Analog & Digital Electronics
Course No: PH-218

Lec-26: Field Effect Transistors (FETs)

Course Instructor:

❖ Dr. A. P. VAJPEYI

Department of Physics,
Indian Institute of Technology Guwahati, India
Field Effect Transistors (FETs)

- Field effect transistors are unipolar device because current is carried by only one type of carriers (majority carriers) while BJTs were bipolar.

- FETs are voltage controlled device where output current is controlled by voltage between two terminals gate and source while BJTs were current controlled device.

- FETs are characterized by very high input resistance (in mega ohm) while BJT have high gain.

- **FETs are less sensitive to temperature variations and are more easily integrated on ICs.**

Types of FETs:

- Junction Field Effect Transistor (JFET)

- Metal Oxide semiconductor Field Effect Transistor (MOSFET)
Junction Field Effect Transistors (JFETs)

- Junction field effect transistor (JFET) is a type FET that operates with a reverse biased p-n junction to control current in a channel.

- Depending on the structure, JFET fall in two categories: n channel and p channel JFET.
Operation of n channel FET

Case I: JFET at $V_{GS}=0$ and $V_{DS} > 0$

- JFET has two p-n junction. When $V_{GS}=0$, both gate and source are at same potential so depletion region in low end of each p material is similar.

- The depletion region is wider near the top of both p type material because of higher potential at upper region. (Upper end of n-channel (drain) is at $V_D$ and lower end (source) is at ground)

The instant $V_{DS}$ is applied across the channel, the electrons are drawn towards the drain giving drain current.

As the $V_{DS}$ is increased from 0V to a few V, the current will increase according to Ohm’s law.

As the $V_{DS}$ approaches to $V_p$, the depletion width increases causing a reduction in channel width.

The value of $V_{DS}$ (at $V_{GS}=0$) for which two depletion region touches is called pinch off voltage and denoted by $V_p$. 

[Diagram of JFET]
Operation of n channel FET

Case II: JFET at $V_{GS} < 0$ and $V_{DS} > 0$

at $V_{GS}=0$ and $V_{DS} > 0$

Channel narrowing effect

The level of $V_{GS}$ that results in $I_D = 0$ mA is $V_{GS} = V_P$

$V_P$ is a negative voltage for n-channel and positive for p-channel JFETs.
Transfer Characteristics

The relationship between $I_D$ and $V_{GS}$ is defined by Shockley’s equation:

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

Where $I_{DSS}$ and $V_P$ are constants and $V_{GS}$ is variable and controllable.

The transfer function curve may be plotted from the characteristic curve, as shown. Notice the parabolic shape due to the square term relationship between $I_D$ and $V_{GS}$.

Remember that, when $V_{GS} = 0$, $I_D = I_{DSS}$ and when $V_{GS} = V_P$, $I_D = 0$ mA.
Biasing scheme of FET: Voltage divider Bias

\[ V_G = \frac{R_2}{R_1 + R_2} V_{DD} \]

\[ V_{GS} = V_G - I_D R_S \]

\[ V_{DS} = V_{DD} - I_D (R_D + R_S) \]

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

Biasing schemes for FETs are similar to BJT. Most popular voltage divider scheme is shown here.