# Field effect transistor

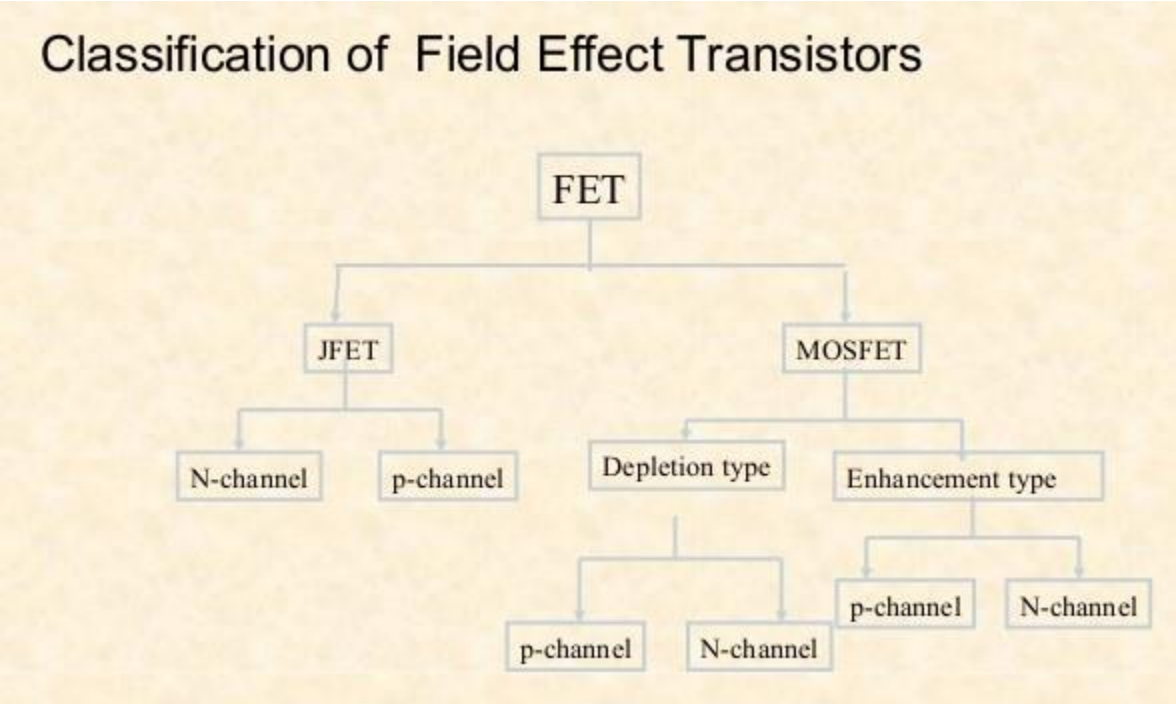
Dr. Mithun Kr. Bhowal

Bangabasi Morning College

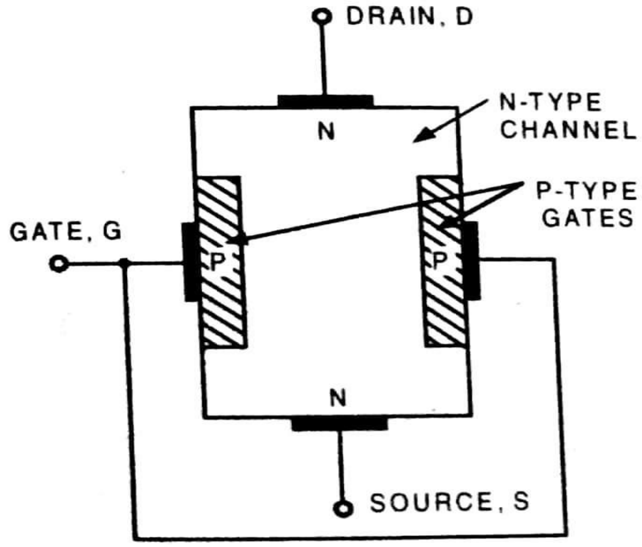
# Introduction:

