Module-II (Basic-Electronics)

Field Effect Transistor

→ JFET - Types (JFET → Junction field effect transistor)

→ Operation and their characteristics

MOSFET's

→ Types

→ operation and their characteristics

CMOS

→ Brief Introduction to CMOS

→ Principle of operation of digital inverters.

→ VTC characteristics.

Expected Questions for internal and Semester (Assignment)

2 Q-1) Differentiate between FET and BJT ?

2 Q-2) Derive pinch-off voltage ?

2 Q-3) Differentiate between JFET & MOSFET

2 Q-5) Draw Transfer characteristic curve of n-channel and p-channel JFET.

Q-6) Draw Drain characteristics of n-channel JFET and P-channel JFET

L.Q Q-7) classify MOSFET ? with its circuit and symbol.

L.Q 8) Defference between Enhancement mode and Depletion Mode MOSFET with its circuit analysis and characteristics curve.

Field Effect Transistor (FET)

→ FET is a unipolar device, because its operation depends on the flow of either free electrons or, holes

→ FET's are more temperature stable than BJT and are much smaller than BJT therefore suitable for use in IC

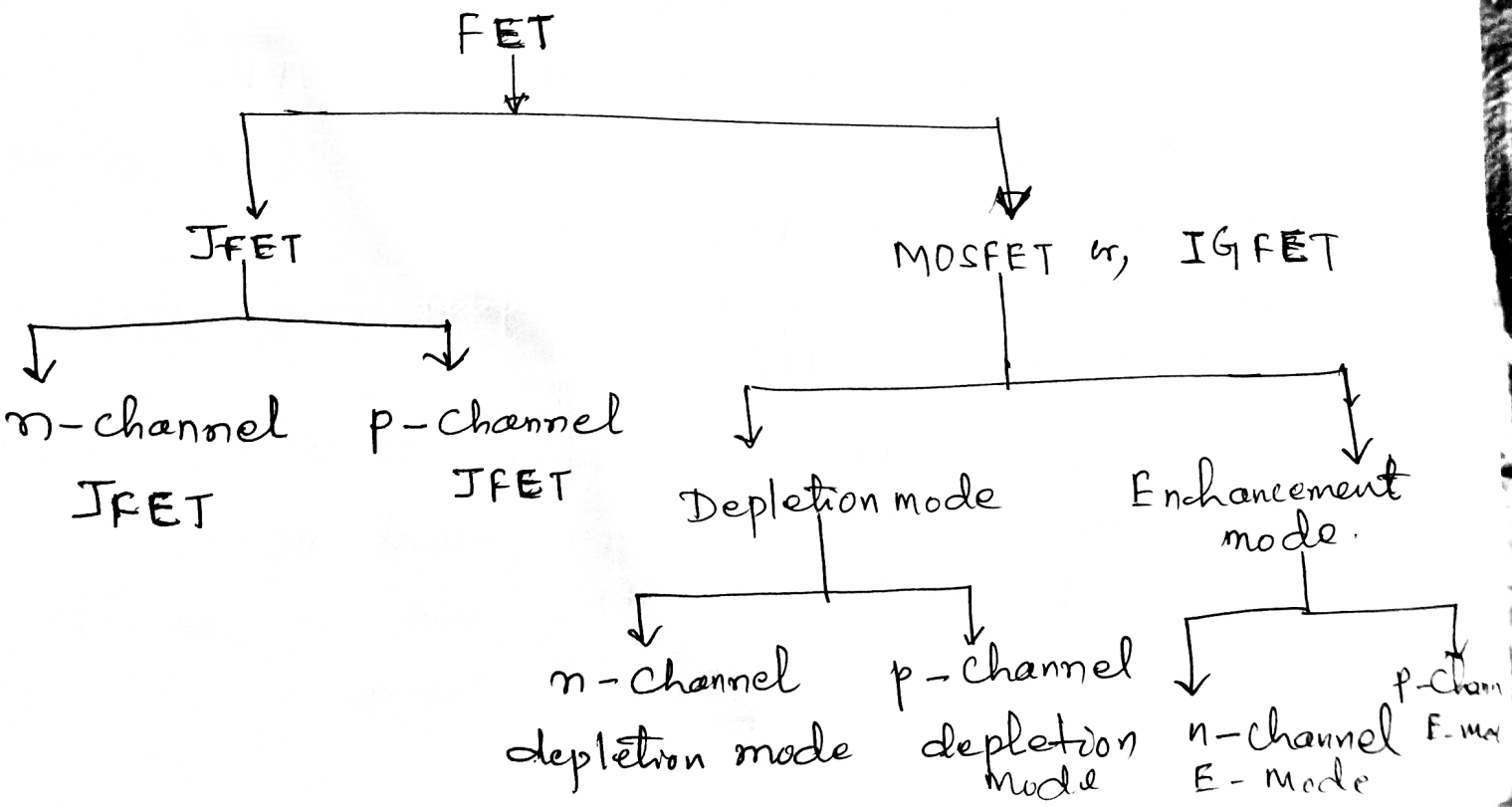
→ FET's are preffered for switching application because there are no minority carrier therefore no store Charge problem.

→ Less noisy

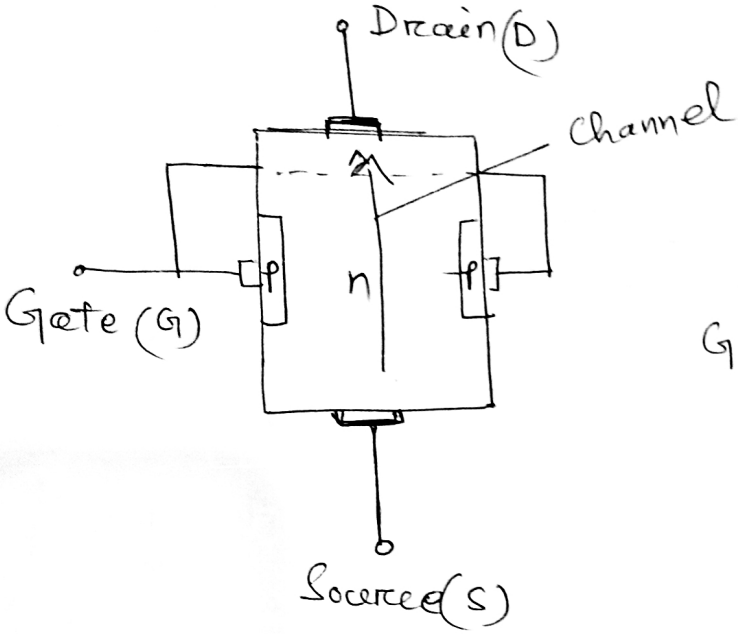
→ FET input resistance is very high (in MΩ)

→ FET has smalled Gain Bandwidth product.

