Junction Field effect transistor: Observation from output and transfer characteristics, JFET parameters, and Numericals

Reference: Electronics Devices and Circuits 1 by Ravish Singh

3.3 JFET CHARACTERISTICS

Fig 3.4 shows experimental set up to draw drain or output characteristics of an n-channel JFET.

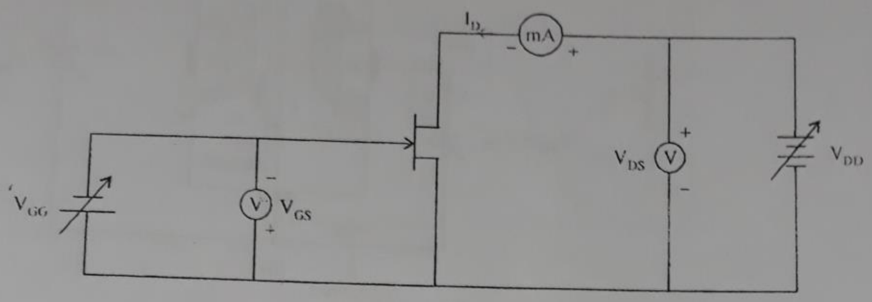

Fig. 3.4

3.3.1 Drain Characteristics

It is the graph of the drain current I_D versus drain to source voltage V_{DS} for different values of gate to source voltage V_{GS}.

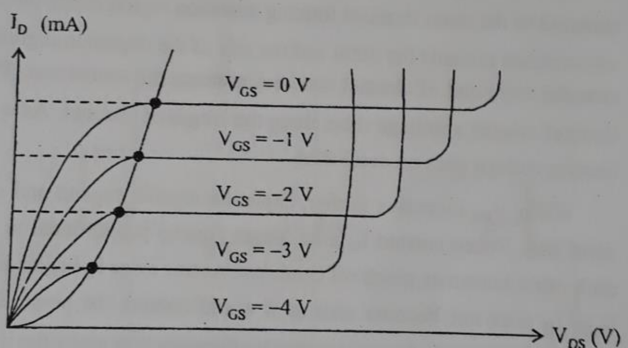

Fig. 3.5

When both V_{GS} and V_{DS} are zero, drain current does not flow. At $V_{GS} = 0$, as V_{DS} is increased from zero, I_D will increase proportionally through the n type material as shown in the graph. As V_{DS} increases, the voltage drop along the channel also increases. This increase in voltage drop increases the reverse bias on gate source junction and causes the depletion region to penetrate into the channel, reducing channel width. Thus rate of increase in I_D w.r.t. V_{DS} is now reduced. At some value of V_{DS}, drain current I_D can not increased further. I_D approaches the constant saturation value. This voltage V_{DS} is called pinch-off voltage V_P. If we increase V_{DS} further, a stage is reached where gate-channel junction breakdown and current I_D begins to increase very rapidly. Breakdown can result in irreversible damage to the device. Hence JFETs are always operated below breakdown and within constant current region.

When an external voltage V_{GS} is applied to the gate and source, the gate channel junction is further reverse biased, reducing the effective channel width. Hence drain current I_D decreases and pinch off voltage is reached at a lower drain current than when $V_{GS} = 0$.

Junction Field effect transistor: Observation from output and transfer characteristics, JFET parameters, and Numericals

When V_{GS} has a sufficiently large negative value, I_D is reduced to zero. This is caused by the widening of the depletion region to a point where it completely closes the channel. The value of V_{GS} that makes I_D approximately zero is called the cutoff voltage $V_{GS\ (off)}$.

Thus pinch-off voltage V_p is the value of the V_{DS} at which drain current reaches a constant value for a given value of V_{GS}. The cutoff voltage $V_{GS\ (off)}$ is the value of V_{GS} at which the drain current is zero. $V_{GS\ (off)}$ and V_p are always equal in magnitude but opposite in sign. For example, if $V_{GS\ (off)} = -4$ V, then $V_P = 4$ V.

3.3.2 Transfer Characteristic

It is the graph of gate to source voltage V_{GS} and drain current I_D. The transfer characteristic can be derived from the drain curve characteristic by plotting values of I_D for the value of V_{GS} taken from the family of drain curves in the pinch-off region as shown in Fig. 3.6. Each point on the transfer characteristic curve corresponds to specific values of V_{GS} and I_D on the drain curves. The transfer characteristic curve is nearly parabolic in shape and can therefore be expressed as,

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

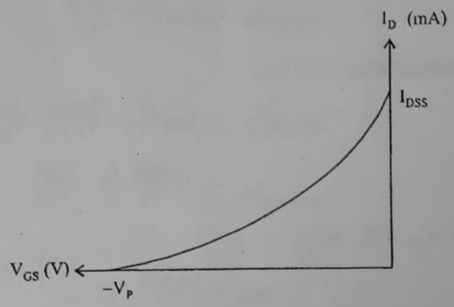

Fig. 3.6

3.4 JFET PARAMETERS

3.4.1 Transconductance (g_m)

It is the ratio of change in drain current to the change in gate source voltage at constant drain to source voltage.

$$g_m = \left.\frac{\Delta I_D}{\Delta V_{GS}}\right|_{V_{DS} = \text{constant.}}$$

It is slope of transfer characteristic.