- **The field effect transistor or FET** is a semiconductor device with the output current controlled by an electric field.
- **Why unipolar?** Since the current carried predominantly by one type of carriers, the FET is known as unipolar device.
- **Difference between FET & BJT?**

| *FET* | *BJT* |
|---|---|
| 1. FET is an unipolar semiconductor device because its operation depends upon the flow of majority carriers *i.e.*, either holes or electrons as the case may be. | 1. BJT is a bipolar semiconductor device because the current constituting elements are both majority carriers as well as minority carriers in this case. |
| 2. The input impedance of FET is much more larger (ranging in Megaohms) than BJT. The reason behind this is that the input terminal *i.e.*, gate to source of FET is reverse biased and reverse bias offers ideally infinite resistance. | 2. The input impedance of BJT is very less in comparison to FET. |
| 3. FET is a voltage controlled device. | 3. BJT is a current controlled device. |
| 4. FET is less noisy. Because there are no junctions. | 4. Much noisy than FET. |
| 5. Higher frequency response. | 5. Frequency variation affects the performance. |
| 6. Good thermal stability because of absence of minority carriers. | 6. Temperature dependent, thermal runaway may cause. |
| 7. Costlier than BJT. | 7. Relatively cheaper. |
| 8. Small sized. | 8. Comparatively bigger. |
| 9. In FET, relationship between input and output quantities is nonlinear due to square term in shockley's equations $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$ | 9. The BJT is an almost linear device or we can say that BJT works linearly in active region as an amplifier. |
| 10. No offset voltage; so it works better as a switch or chopper. | 10. There is always an offset voltage before switching. |
| 11. Small gain bandwith product. | 11. Greater than FET. |

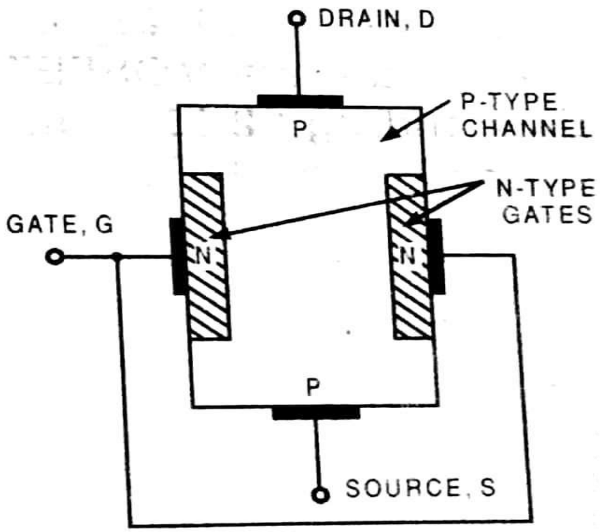


## Junction field effect transistor (JFET):



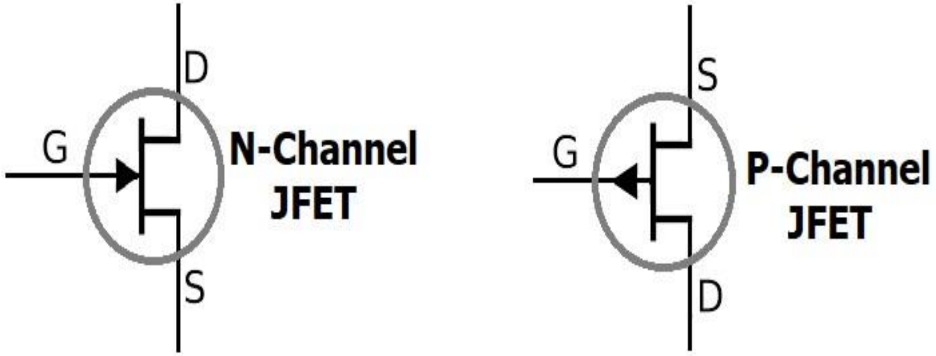



(a) N-Channel JFET




(b) P-Channel JFET

- The terminal through which the majority carrier enter is called the **source**.
- The terminal through which the majority carrier leave is called the **drain**.
- The region between the two **gate** regions through which majority carrier move from source to drain is called the **channel**.