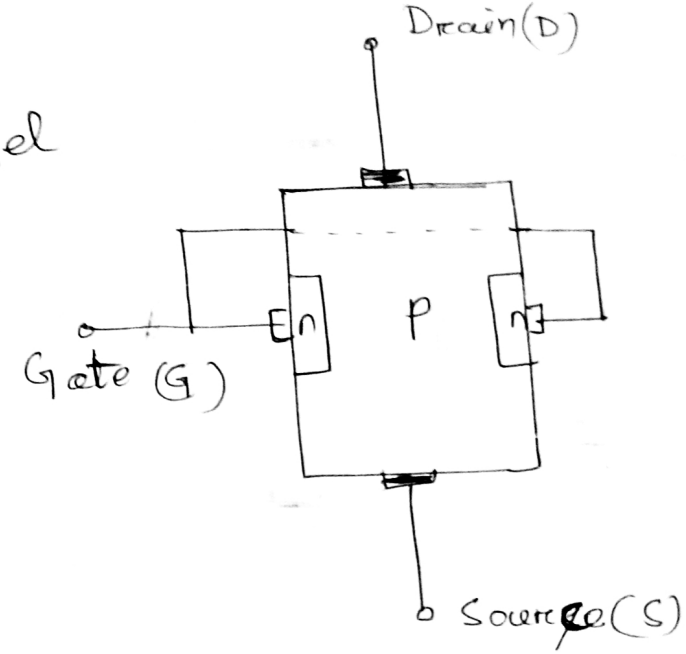
classification



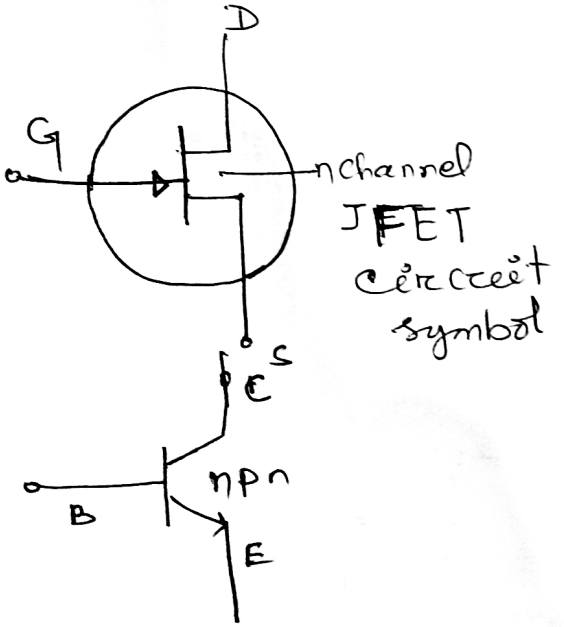
Basic Construction :-

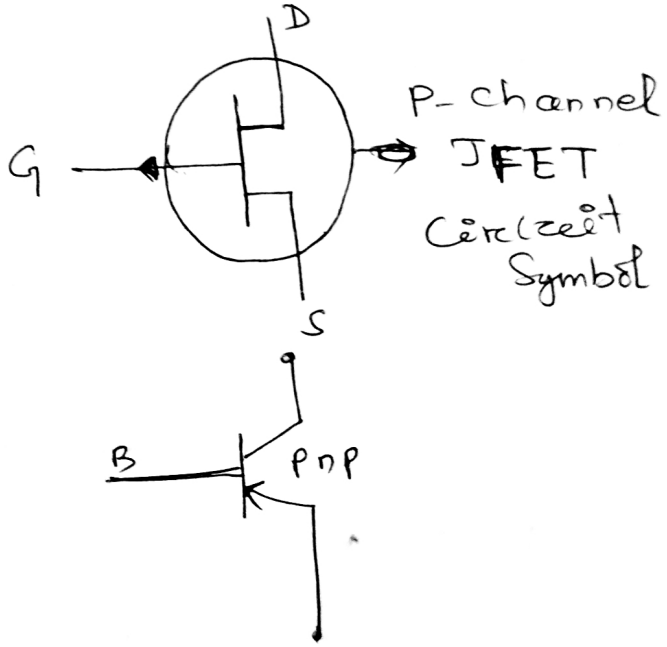


n-channel JFET

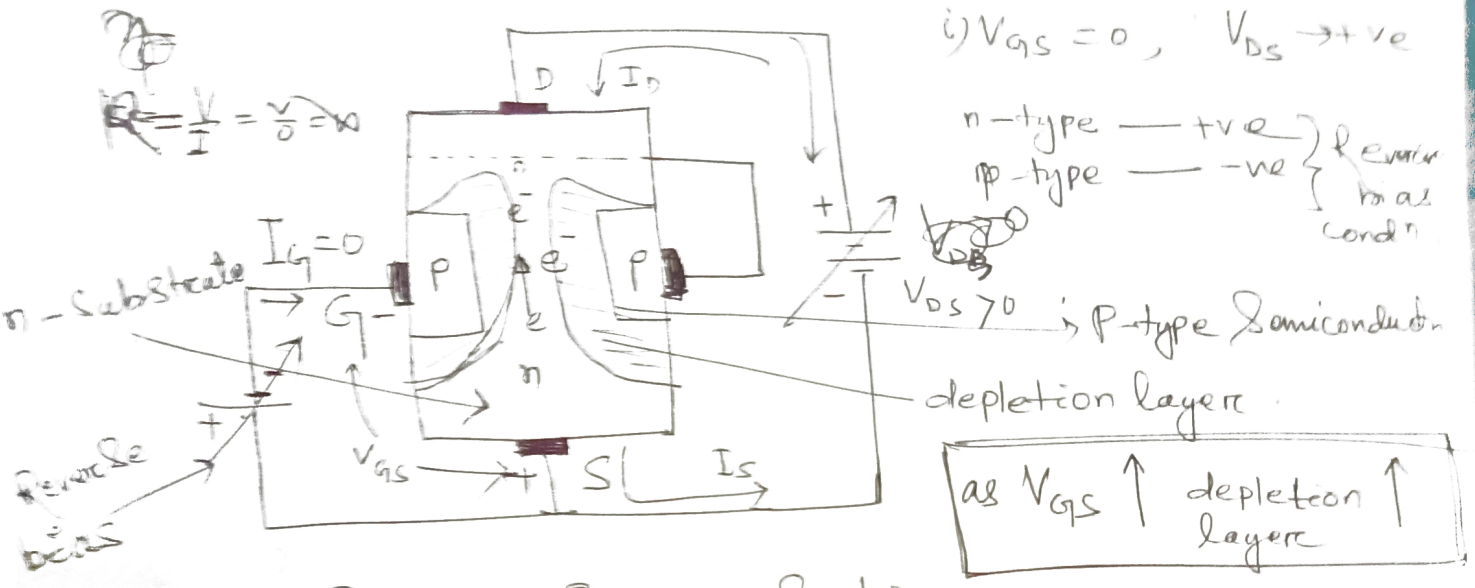


P-Channel JFET





operation & working principle of n-channel JFET



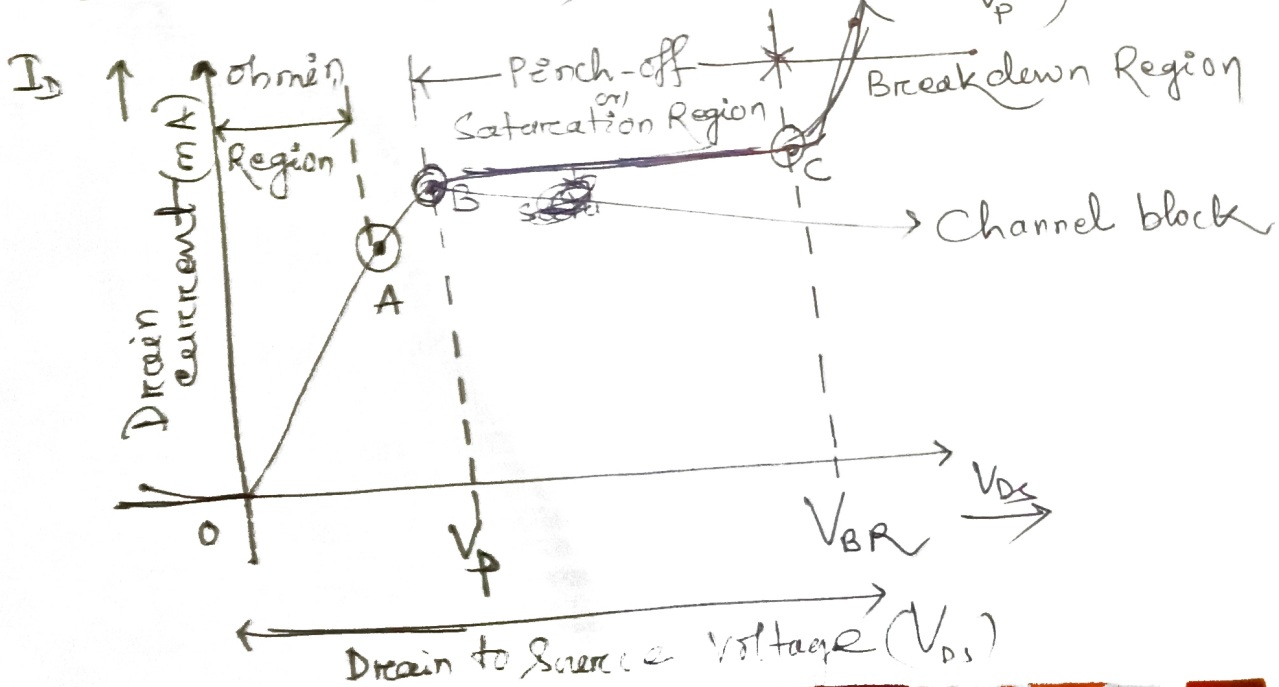
→ Gate-Source is reverse biased.

→ The more negative the Gate voltage, the smaller current between the Source and drain

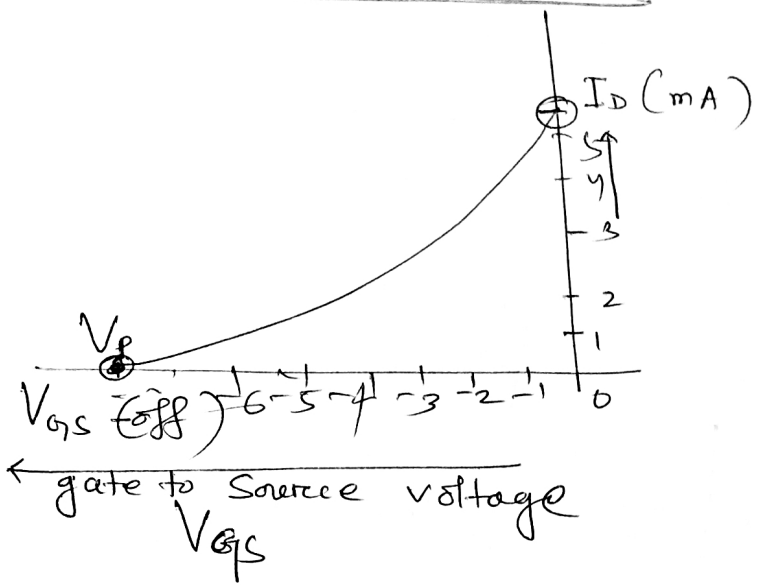
→ Therefore JFET is called as a voltage controlled device.

