FET

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B.Sc Part-III
Paper-VI

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Field Effect Transistor

FET is a semiconductor device with the output current controlled by ~~one~~ an electric field since the current is carried predominantly by one type of carrier (majority carrier). The FET is known as unipolar transistor. There are two main classes of FET.

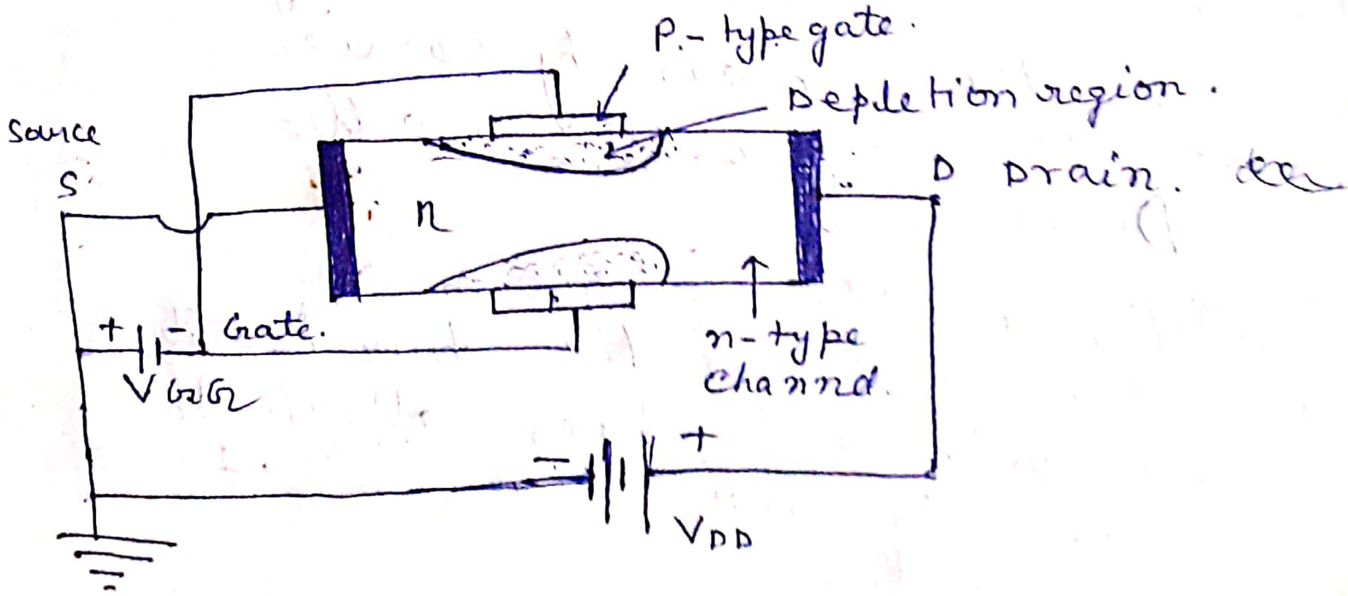
(i) The junction field effect transistor (JFET).

(ii) Metal oxide semiconduct field effect transistor (MOSFET).

The different classes of FET are characterised by a high input impedence. These devices are used in controlled switching between conducting and non-conducting states in digital ckt.

Junction Field Effect Transistor (JFET):-

A ~~symme~~ schematic diagram of a JFET is shown in figure.



It consist of a uniformly doped semiconductor bar (also called a channel) usually of Si or GaAs. with ohomic contacts at both ends and with semiconductor junction on both sides of the bar. The semiconductor bar may be of n-type material or p-type material. If the semiconductor bar is n-type the JFET is called an n-~~chatte~~ channel JFET. on the other hand if the bar is p-type the device is termed as a p-channel JFET. Two sides of the bar are heavily doped with impurities opposite to that of a bar i.e. p-type impurities for an n-type bar and vice-versa.

□ <u>Source → (S)</u> → The terminal through which the majority carrier enter the channel region is called the source.

<u>Drain (D)</u> – The terminal through which the majority carrier leave the channel is called the Drain.

<u>Gate (G)</u> → The regions on the two sides of the bar heavily doped with impurities opposite to that of the bar are called the Gate.

Channel → The portion of the semi-conductor bar between the depletion region through which the majority carriers move from source to drain is called the channel. The channel opening decreases with increasing depletion width.

