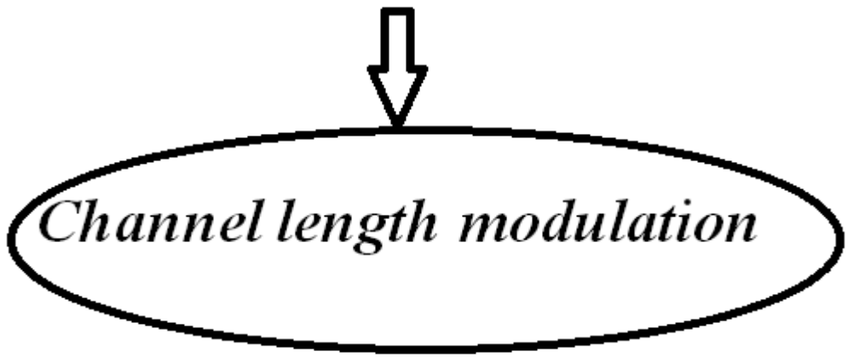


Figure 9: Variation of channel length of the n- channel enhancement type MOSFET under channel length modulation.

As V_{DS} increases further ($V_{DS} > V_{DS\ at}$),the channel gradually moves toward the source end i.e. The channel length decreases(L) with increase in V_{DS}