→ When the depletion layers from both touch each other is known as pinch-off condn.

→ I_D - Drain current, $I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2$



Transfer characteristics



Now According Shockely equation

$$I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2$$

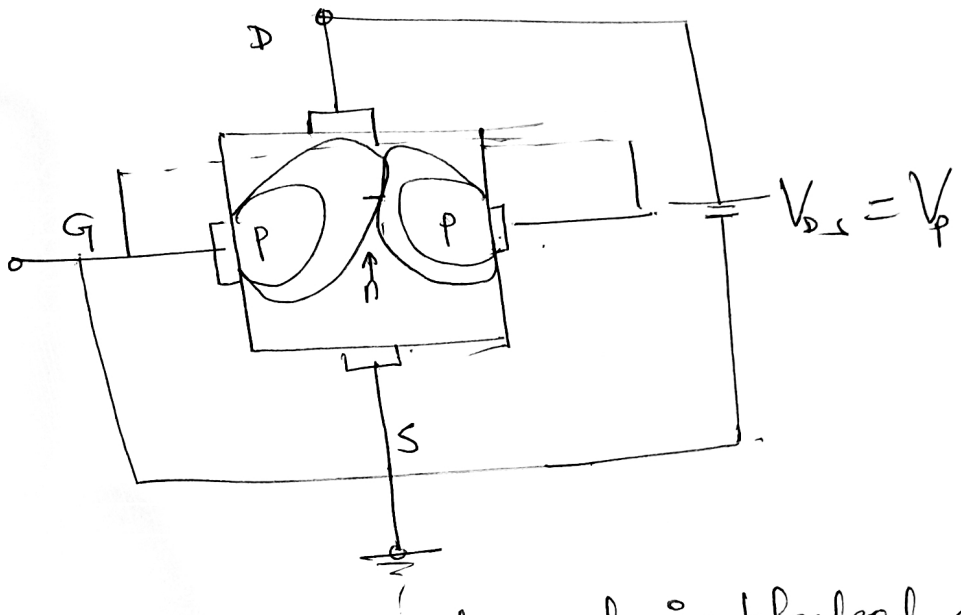
→ When the voltage between drain and Source terminal V_{DS}, is kept positive i/e when $V_{DS} > V_{GS}$ the electrons which are majority carriers in n-channel are attracted towards positive terminal of the battery V_{DS}

→ Further increase V_{DS}, more electrons moves towards the positive terminal of the battery V_{DS} and drain current I_D start to flow from Source to drain

→ $I_G = 0$ Since $V_{GS} = 0$.

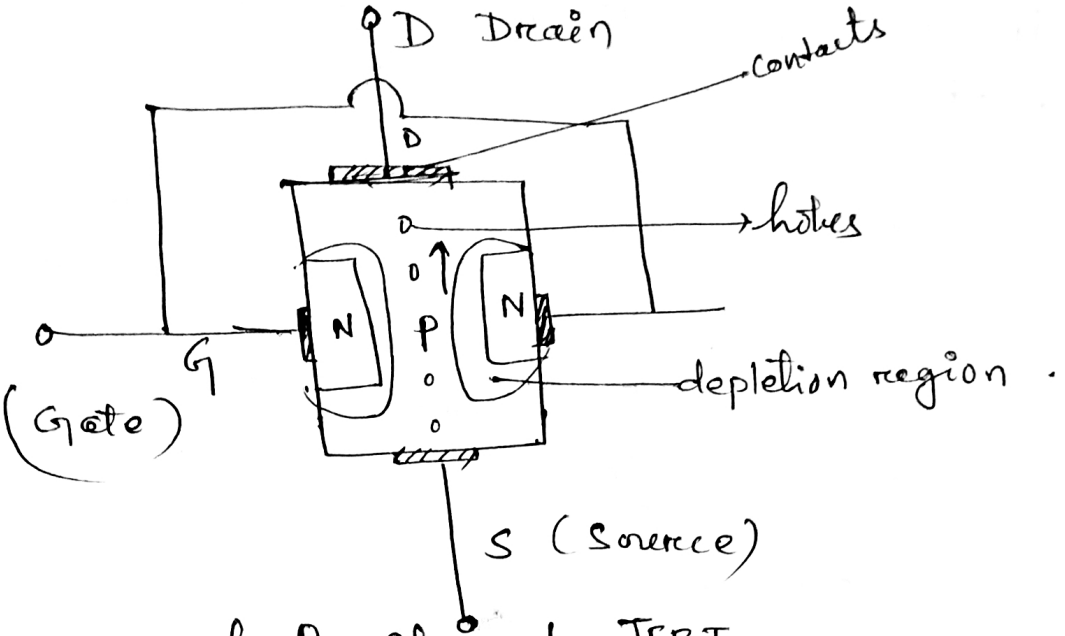
→ In this situation depletion region develop and the thickness of the depletion layer is more wider at the top side of n-channel and less wider at the bottm side n-channel.

→ As there is further change of drain to source voltage V_{DS}, it reaches a certain limit of voltage where depletion layer becomes much wider that they touch each other.

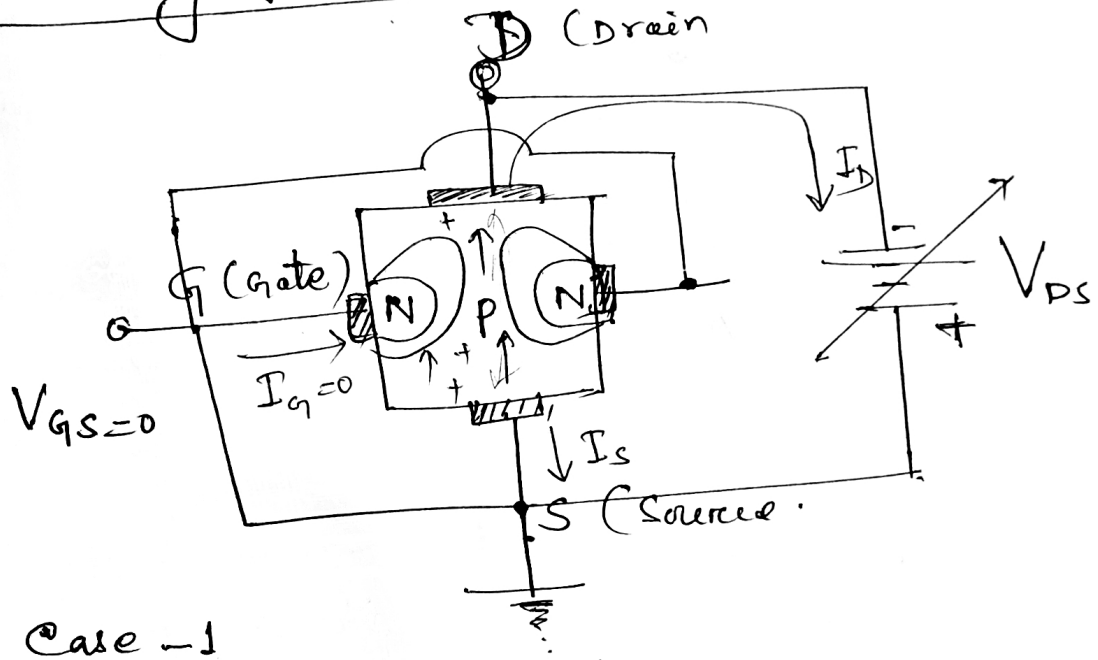


→ In this case n-channel is blocked and it stops flow of electrons from source to drain through channel. As we increase V_{DS} further, the drain I_D is not changed, it will be constant,

P-Channel JFET



Working of P-Channel JFET



Case - 1

When $V_{GS} = 0$ $V_{DS} < 0$

→ In this case, the voltage between drain and Source (V_{DS}) is kept negative, as compared to V_{GS}.

$V_{GS} = 0$. (by short-circuiting gate and Source terminal.)

→ holes are the majority carriers in p-channel are attracted towards the negative terminal of the battery V_{DS}.

→ as V_{DS} increases, more holes moves towards the negative terminale of the battery terminal. and the drain current starts to flow in the same direction of holes.

i.e.,

→ $I_G = 0$ since $V_{GS} = 0$.

→ The depletion layer becomes more wider at the Top side of the p-channel and less wider at the bottom of the P-channel.

→ further change in V_{DS} (beyond limit) a certain cond^n reach where the depletion layer from both side touch each.

