VIVEKANANDA COLLEGE
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NAAC ACCREDITED 'A' GRADE

Topic: JFET

Course Title: Electronics device and circuit

Paper: CMS-A-CC-2-4-TH

Unit: Unipolar junction transistor

Semester: second

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Name of the Department: Electronic Science

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Unipolar Junction Transistor
(CC4)

(1) Why is FET known as unipolar transistor?

Because the current is carried by one type of carriers.

(2) Why is it called field-effect transistor?

Because the output current is controlled by an electric field

(3) Comparison of FET and BJT

FET	BJT
(1) only one type of carriers are involved in operation.	(1) Both electron and holes are involved.
(2) input impedance is very large	(2) input impedance is very low (1K-3K)
(3) It is a voltage controlled device	(3) It is current controlled device,

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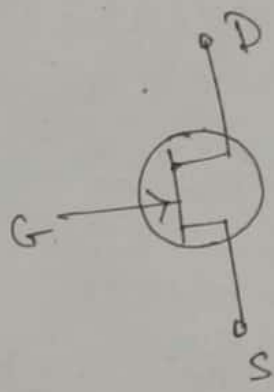
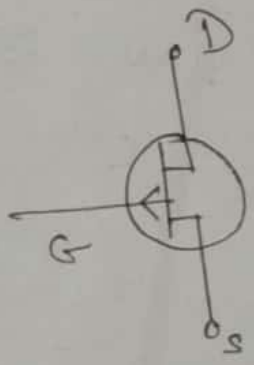
FET	BJT
4) It is less noisy	4) It is more noisy
5) It has high current gain and low voltage gain.	5) It has low current gain and high voltage gain
6) Switching time is fast	6) Switching time is medium.

Junction Field-EFFECT Transistor (J-FET)

circuit symbol :-



n-channel JFET



P-channel JFET

G — Gate
D — Drain
S — Source

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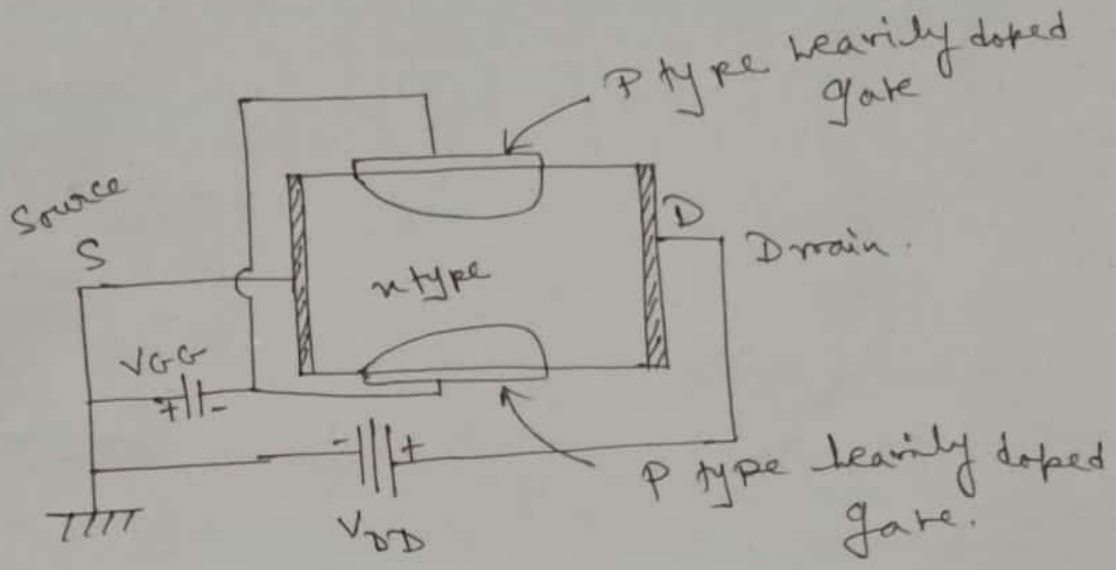
→ Source — Through which the carriers enter the channel.

Drain — Through which the carriers leave the channel.