Circuit symbol

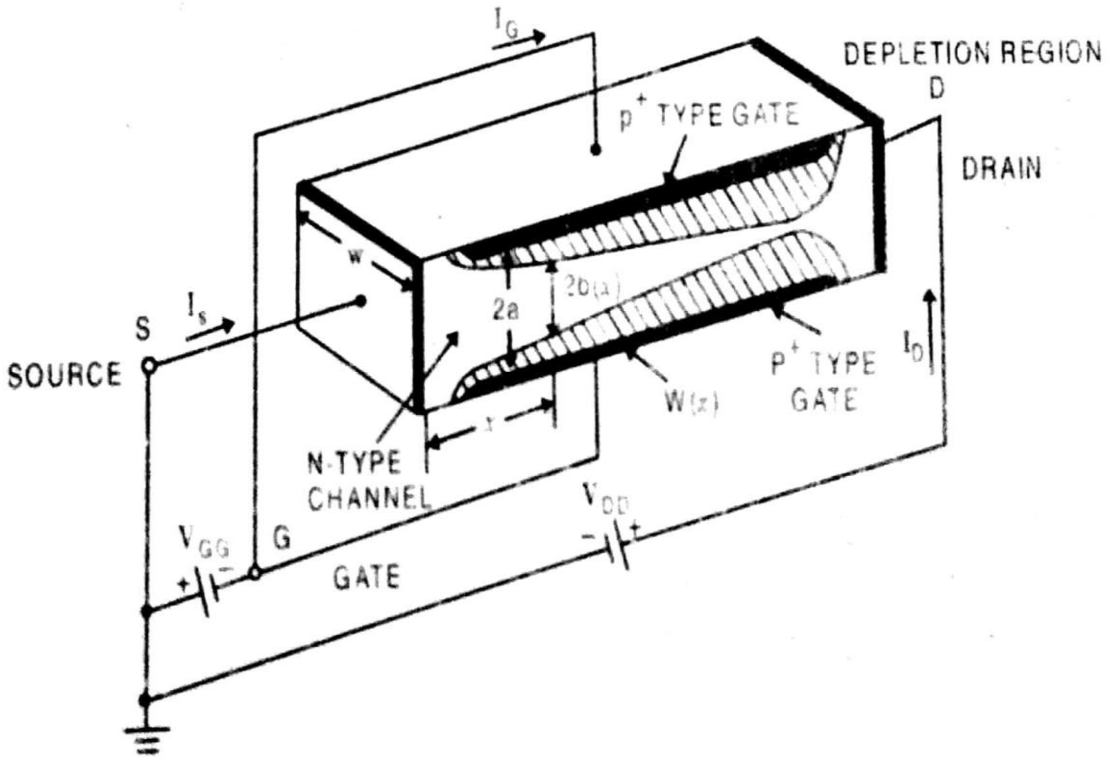
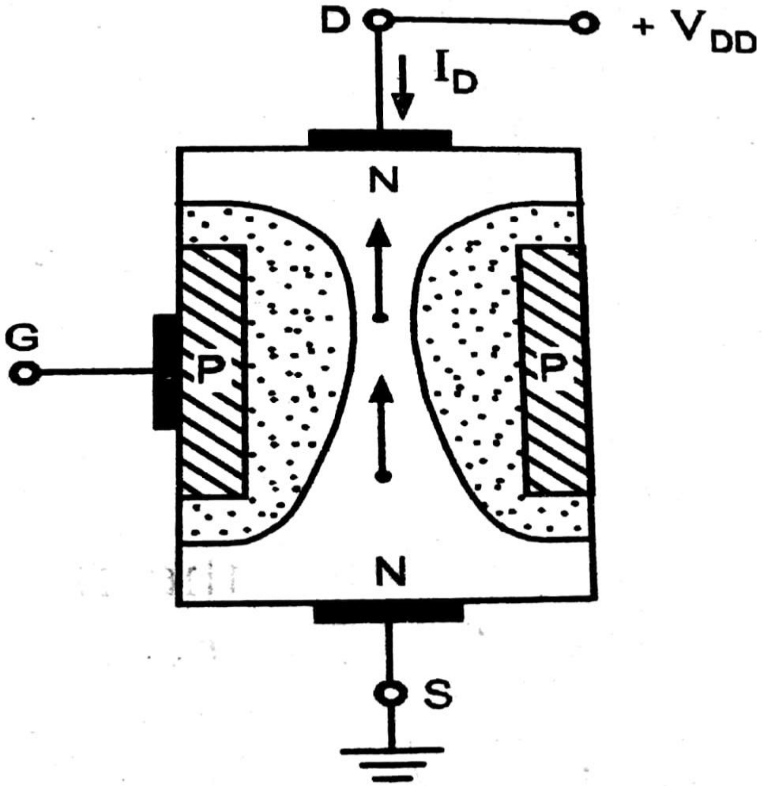
