**Ministry of Higher Education and Scientific Research**

**Al-Mustaqbal University College**

**Department of Medical Physics**

# Analog Electronics

## Lecture 7

# Field Effect Transistor (FET)

**By**

**M. Sc. Hasanein Ameer Hamza**

**2021 A.D** **1443 A.H**

# Field Effect Transistor

A Field Effect Transistor (FET) is a three-terminal semiconductor device. Its operation is based on a controlled input voltage. By appearance JFET and bipolar transistors are very similar. However, BJT is a current controlled device and JFET is controlled by input voltage. Most commonly two types of FETs are available.

- Junction Field Effect Transistor (JFET).
- Metal Oxide Semiconductor FET (MOSFET).

# Junction Field Effect Transistor (JFET)

The functioning of Junction Field Effect Transistor depends upon the flow of majority carriers (electrons or holes) only. Basically, JFETs consist of an N-type or P-type silicon bar containing PN junctions at the sides. There are two types of JFETs commonly used in the field semiconductor devices: N-Channel JFET and P-Channel JFET. Following are some important points to remember about FET:

- **Gate (G):** By using diffusion or alloying technique, both sides of N-type bar are heavily doped to create PN junction.
- **Source (S):** It is the entry point for majority carriers through which they enter into the semiconductor bar.
- **Drain (D):** It is the exit point for majority carriers through which they leave the semiconductor bar.
- **Channel:** It is the area of N-type material through which majority carriers pass from the source to drain.

# N-Channel JFET

It has a thin layer of N-type material formed on P-type substrate. Following figure shows the crystal structure and schematic symbol of an N-channel JFET. Then the gate is formed on top of the N-channel with P-type material. At the end of the channel and the gate, lead wires are attached and the substrate has no connection.

When a DC voltage source is connected to the source and the drain leads of a JFET, maximum current will flow through the channel. The same amount of current will flow from the source and the drain terminals. The amount of channel current flow will be determined by the value of $V_{DD}$ and the internal resistance of the channel.

A typical value of source-drain resistance of a JFET is quite a few hundred ohms. It is clear that even when the gate is open full current conduction will take place in the channel. Essentially, the amount of bias voltage applied at $I_D$, controls the flow of current carriers passing through the channel of a JFET. With a small change in gate voltage, JFET can be controlled anywhere between full conduction and cutoff state.

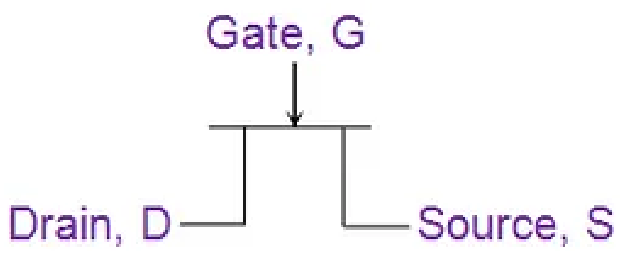


Figure (42) N-channel JFET Circuit Symbol.

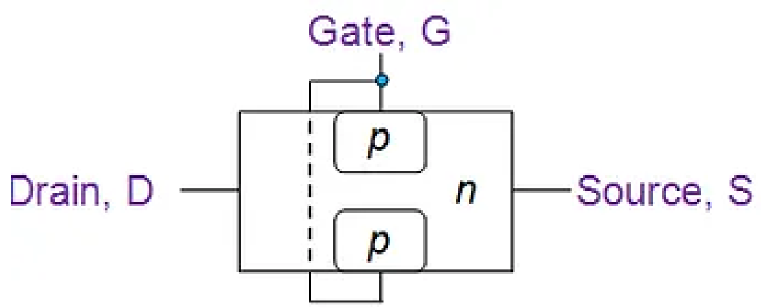


Figure (43) N-channel JFET Layered Structure.

## Working of N-channel JFET

In n-channel JFET, the majority charge carriers will be the electrons as the channel formed in-between the source and the drain is of N-type. Further, the working of these devices depends upon the voltages applied at its terminals.

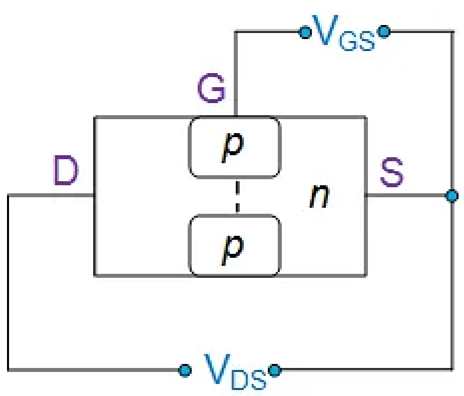


Figure (44) N-channel JFET in Biased state.

# P-Channel JFET

It has a thin layer of P-type material formed on N-type substrate. The following figure shows the crystal structure and schematic symbol of an N-channel JFET. The gate is formed on top of the P-channel with N-type material. At the end of the channel and the gate, lead wires are attached. Rest of the construction details are similar to that of N-channel JFET.

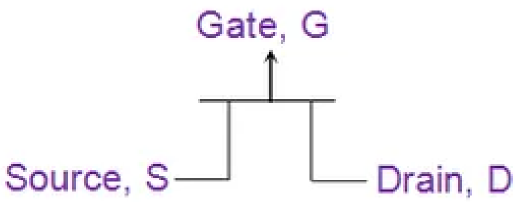


Figure (45) P-channel JFET Circuit Symbol.