Basic structure of n-channel JFET



Let us consider, a uniformly doped n-type semiconductor bar. There are two ohmic contacts at the end of the bar.

There are two heavily doped p-type regions on opposite faces of the bar. These two p-type regions are jointly called the gate terminal which is connected to the negative terminal of battery V_{GG}.

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The source terminal through which the carriers enter the n-type channel is connected to ground. The drain terminal is connected to the positive terminal of V_{DD}.

Operations of FET :-

Normally the two gates are reversed biased w.r.t n-type substrate. As the two gates are heavily doped the depletion region inside of p-type gate are ignored.

There is a gradual increase in potential difference from source to drain end of n type substrate due to battery V_{DD}.

Therefore the reverse biased at two gates gradually increase from source to drain. These explain the wedge shaped depletion region in n-type substrate.

By changing the reverse bias voltage or electric field of two

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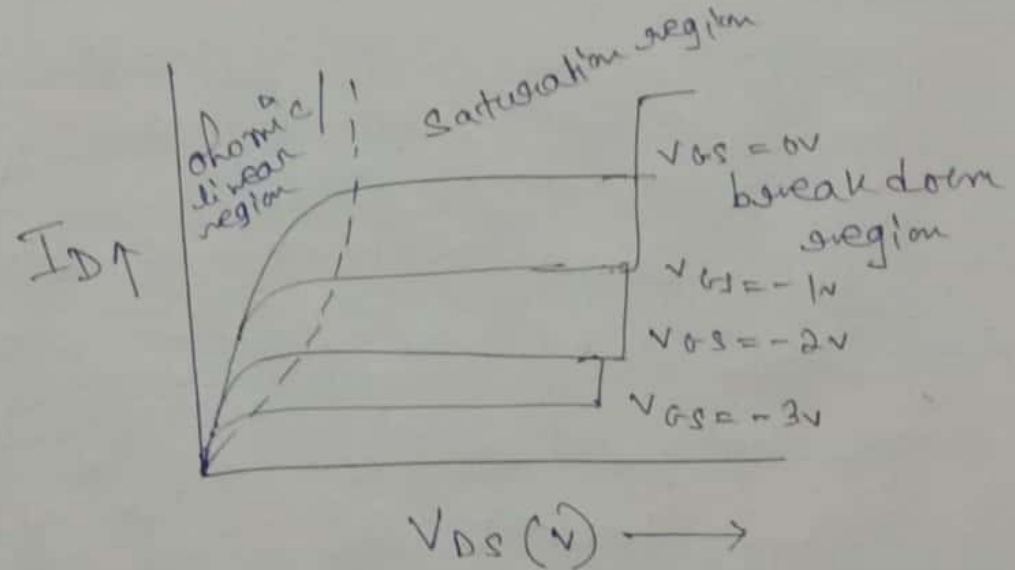
gates. the channel cross section can be controlled and hence the current. That is, why the device is called field effect transistor.

↑

So question can arise → "why JFET is called "field effect transistor"?".

To be continued...

Static characteristics of JFET :—



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In case of a JFET, when the drain current I_D is plotted against the drain to source voltage V_{DS}, keeping gate to source voltage V_{GS} constant, the output / static curve is obtained.

There are three regions of the curve → i) Linear or ohmic region
ii) Saturation region
iii) Breakdown region

Linear region :- In this region for small value of V_{DS}, the drain current is found to be increased almost linearly with drain to source voltage V_{DS}. This property puts the device in the application of VVR (voltage variable resistor)

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ii) Saturation region :-

when drain to source voltage V_{DS} is enough for a particular gate to source voltage V_{GS}, so that the two depletion regions in the channel touch each other at the drain end, pinch-off occurs, From this point the current I_D almost constant. with further increase in V_{DS}, practically the number of carriers remains same and they travel through the depletion region.