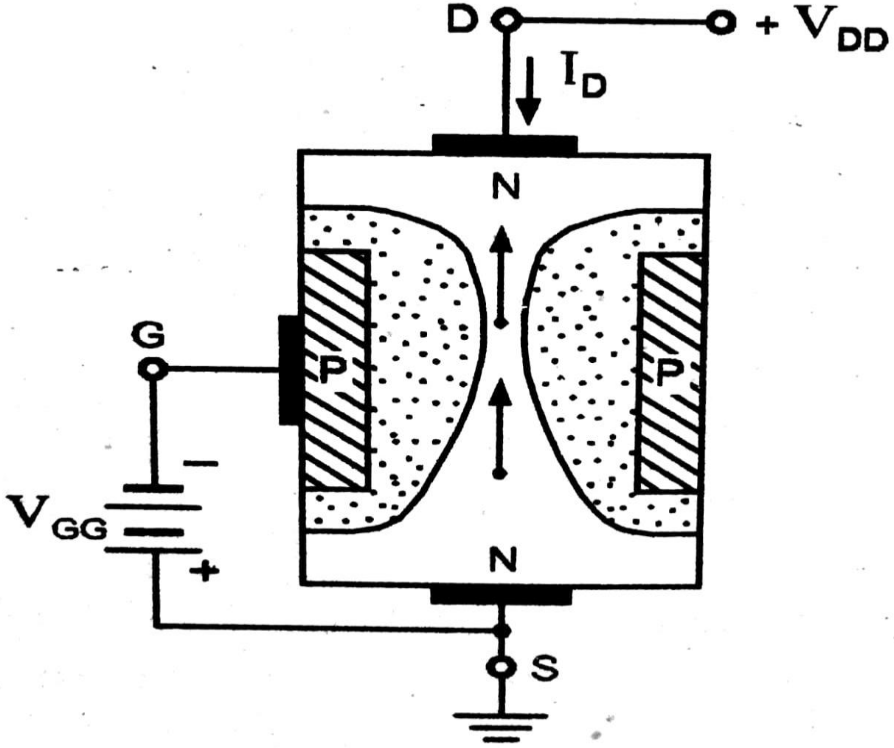
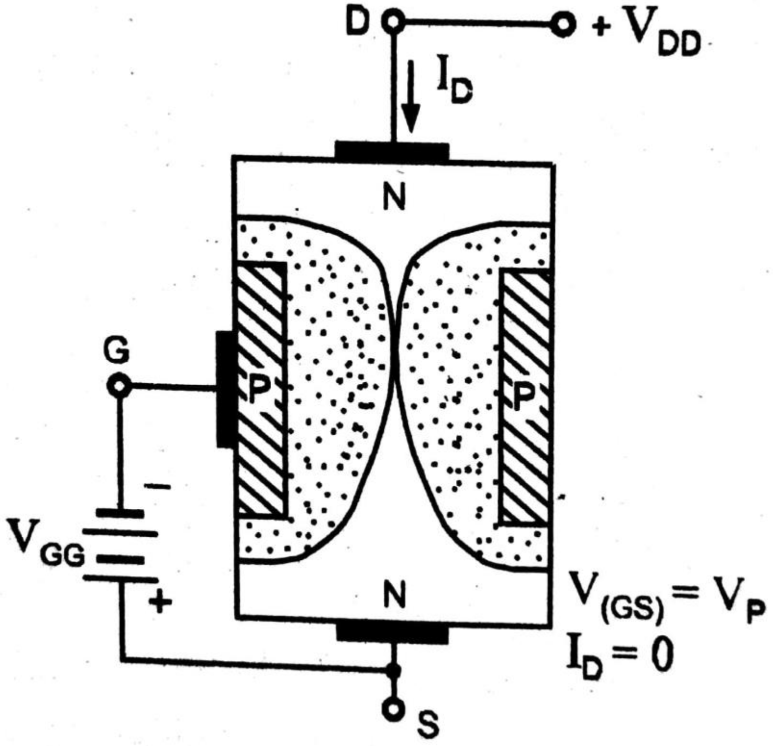