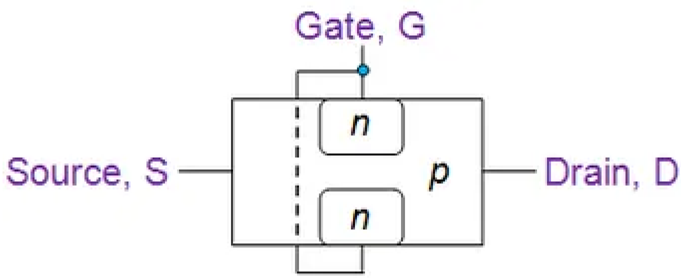


Figure (46) P-channel JFET Layered Structure.

Normally for general operation, the gate terminal is made positive with respect to the source terminal. The size of the P-N junction depletion layer depends upon fluctuations in the values of reverse biased gate voltage. With a small change in gate voltage, JFET can be controlled anywhere between full conduction and cutoff state.

## Working of P-channel JFET

Similar to the case of n-channel JFETs, the working of these devices also depends upon the voltages applied at its terminals.

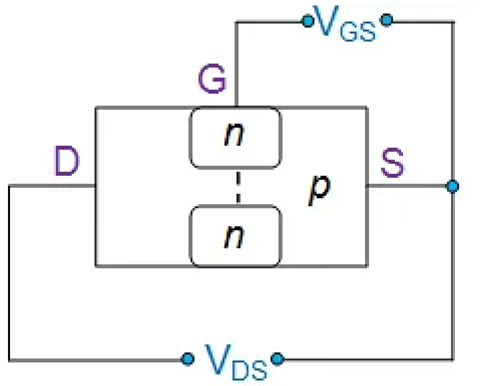


Figure (47) P-channel JFET in Biased state.

## JFET V-I Characteristics

The V-I characteristics of N-channel JFET are shown below. In this N-channel JFET structure the gate voltage ($V_{GS}$) controls the current flow between the source drain. The JFET is a voltage controlled device so no current flows through the gate, then the source current ($I_S$) is equal to the drain current ($I_D$) i.e. $I_D = I_S$. In this V-I characteristic the voltage $V_{GS}$ represents the voltage applied between the gate and the source and the voltage $V_{DS}$ represents the voltage applied between the drain and source.

The JFET has different characteristics at different stages of operation depending on the input voltages and the characteristics of JFET at different regions are explained below. Mainly the JFET operates in ohmic, saturation, cut-off and break-down regions.

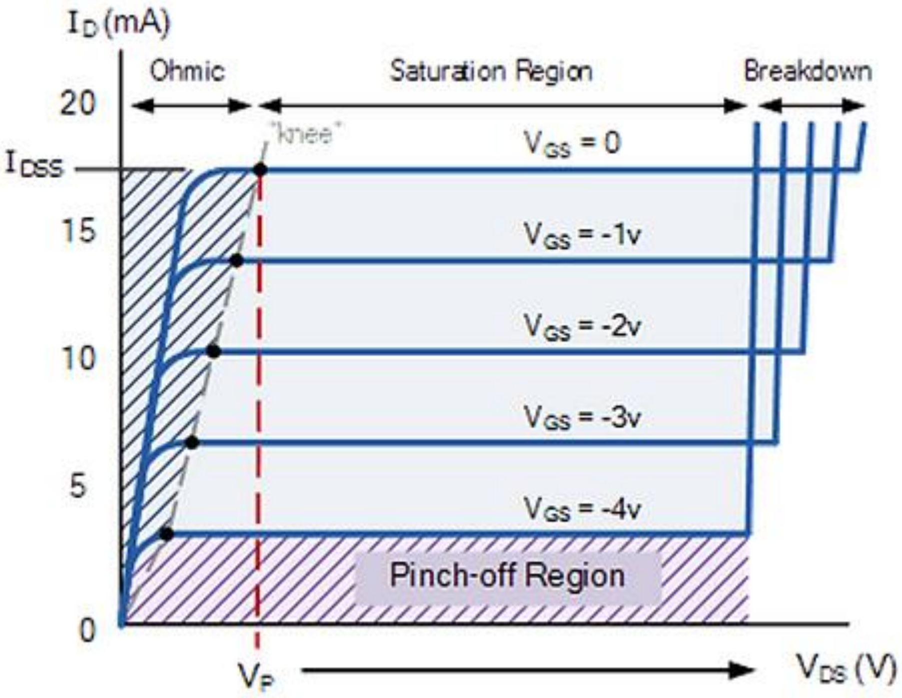


Figure (48) I-V Characteristics curve of JFET.

## Advantages of JFET

- The JFET has high input impedance.
- The JFET can be fabricated in small size area.
- It is a majority charge carrier device, hence it has less noise.
- It is a low power consumption device.
- It can be fabricated in small size area.
- It occupies less space in circuits due to its smaller size.
- It has a negative temperature coefficient of resistance, so they possess higher Temperature Stability.

## Disadvantages of JFET

- The main disadvantage of the JFET is the relatively low gain bandwidth product.
- The performance of JFET goes downs as frequency increases due to feedback by internal capacitance.

## JFET Applications

- JFET is used as a switch.
- JFET is used as a chopper.
- Used as an amplifier.
- Used as a buffer.
- Used in the oscillatory circuits because of its low frequency drift.
- Used in digital circuits, such as computers, LCD and memory circuits because of their small size.
- Used in communication equipment, such as FM and TV receivers because of their low modulation distortion.
- Used as voltage controlled resistors in operational amplifiers.
- JFETs are used in cascade amplifiers and in RF amplifiers.