→ In this case p-channel blocked and stops the flow of holes from source to drain through channel. the drain current I_D is not changed and become constant.

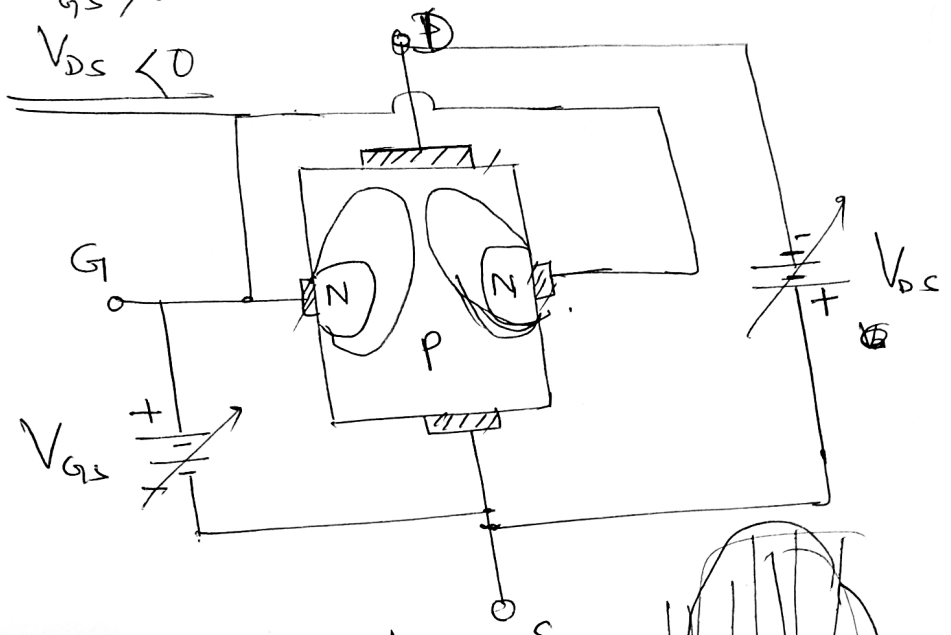
Case-2 (When $V_{GS} > 0$, $V_{DS} < 0$)

→ when V_{GS} becomes more positive, and V_{DS} more negative, depletion layer at both side touch each other. The constant current start to flow before V_p

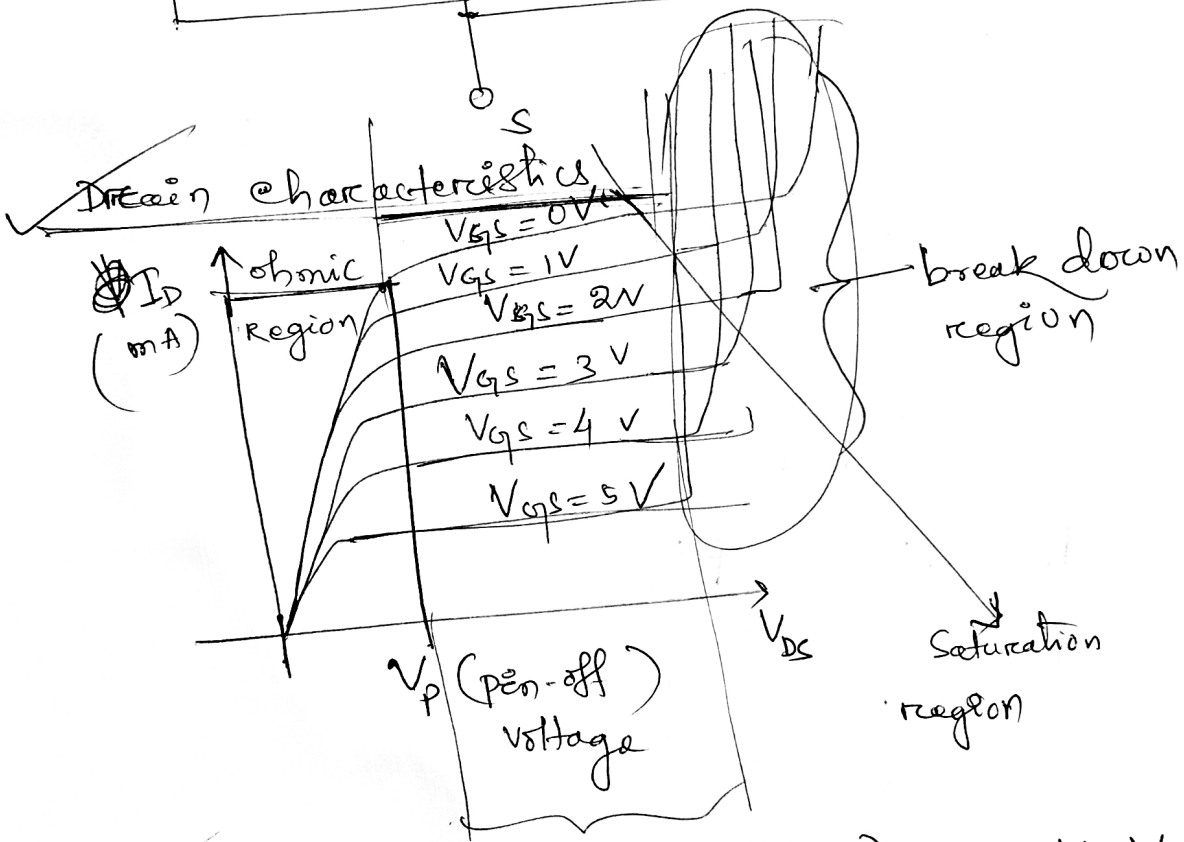
Case-2

$V_{GS} > 0$

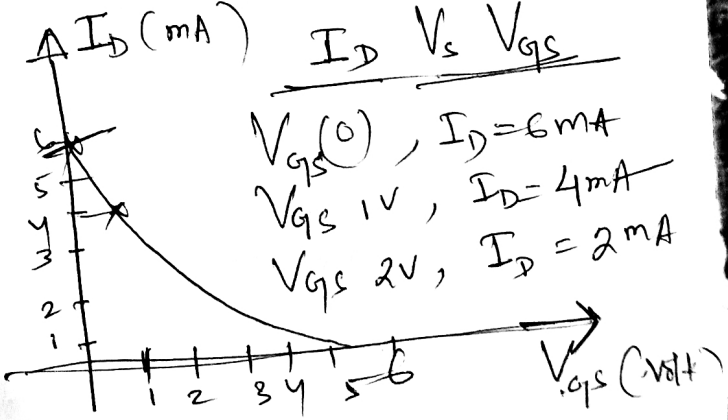
$V_{DS} < 0$



Drain characteristics



Transfer characteristics



I_D Vs V_{GS}

$V_{GS}(0)$, $I_D = 6mA$

V_{GS} 1V, $I_D = 4mA$

V_{GS} 2V, $I_D = 2mA$

MOSFET:—

→ MOSFET → stands for Metal oxide Silicon field effect transistor.

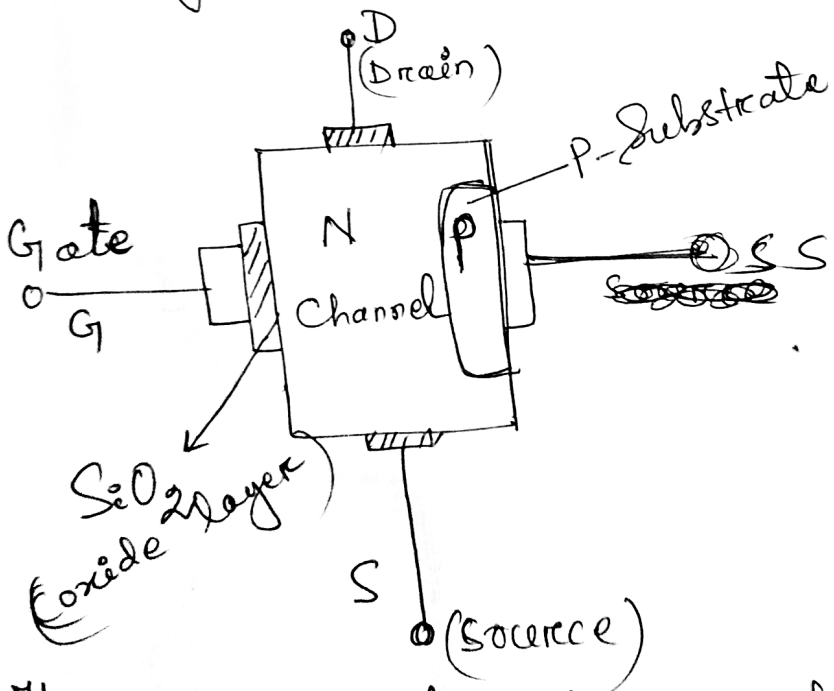
→ It is also called IGFET – insulated Gate field effect transistor.