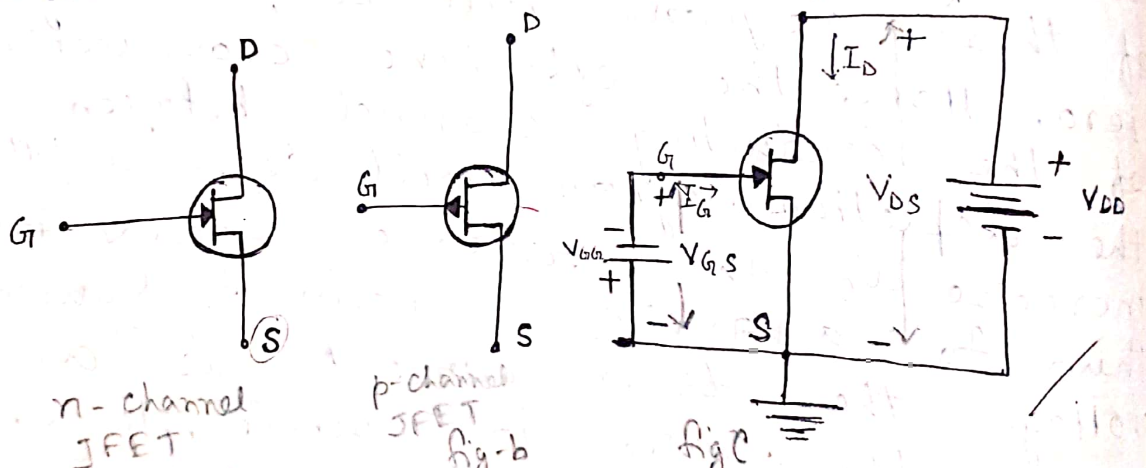
Principle of JFET operation :→

The junction between the bar and the Gate is reversed biased by applying a voltage V_{GG}. The resulting depleation region extended into the bar. The widths of the depletion ~~ca~~ region can be controlled by gate to source voltage. The depleation region contains only immobile charges and no free carriers. Therefore the conductivity of these regions will be practically zero. Hence the effective cross-section of the conducting channel between the depletion region will decrease with the increase in the reverse bias voltage. Thus for a given Drain to Source voltage the drain current is a fn of the Gate to source voltage.

(The device is basically a voltage controlled transistor, the resistance being controlled by the gate voltage. The name field effect is used for the ~~dev~~ device since the transverse field introduced by the gate) controlls the channel conductance and hence the device current.

CKt operation :→ The CKt. symbol of an n-channel JFET and that of a p-channel JFET are shown in fig. The arrow on the gate terminal refers to the direction of the gate source gate current when the gate source Jn is forward biased.

In the normal operation the gate source jn is reversed biased. For an n-channel JFET, the electrons drift from source to drain, so that the conventional current flows from drain to source. On the other hand for a p-channel JFET the holes move from source to drain and the conventional current is in the same direction.



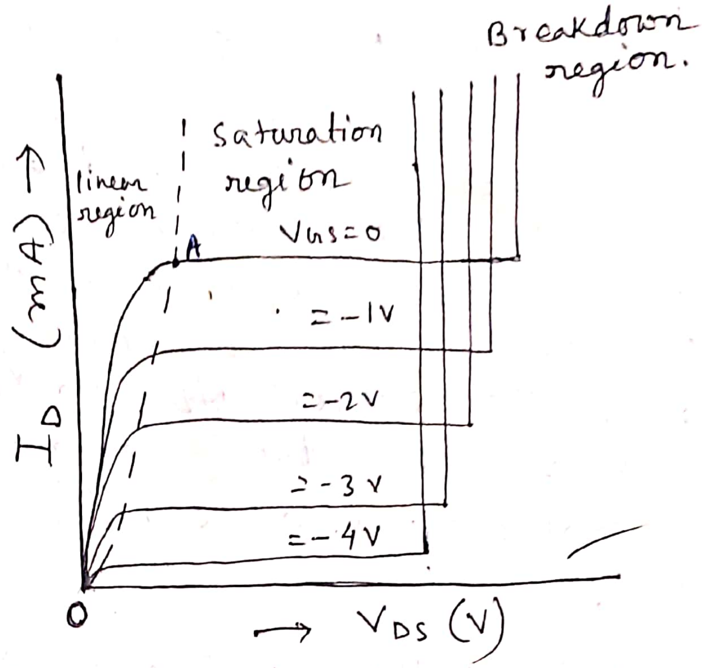
n-channel JFET fig-a

p-channel JFET fig-b

fig c.

Static Characteristics of JFET :-

The graphical plots of drain currents I_D against the drain to source voltage V_{DS} with the gate to source voltage V_{GS} as a const. are known as the static or common source drain characteristics of a JFET. The typical static characteristics of n-channel JFET is shown in fig.



The drain characteristics are found to consist of three region ① The linear or ohmic region. where the voltage V_{GS} is small and I_D is linearly proportional to V_{DS}.