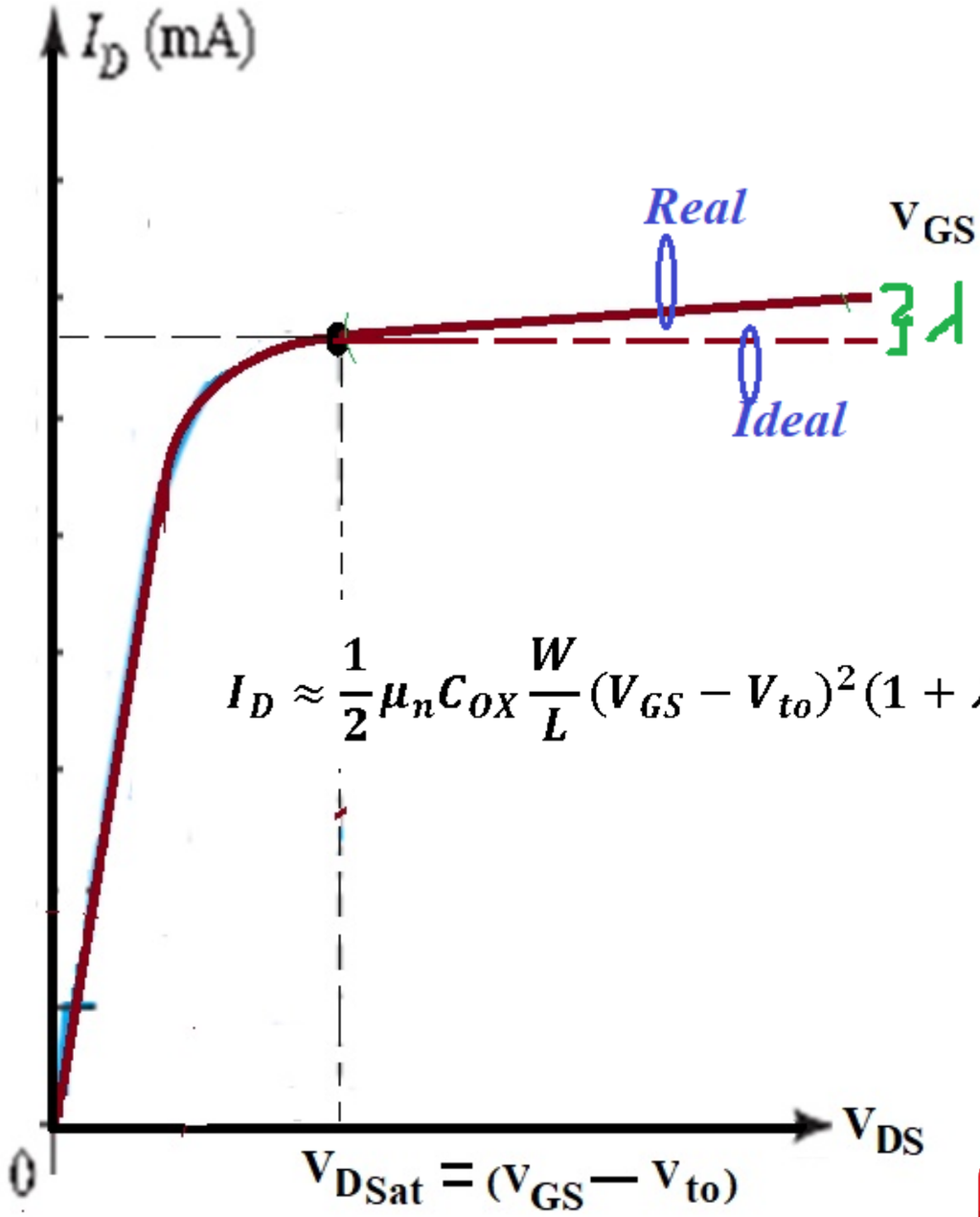


Figure 10: Output characteristic of the n- channel enhancement type MOSFET under channel length modulation.