→ It operates both in enhancement mode and depletion modes of operation.

Construction :—

→ The construction is very similar to JFET

→ An oxide layer is deposited on the substrate which gate is connected.



→ The voltage at gate controls the operation of MOSFET.

→ both positive and gate voltages can be applied on the gate.

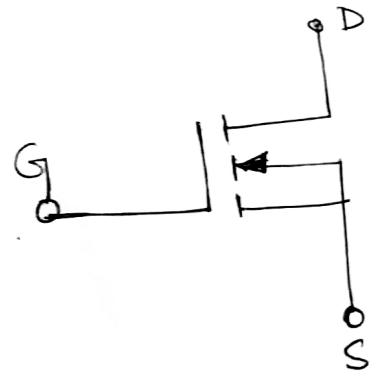
→ With negative gate bias voltage it act as depletion MOSFET

→ With positive gate bias voltage it act as Enhancement MOSFET

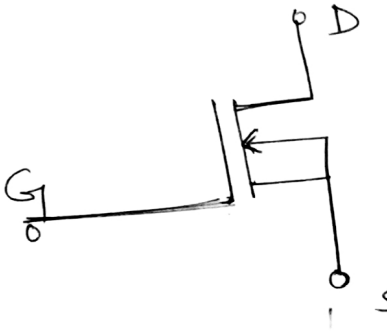
classification

MOSFET

- Enhancement Mode MOSFET
  - P-Channel E-MOSFET
  - N-channel E-MOSFET
- Depletion Mode MOSFET
  - P-channel D-MOSFET
  - N-Channel D-MOSFET

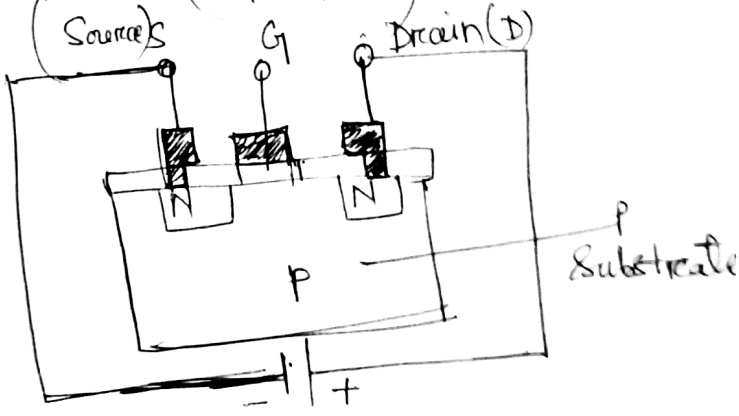


Enhancement Mode (MOSFET)



Depletion Mode (MOSFET)

N-channel MOSFET



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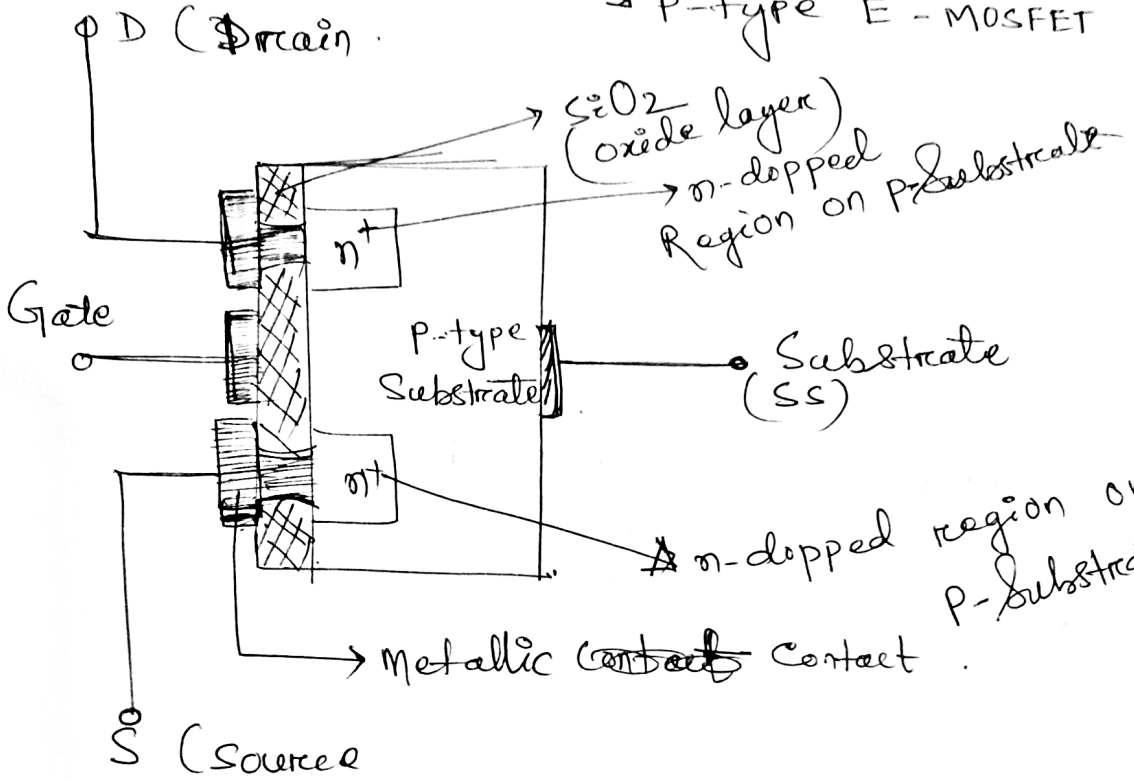
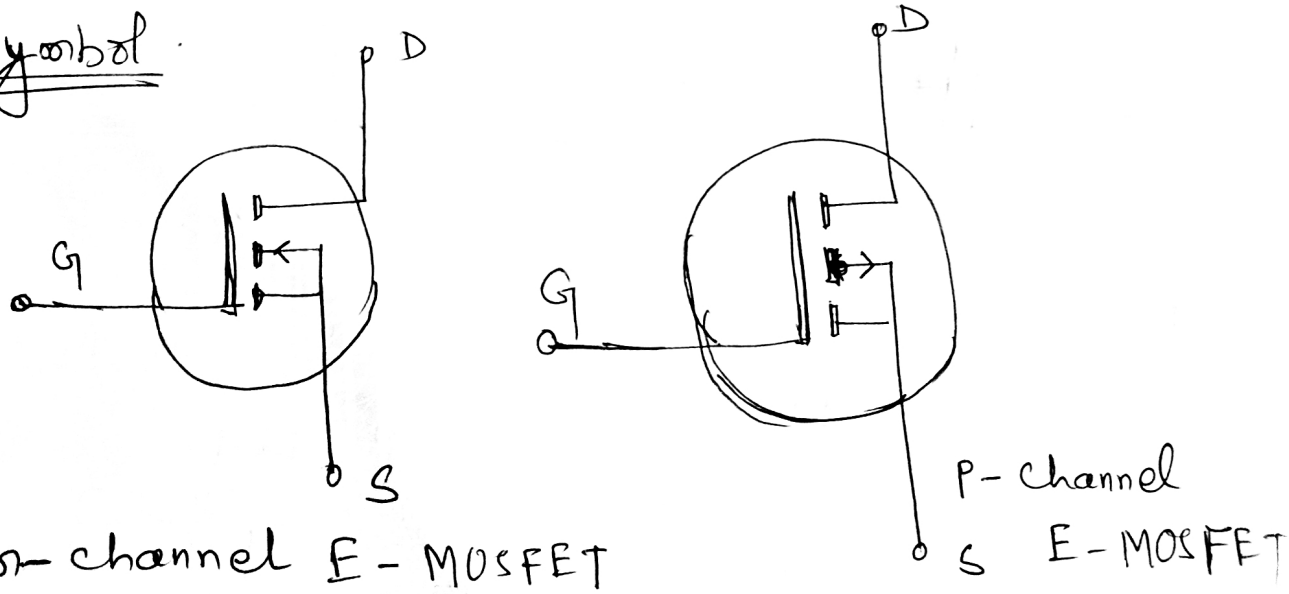
Write Short Note on