**Fig. 12.3.** ***Basic Structure of an N-Channel FET***

## Operation:

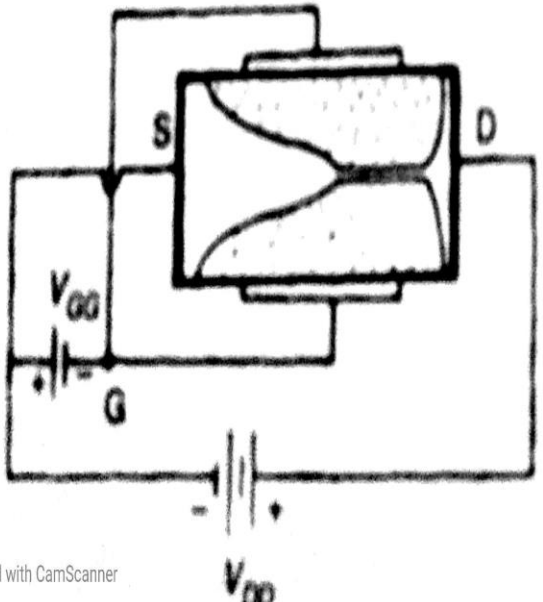



*(c)*

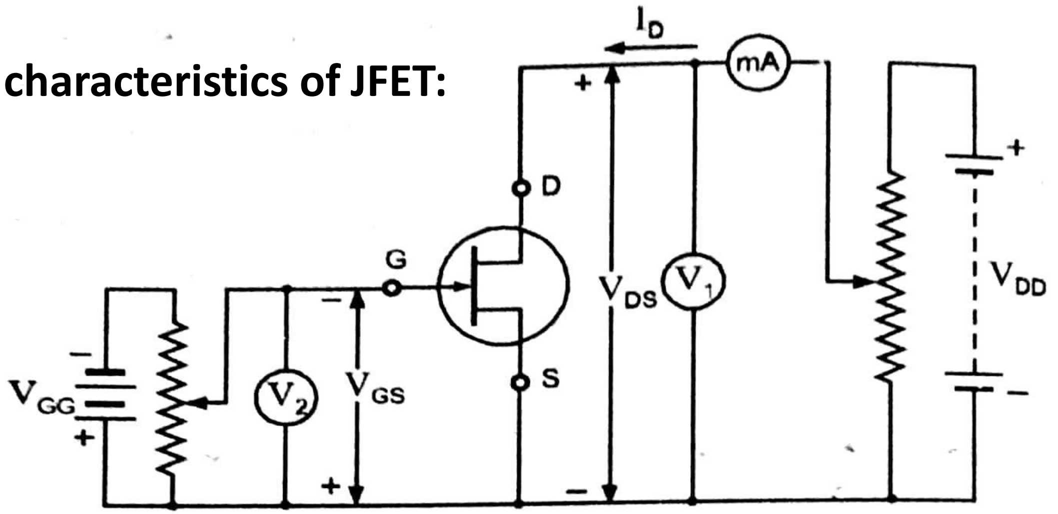




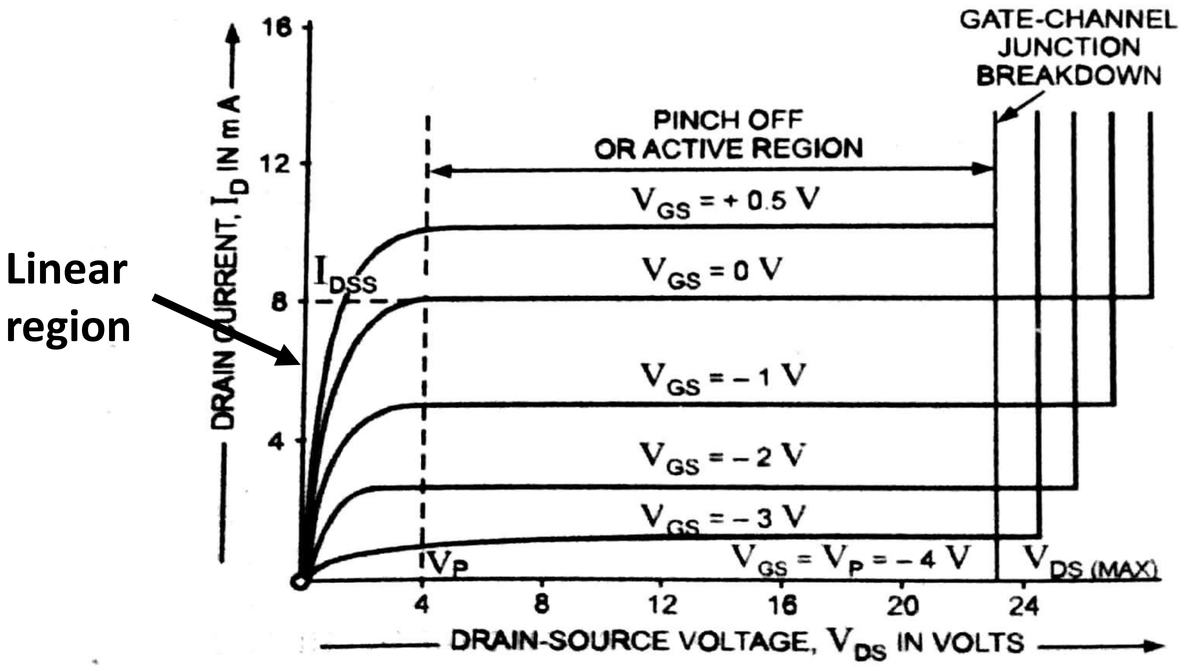



Pinch off

**Static characteristics of JFET:**




*(a) Circuit Diagram For Determining Drain Characteristic With External Bias For an N-Channel JFET*






*(b) JFET Drain-Characteristics With External Bias*

# FET Parameters

- Drain Resistance ($r_d$)
  - The dynamic a.c. resistance is defined as the ratio of infinitesimal change in $V_{DS}$ to the corresponding change in drain current $I_D$ at a constant value of $V_{GS}$ $r_d = \frac{\Delta V_{DS}}{\Delta I_D}$
- Transconductance ($g_m$)
  - The mutual conductance is defined as the ratio of the change in drain current to the corresponding change in $V_{GS}$ at a constant value of $V_{DS}$

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}}$$