② The saturation region → where I_D is fairly const. and independent of V_{DS}.

③ The Breakdown region → where I_D increase rapidly with a small increase of V_{DS}.

The const drain current in the saturation region of the characteristics is called the saturation current $I_D|_{sat}$. The min value of V_{DS}, at which the drain current saturates at a given V_{GS}, is called the sat. voltage $V_D|_{sat}$.

Explanation of the characteristics curve → Ohmic voltage drop is caused in the bar due to the flow of current I_D. This voltage drop along the length of the channel reverse biases the gate jn. The reverse biasing of the gate jn is not uniform throughout. the reverse bias is more at the drain end than at the source end of the channel. So, as V_{DS} is increased, the channel starts constricting, more at the drain end. i.e. the depletion layer width is increased. The channel is eventually pinched off. The current I_D no longer increases with the increase in V_{DS}. It approaches a const, saturation value.

Pinch-Off Voltage → The drain to source voltage V_{DS} at which the channel is pinched off (i.e. all the free charges from the channel are removed) is called pinch off voltage V_p. V_p is smaller when the gate to source reverse bias voltage is increased. The excess voltage above V_p is absorbed by depleation region. Thereby increasing the depletion area.

The region of the curve to the right of pt. A is called pinch-off region. Beyond pinch-off voltage the current I_D saturates at a value $I_{D|sat}$.

As V_{DS} increases above $V_{D|sat}$ the excess voltage is absorbed by the depleation region. Thus the depleation region meets at a pt. before the drain. The channel becomes very narrow & from the pt. where the depletion region nearly meet upto the drain. For the large value of V_{DS} the reverse voltage between the channel and the Gate becomes sufficient to cause a break down of the gate j^n resulting in a sharp increase of the drain current.

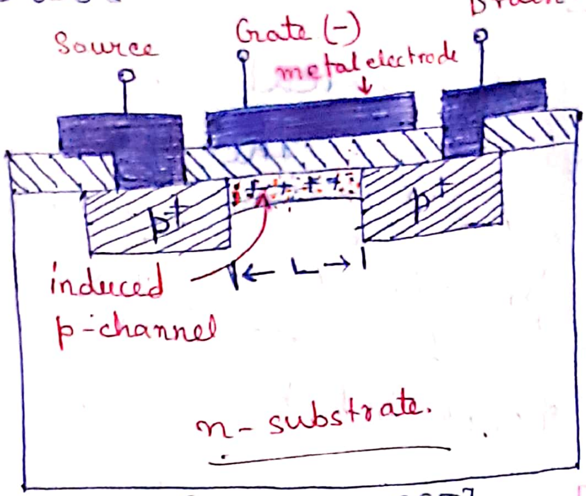
~~Metal oxide~~

Application → JFET's are useful for low noise amplification. The noise is less because only the majority carriers participate in the device operation. In ~~the~~ practical devices thermal resistances ~~devices~~ contributes noise in the to the noise behaviour.

MOSFET :→ MOSFET is an important power device. MOSFET can be of n-channel & p-channel types. A MOSFET has been constructed with various semiconductor such as Si & GaAs and with different insulator like SiO_2 & Al_2O_3. The Si – SiO_2 combination is the most common system.

The basic structure of a p-channel MOSFET is shown fig. It consist of a lightly doped n-type S.C. subtrate into which two heavily dope p-regions (p^+) are formed. These p^+ ~~are~~ source & region are act as a Drain. A thin layer of insulating ~~SiO~~ silicon di-oxide (SiO_2) is grown on the ~~surf~~ surface of the structure. The metal contact on the insulator is called the Gate. The distance between the two metallurgical p⁺ j'n is referred to as the channel length L.

An n-channel MOSFET has two n^+ end region surving as the source and the drain on a p-type S.C. substrate.



[p-type MOSFET] ←: MOSFET

The n & p channel MOSFET can be of two types.

(i) Enhancement MOSFET.
(ii) Depletion ".

(i) <u>Enhancement MOSFET</u>:→ If the n-type subtrate Grounded and a (-)ve voltage is applied to the Gate, (+)ve charges will be induced on the S.C. side due to capacitor action. These (+)ve charges produce an inversion layer. The induced (+)ve charge in the S.C. increases with increase in the (-)ve Gate voltage. These (+)ve charges are the p-type carriers confined to ~~the~~ a thin region called the channel below the oxide layer. The conductivity of the induced channel & hence the drain current is enhance by the negative gate voltage. Hence the device is known as enhancement MOSFET.