Enchancement type MOSFET

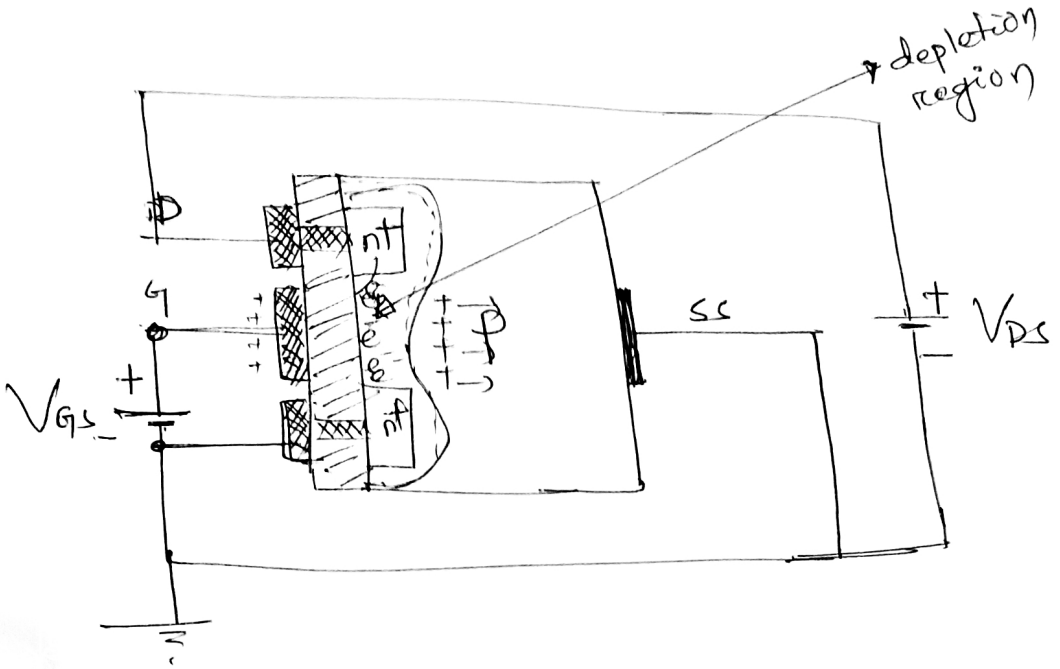
E-MOSFET → N-type E-MOSFET
E-MOSFET → P-type E-MOSFET



Symbol.



Operation of E-MOSFET



→ If $V_{GS} = 0V$, and $V_{DS} = +ve$, no current flows due to absence of channel. (all the electrons gets attracted to the gate terminal)

→ If $V_{GS} = +ve$, $V_{DS} = +ve$

all the electrons from N-well and p-Substrate will get attracted towards the Gate terminals.

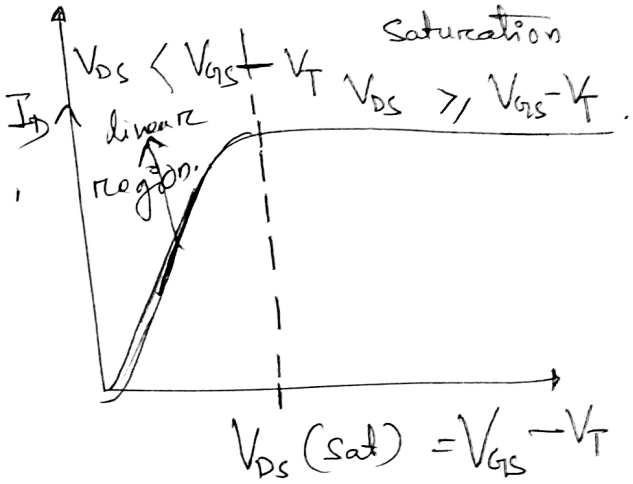
→ The level of V_{GS} at which the channel begins to conduct is called threshold voltag V_T

When $V_{DS} > V_T$, the electron will ~~starts~~ starts to flow the channel.

→ ~~Since~~ Since the channel non-existent with $V_{GS} = 0$ and it is enhanced by the application of a +ve gate to Source voltage, this type of MOSFET is called as Enhancement type MOSFET

→ As V_{GS} is increased beyond the threshold level, the density of free carriers in the induced channel will increase resulting in an increased level of drain current.

→ If we hold V_{GS} = constant and increase the level of V_{DS} following condition occurs:



→ If $V_{DS} < V_{GS} - V_T$

i.e linear region

$I_D \uparrow$ with $V_{DS} \uparrow$

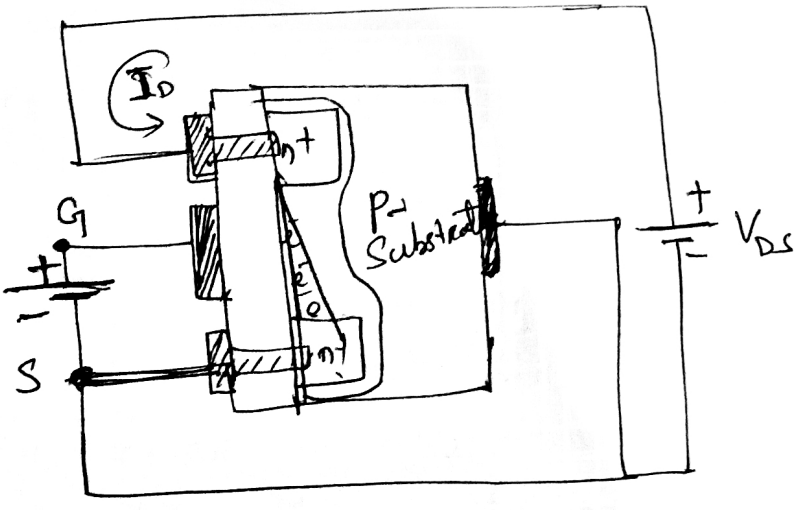
→ $V_{DS} = V_{GS} - V_T$, when the channel is pinched off

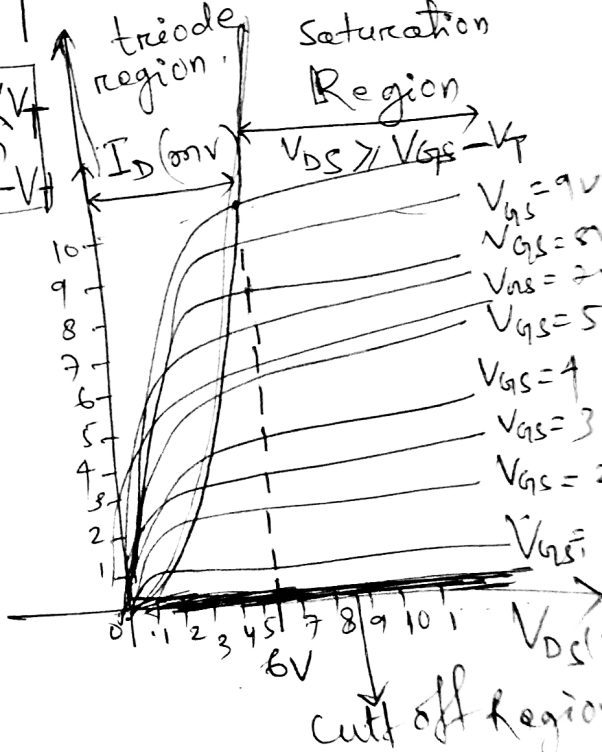
→ $V_{DS} \geq V_{GS} - V_T$, Saturation region