**(iii) Amplification factor ($\mu$).** *It is the ratio of change in drain-source voltage ($\Delta V_{DS}$) to the change in gate-source voltage ($\Delta V_{GS}$) at constant drain current i.e.*

$$\text{Amplification factor, } \mu = \frac{\Delta V_{DS}}{\Delta V_{GS}} \text{ at constant } I_D$$

## Relation between $\mu$, $r_d$ and $g_m$

The drain current $I_D$ is a function of drain voltage $V_{DS}$ and gate voltage $V_{GS}$ i.e.,

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

$$\therefore \quad dI_D = \left.\frac{\partial I_D}{\partial V_{DS}}\right|_{V_{GS}} dV_{DS} + \left.\frac{\partial I_D}{\partial V_{GS}}\right|_{V_{DS}} .dV_{GS} \qquad (9.5\text{-}4)$$

If $V_{DS}$ and $V_{GS}$ are simultaneously so changed that $I_D$ remains constant then $dI_D = 0$ and we can write from Eq. (9.5-4) after rearrangement,

$$\left.\frac{\partial I_D}{\partial V_{DS}}\right|_{V_{GS}} \cdot \left.\frac{\partial V_{DS}}{\partial V_{GS}}\right|_{I_D} + \left.\frac{\partial I_D}{\partial V_{GS}}\right|_{V_{DS}} = 0$$

Now using the definitions (9.5.1)–(9.5-3),

$$\frac{1}{r_d}(-\mu) + g_m = 0$$

$$\text{or,} \quad \mu = r_d \cdot g_m$$

# Thank you