Output characteristics of enhancement type NMOS

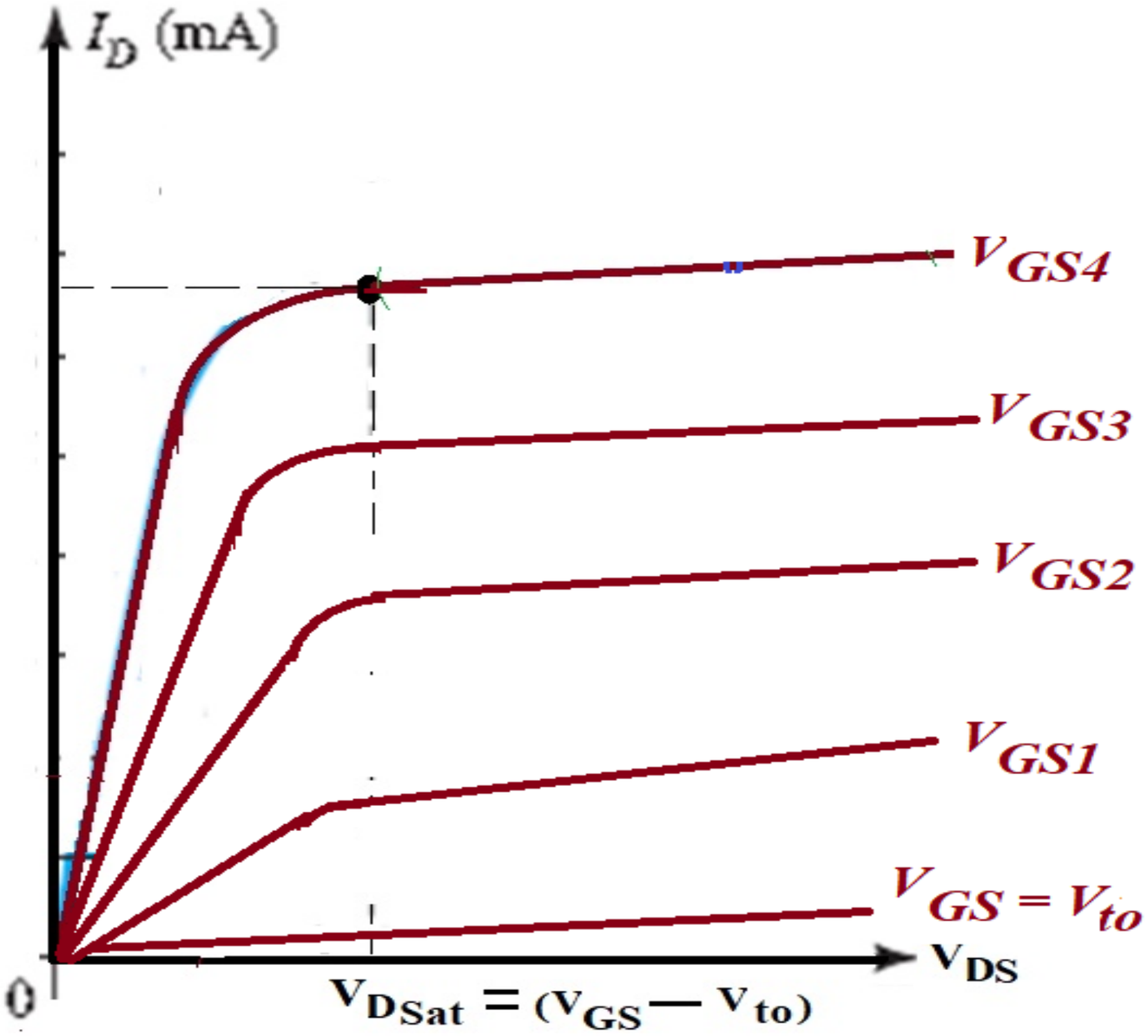
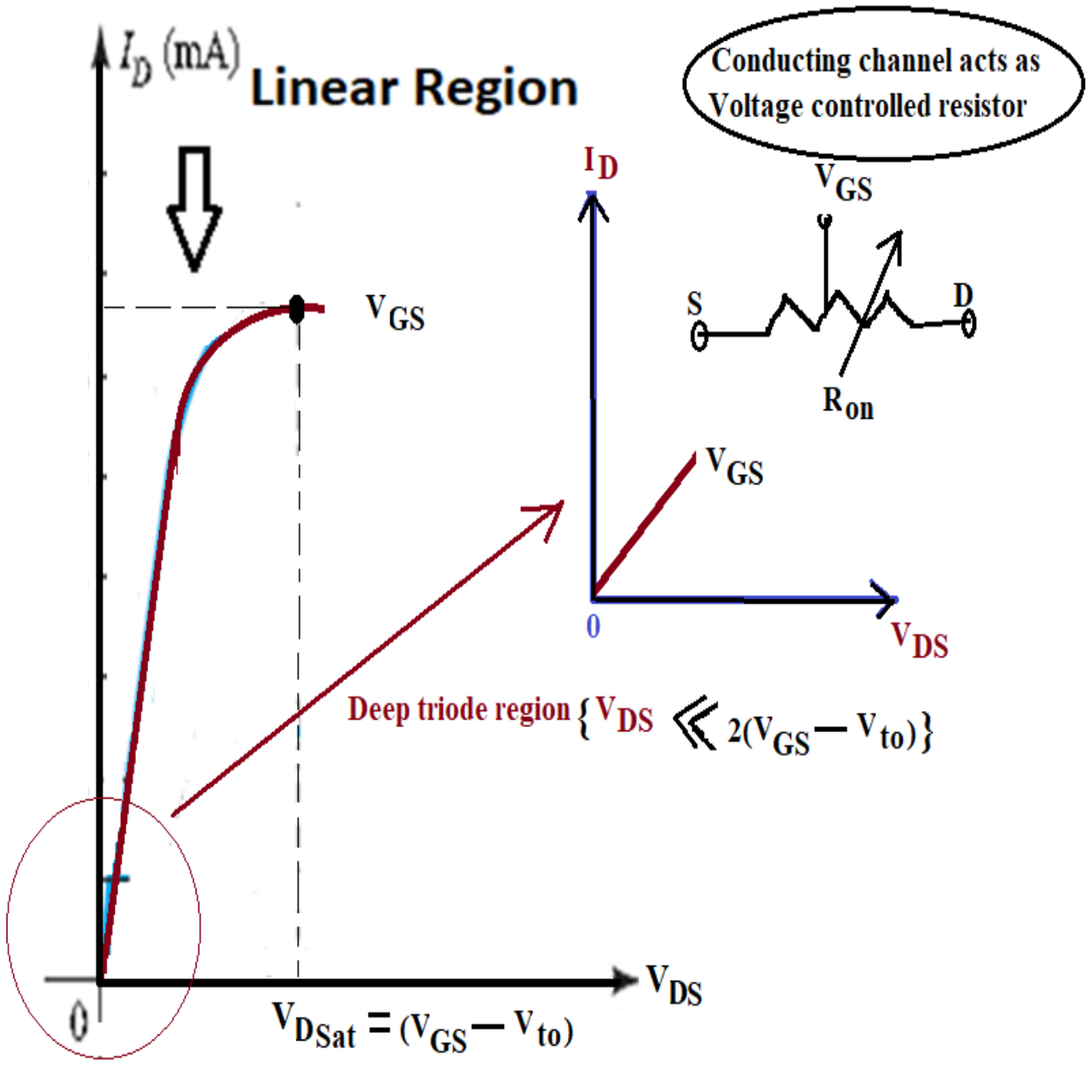
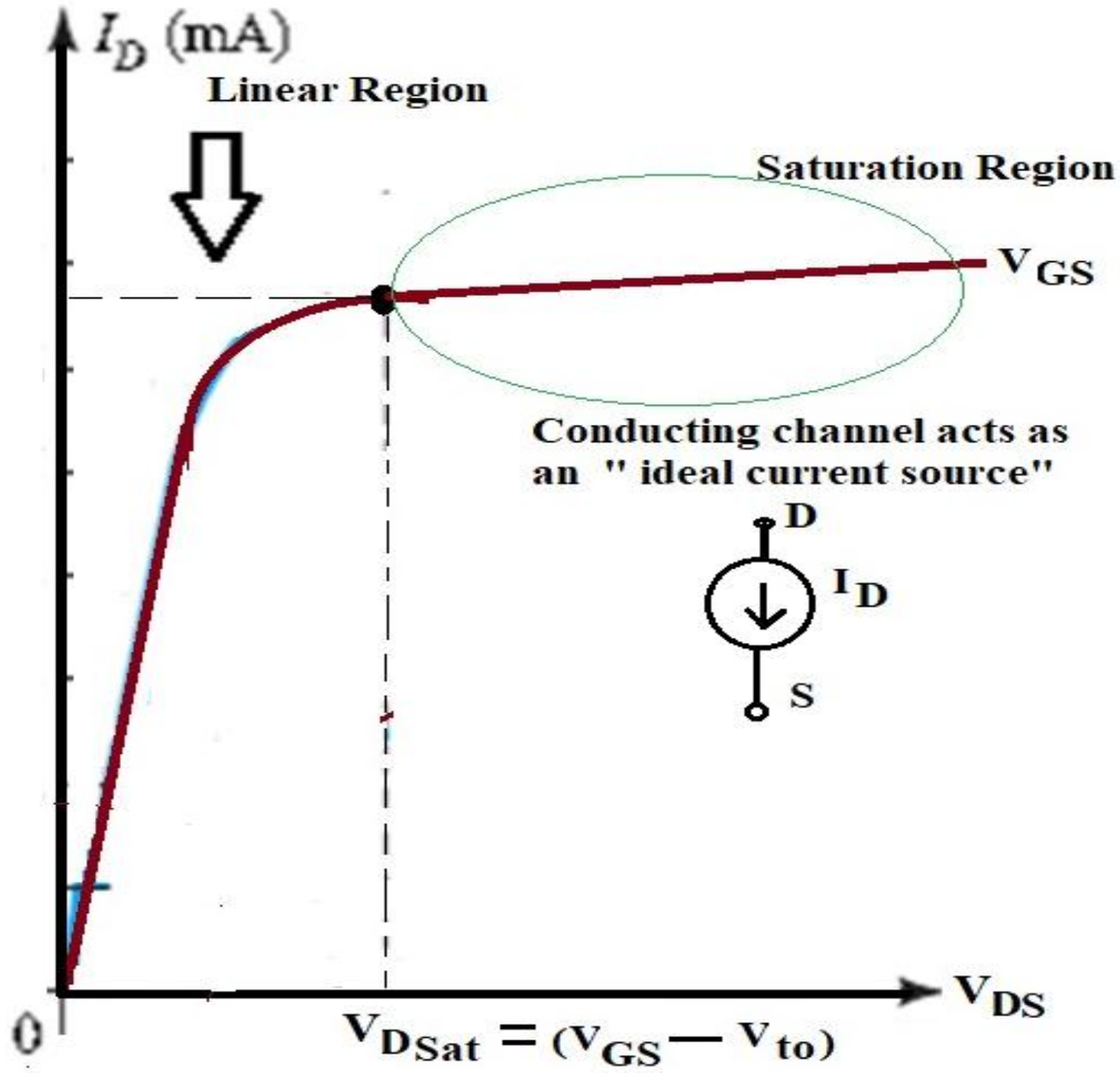


Figure 11: Output characteristics of the n- channel enhancement type MOSFET.

Summary



Triode(Linear) Region



Saturation Region

Thank You