Junction Field effect transistor: Observation from output and transfer characteristics, JFET parameters, and Numericals

Expression for g_m

We know that

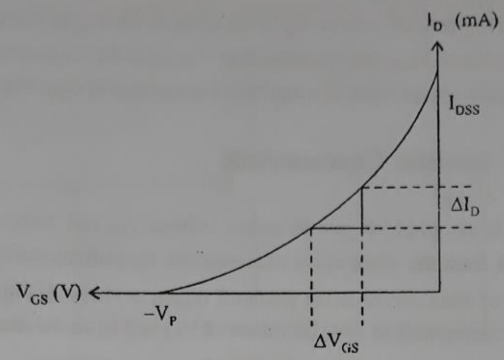

Fig. 3.7

$$I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_p}\right)^2$$

Differentiating w.r.t. V_{GS},

$$\frac{\partial I_D}{\partial V_{GS}} = I_{DSS}\, 2\left(1-\frac{V_{GS}}{V_P}\right)\left(-\frac{1}{V_p}\right)$$

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

If $V_{GS} = 0$,

$$g_{mo} = \frac{-2 I_{DSS}}{V_p}$$

$$g_{mo} = \frac{2 I_{DSS}}{|V_p|}$$

$$g_m = g_{mo}\left(1-\frac{V_{GS}}{V_p}\right) = \frac{2 I_{DSS}}{|V_p|}\sqrt{\frac{I_D}{I_{DSS}}}$$

where g_{mo} is maximum value of transconductance.

A large change in V_{GS} causes small change in I_D. Hence g_m is very small.

3.4.2 Drain resistance (r_d)

It is the ratio of change in drain source voltage to the change in drain current at constant gate source voltage

$$r_d = \left.\frac{\Delta V_{DS}}{\Delta I_D}\right|_{V_{GS} = \text{constant}}$$

Junction Field effect transistor: Observation from output and transfer characteristics, JFET parameters, and Numericals

It is reciprocal of the slope of drain source characteristics

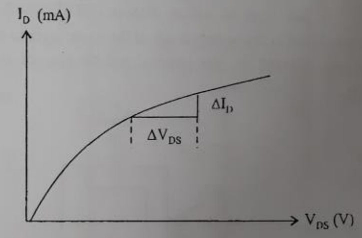

Fig. 3.8

3.4.3 Amplification factor (μ)

It is the ratio of change in drain source voltage to the change in gate source voltage at constant drain current.

$$\mu = \left.\frac{\Delta V_{DS}}{\Delta V_{GS}}\right|_{I_D = \text{ constant}}$$

We know that,

$$g_m = \left.\frac{\Delta I_D}{\Delta V_{GS}}\right|_{V_{DS} = \text{constant.}}$$

$$r_d = \left.\frac{\Delta V_{DS}}{\Delta I_D}\right|_{V_{GS} = \text{constant}}$$

$$g_m\, r_d = \frac{\Delta I_D}{\Delta V_{GS}} \frac{\Delta V_{DS}}{\Delta I_D} = \frac{\Delta V_{DS}}{\Delta V_{GS}}$$

$$\mu = g_m\, r_d$$

JFET

01
18/8/17

Numerical 01

A n-channel JFET has a drain current of 5mA. If $I_{DSS} = 10mA$ and $V_{GS(off)} = -6V$. Find value of a) V_{GS} (Gate to source voltage)
b) V_P

Soln:- a) $$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$$

$$5mA = 10mA\left(1 + \frac{V_{GS}}{6}\right)^2$$

$$\frac{1}{2} = \left(1 + \frac{V_{GS}}{6}\right)^2$$

ie $$1 + \frac{V_{GS}}{6} = \frac{1}{\sqrt{2}} = 0.707$$

ie $V_{GS} = -1.757\ V$

b) $V_P = |V_{GS(off)}| = 6V$

Numerical 02

02

The datasheet of an n JFET gives the following information:-

$I_{DSS} = 7\,mA$, $V_{GS(off)} = -2.5\,V$

Find a) g_m (transconductance) for $V_{GS} = -1.5\,V$

b) Drain current at this point

Soln:- a)

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

$$= \frac{-2 \times 7 \times 10^{-3}}{-2.5}\left(1 - \frac{(-1.5)}{(-2.5)}\right)$$

$$g_m = 2.24\ \frac{mA}{V}$$

b)

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2 = 7\,mA\left(1 - \frac{(-1.5)}{(-2.5)}\right)^2$$

$$I_D = 1.12\ mA$$