I_D = constant, $V_{DS} \uparrow$

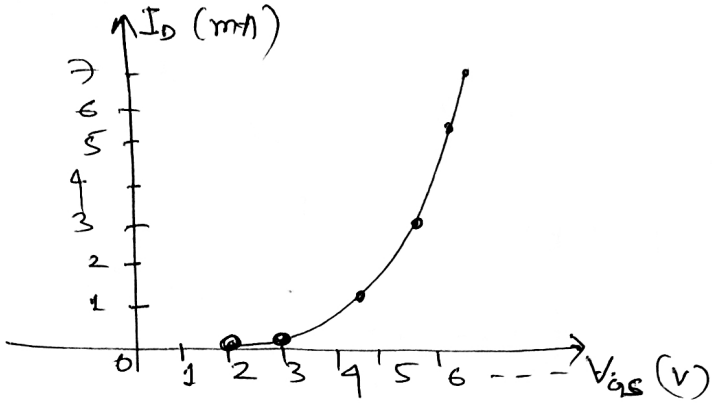
Drain Characteristics

cut off – $V_{GS} < V_T$
Triode Region
$V_{DS} < V_{GS} - V_T$





Transfer Characteristics of E-MOSFET

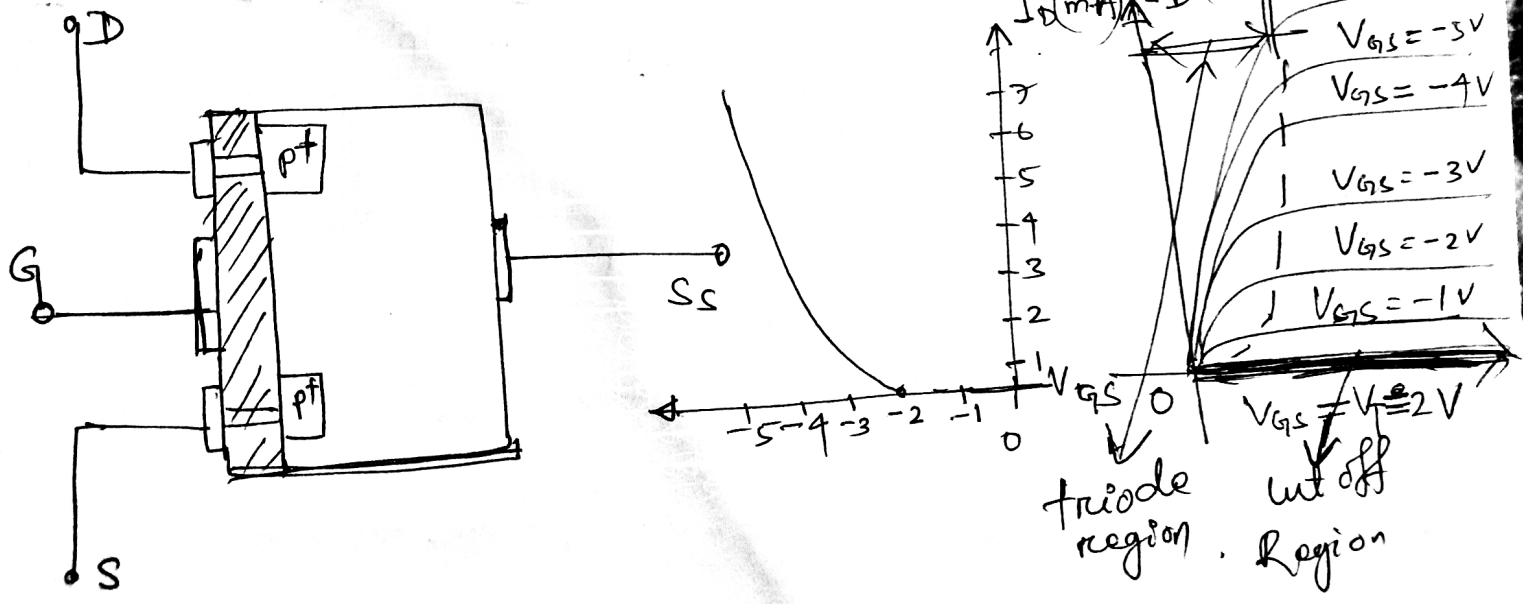


The Drain current is related to applied gate-to-Source Voltage by the following Non-linear relationship

$$I_D = K(V_{GS} - V_T)^2$$

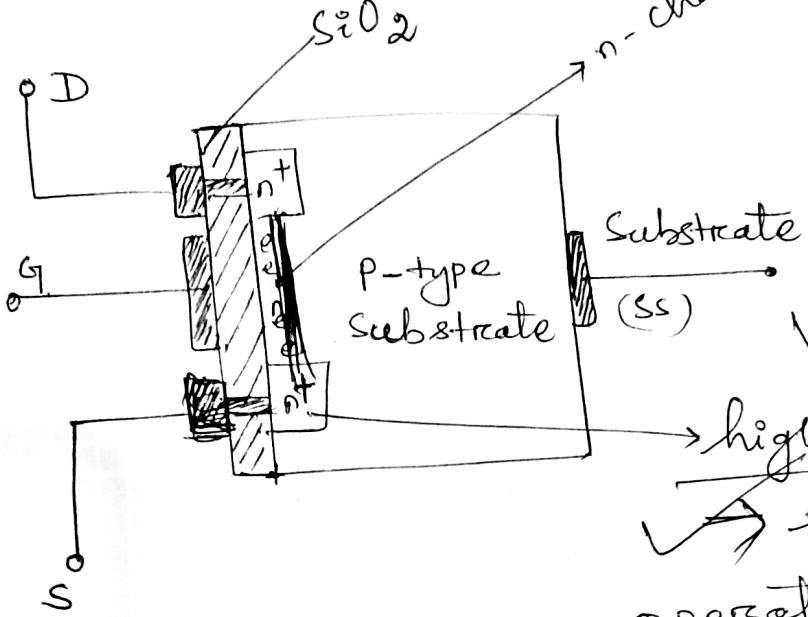
Where K = constant

P-channel Enhancement type MOSFET



Depletion type MOSFET :-

construction



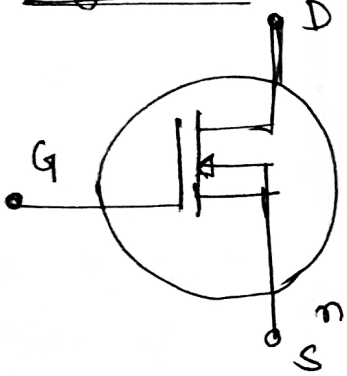
When the gate terminal is given positive potential at V_{GG}, than the drain source voltage V_{DD}, then due to the repulsion,

→ In depletion occurs due to which flow of current reduce

→ highly doped n-region

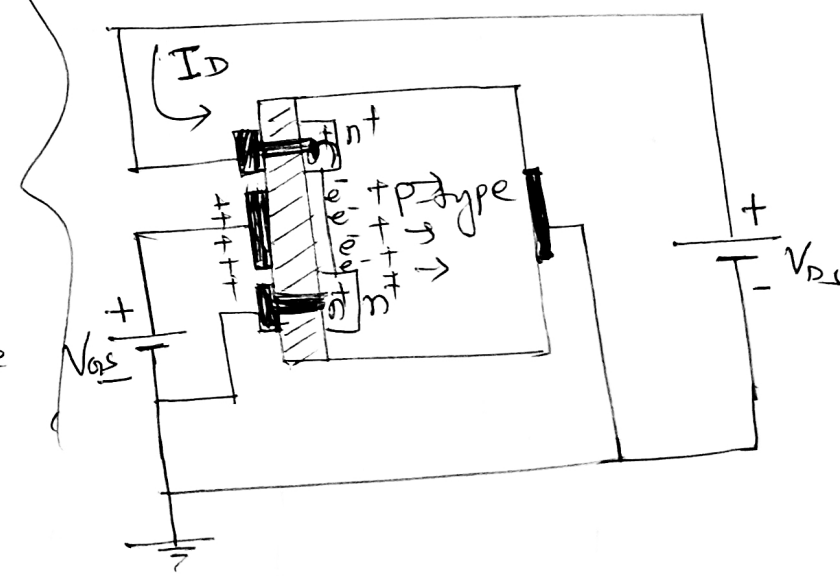
→ hence works in depletion mode.