This property puts the device in the application area of constant current source.

iii) Breakdown region :-

If drain to source voltage V_{DS} increased to fairly high value (depends on manufacturer) there is a increase in I_D. It occurs due to avalench breakdown in depletion

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region. If the power dissipation exceed the limiting value then the device burns out.

channel length modulation :-

when V_{DS} increases above V_{DSat}, the excess voltage is absorbed by depletion region. The channel becomes very narrow from the point where depletion regions nearly meet, up to drain. The depletion area widens and the effective channel resistance increase to keep the drain current constant.

The I_D slowly increase with V_{DS} in saturation region. This effect is refered to as channel-length modulation.

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V_{DSat}^{*} → Saturation voltage of V_{DS}.

the voltage at which depletion regions meet the drain to pinch-off the channel.

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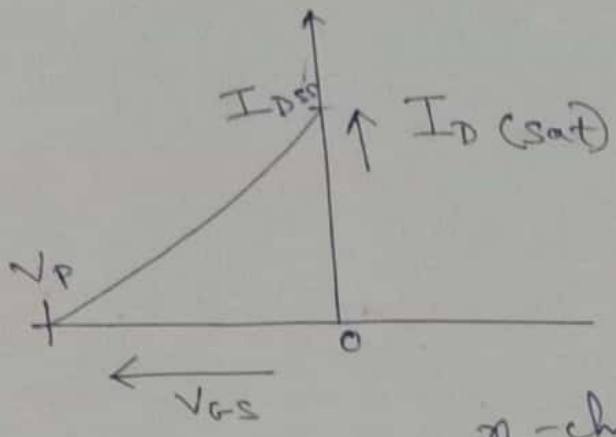
Transfer characteristics :-



n-channel

When the saturation drain current $I_{D(sat)}$ is plotted against the gate to source voltage, the transfer characteristics is obtained.

The nature of transfer characteristic is represented by shockley equation

$$I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$ [V_P = pinch-off voltage]

differentiating with respect to V_{GS}

$$\frac{2I_{DS}}{2V_{GS}} = 2I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)\left(-\frac{1}{V_P}\right)$$

let, $\frac{2I_{DS}}{2V_{GS}} = 0$

$$2I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)\left(-\frac{1}{V_P}\right) = 0$$

$$1 - \frac{V_{GS}}{V_P} = 0$$

$$V_P = V_{GS}$$

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$$\left.\frac{\partial I_{DS}}{\partial V_{GS}}\right|_{V_{GS}=0} = -\frac{2I_{DSS}}{V_P} = -\frac{I_{DSS}}{V_P/2}$$

FET Parameter :-

In case of JFET, the drain current I_D is a function of V_{GS} and V_{DS}

i.e, $I_D = f(V_{DS}, V_{GS})$

$$\Delta I_D = \left.\frac{\partial I_D}{\partial V_{GS}}\right|_{V_{DS}=\text{const}} \times \Delta V_{GS} + \left.\frac{\partial I_D}{\partial V_{DS}}\right|_{V_{GS}=\text{const}} \times \Delta V_{DS}$$

$$i_d = \left.\frac{i_d}{v_g}\right|_{v_d=0} \times v_g + \left.\frac{i_d}{v_d}\right|_{v_g=0} \times v_d$$

$$= g_m v_g + \frac{v_d}{r_d}$$

where $\left.\frac{i_d}{v_g}\right|_{v_d=0} = g_m$

$$\frac{1}{r_d} = \left.\frac{i_d}{v_d}\right|_{v_g=0}$$

1) Transconductance / mutual conductance / common-source forward transadmittance

The ratio of the change in drain current to the corresponding change in gate-source voltage for a constant drain-source voltage is defined as transconductance.

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ii) AC drain / output resistance / AC channel resistance

The ratio of the change in drain-source voltage to the corresponding change in drain current when gate-source voltage is ~~current~~ constant.

iii) Amplification factor (μ) :-

The ratio of the change in drain-source voltage to the corresponding change in gate-source voltage for a constant drain-current is defined as amplification factor.

$$i_d = g_m v_g + \frac{v_d}{r_d}$$

$$0 = g_m v_g + \frac{v_d}{r_d}$$

$$-g_m v_g = v_d / r_d$$

$$-\frac{v_d}{v_g}\bigg|_{i_d=0} = g_m r_d = \mu.$$

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