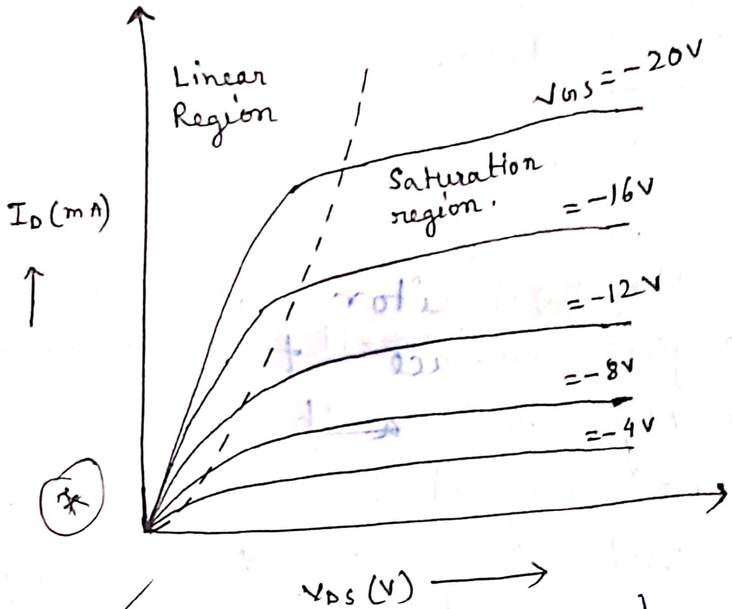
(ii) Depletion MOSFET :→ When the Gate voltage is (−)ve, (+)ve charges are induced in the diffused n-channel due to the capacitor action. The induced (+)ve charges reduce the channel conductivity ~~as a portion of the channel is depleted of carriers~~ since the current in a FET is due to the drift of the majority carriers only i.e. electron for an n-type channel thus the drain current decreases as the gate to source voltage is made more (−)ve. The induce (+) ve charges after redistribution cause an effective depletion of the majority carriers. This accounts for the name depletion MOSFET.

The shape of the depletion region MOSFET is shown in the fig. (Page - 323). Rakhit Chattopadhyay

Static Characteristics of MOSFET :→

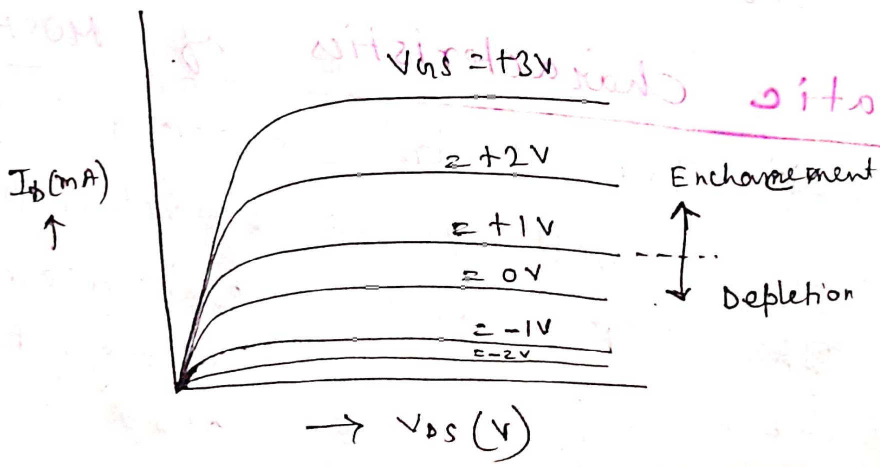
The drain characteristics (also known as volt-ampere characteristics) of a p-~~type~~ channel enhancement type MOSFET are shown in fig. Each characteristics curve displays the

variation of drain current Source to drain
I_D with the decrease of
voltage V_{DS} for a fixed gate
to source voltage V_{GS}.



(p-channel MOSFET.)

The static drain characteristics of an n-channel MOSFET which may be operated in either the enhancement mode or the depletion mode is shown in fig. The (+) ve values of the Gate source voltage produces the enhancement mode & (−) ve value of V_{GS} results in the depletion mode.



n-channel MOSFET.

What are the difference between BJT and JFET?

(i) BJT is bipolar device. FET is unipolar device. i.e. only majority carriers are involved in the operation of a FET. Both majority & minority carriers are involved in BJT.

(ii) FET is less noisy than BJT.

(iii) FET's are thermally more stable than BJT.

(iv) FET is a voltage controlled device; BJT is a basically current controlled device.

(v) FET's offer higher input impedences than BJT.

(vi) At audio freq. FET offers a large power gain than BJT.

(vii) FET can be easily fabricated than BJT.

Application of MOSFET →

n-Channel MOSFET are faster in switching application.