Symbol



n-channel depletion type MOSFET

operation

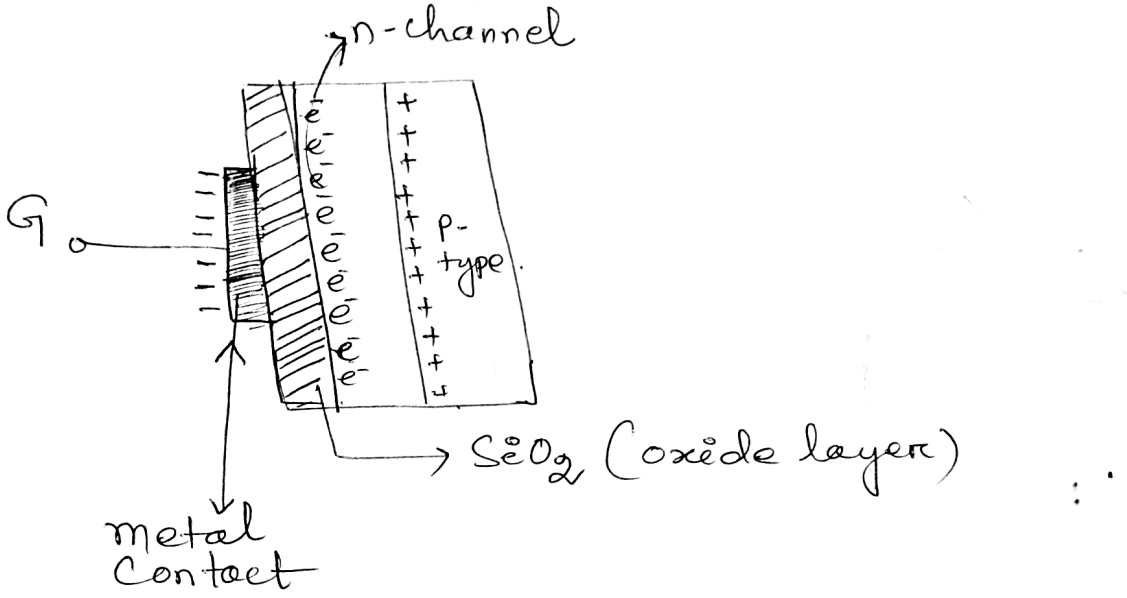


→ operation with $V_{GS} = 0$

$V_{DS} = +ve$

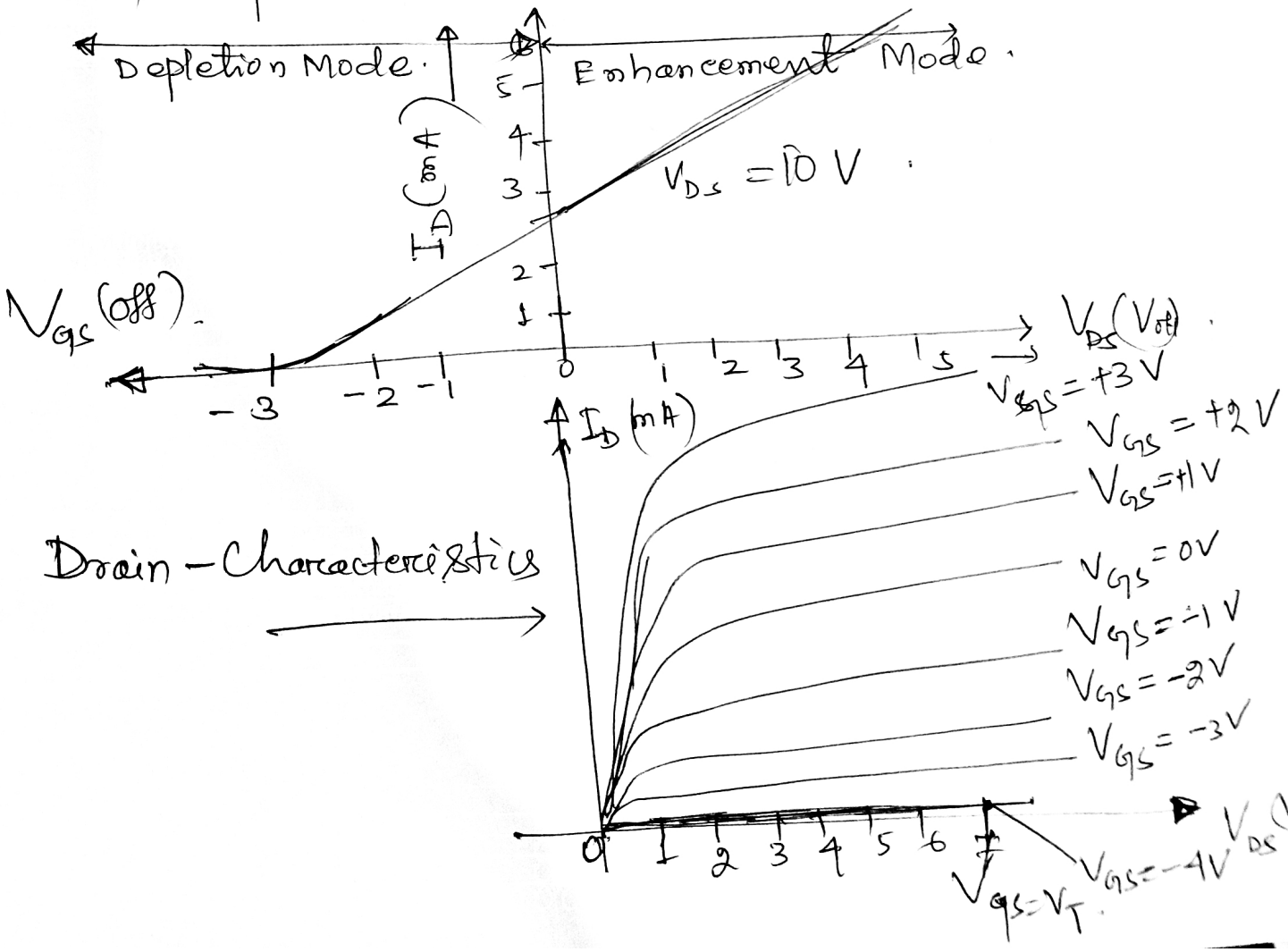
→ Operation with $V_{GS} = +ve$, $V_{DS} = +ve$

→ Operation with $V_{GS} = -ve$, $V_{DS} = +ve$

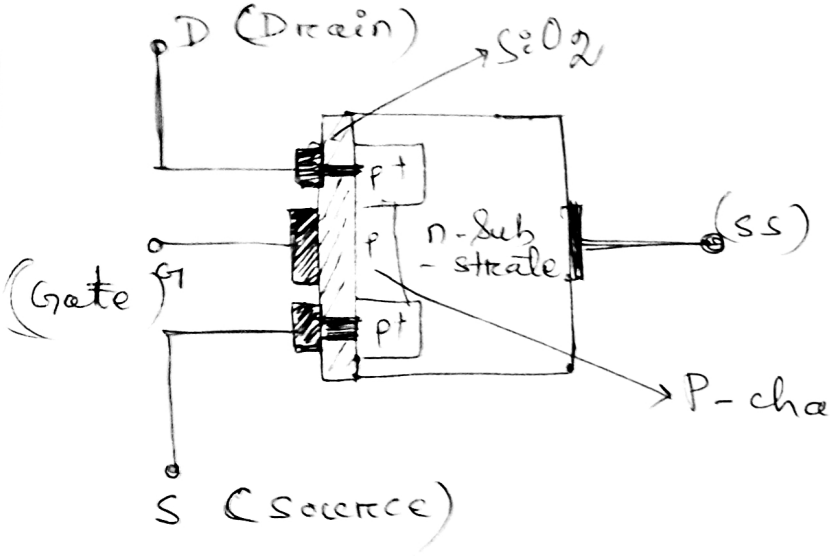


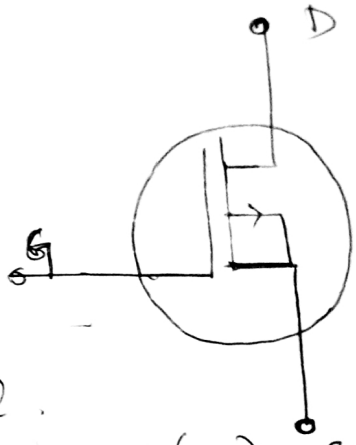
Transfer Characteristics :—

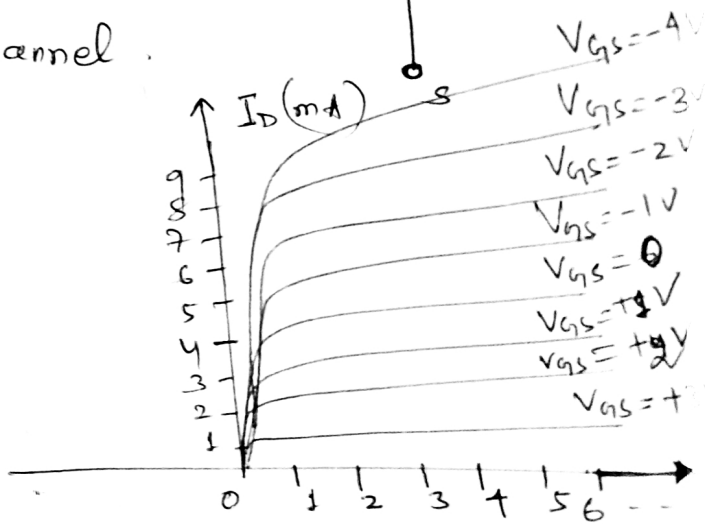
Transfer characteristics define the change in the value of V_{DS} with the change in I_D and V_{GS} in both depletion and enhancement mode.



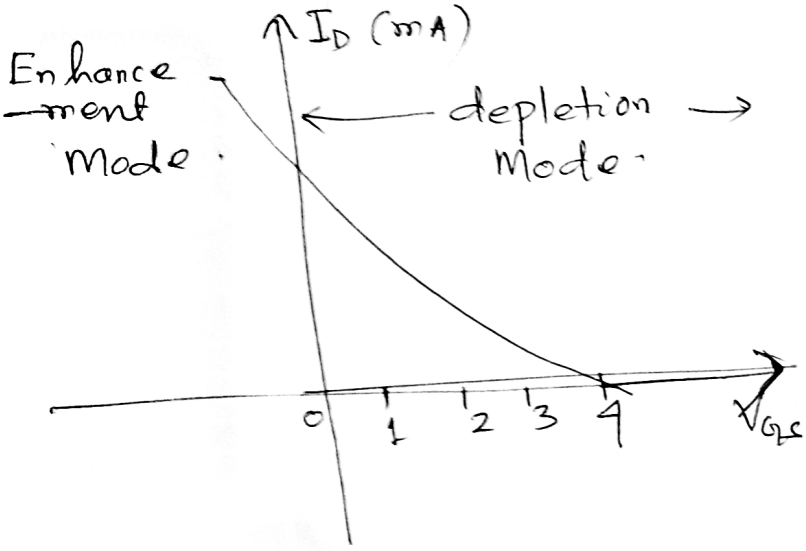
P-channel depletion Type MOSFET







Drain-Characteristic curve.



Q Short Note on

(8) inverters using CMOS