Session 2

BALAJI C

Characteristics of JFET (CS, Common Drain and Common Gate configurations) and uses Differences between BJT and JFET

The Junction Field Effect Transistor is a voltage controlled device. In other words, voltage appearing on the gate, control the operation of the device. Field-effect transistors are unipolar devices. That is, the main current through them is comprised either of electrons in an N-channel JFET or holes in a P-Channel JFET.

The construction and symbol of the N-channel and P-channel devices are shown in Figure 1. They operate in similar manner, although the charge carriers are inverted, i.e. electrons in one and holes in the other. The N-channel device will be described here as this commonly used.

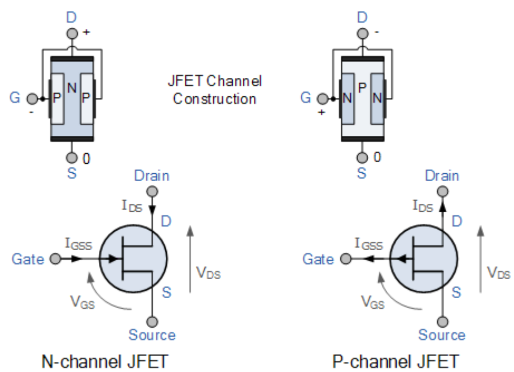

Figure 1. Construction, types and symbols

JFET has three terminals: Drain (D) and Source (S) are connected to n-channel and Gate (G) is connected to the p-type material. Always Input is reverse biased in JFET. The depletion region becomes thicker with increased reverse bias. The input should never be forward biased.

There are three JFET circuit configurations as follows

1. **Common Source (CS) configuration (Good voltage amplifier)**
   This amplifiers are mostly used. This is similar to CE transistor. Generally used in audio frequency amplifiers and in high input impedance pre-amplifier stages.
2. **Common Drain (CD) configuration (Good voltage buffer)**
   It works as the Source follower. It is referred to as "Common Drain" because there is no signal available at the drain connection. It features a high input impedance and a low output impedance. Since the voltage gain is nearly unity, these amplifiers are used in buffer amplifiers.
3. **Common Gate (CG) configuration (Good current buffer)**
   This amplifier has a low input impedance, but a high output impedance.

It is used in high frequency circuits or in impedance matching circuits where a low input impedance needs to be matched to a high output impedance. Another application of CG amplifier is Microphone amplifiers.

CS Amplifier

Session 2

BALAJI C

In CS configuration, the input is given to the gate and the output is taken from the drain as shown in Figure 2. It produces 180 degree phase shift between input and output. The features are

Good voltage amplifier	Better transconductance amplifier
Large voltage gain	High input resistance
Medium / high output resistance	

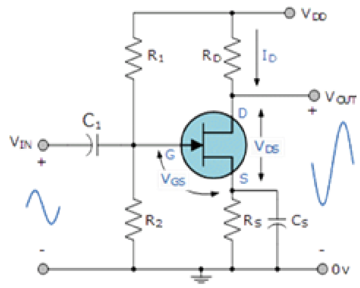

Figure 2. Typical circuit with components

Working of n-channel CS JFET

Operation analysis includes

- Without external bias: (V_{GS} =0)
- With external bias.

Consider that the gate is shorted (V_{GS}=0) with respect to the source. So, the drain is biased positively with respect to the source, so that $V_{DS} > 0$. For an n channel, this leads to electrons flowing from the source to the drain. The current flow in this scenario, with increasing V_{DS}, is shown in figure 3(b). The p regions are heavily doped so that the depletion region falls in the n side and the channel width reduces. Hence, the reduced current flow from drain to source.

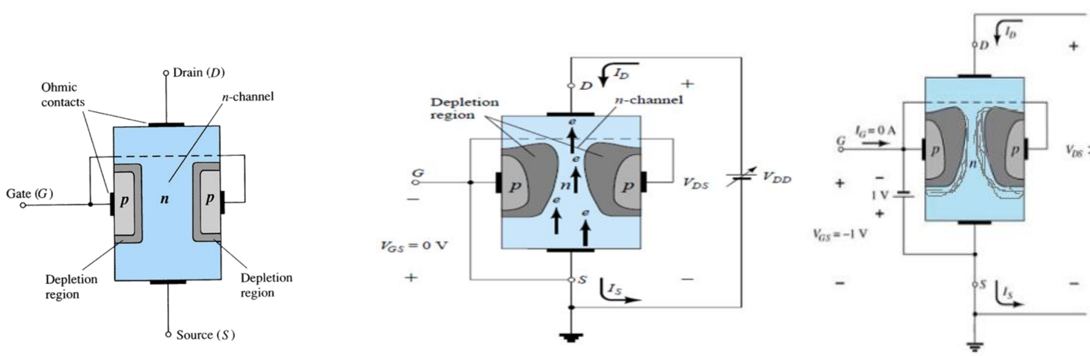

Figure 3.(a) When V_{GS}=0 and V_{DS}=0 (b) Operation with V_{GS}=0, (c) with V_{GS}<0 and V_{DS}>0

In the bias condition shown in figure 3(c), the region between the source and the Gate is reverse biased while the region between the drain and source is forward biased. With increase in V_{DS} the current flow in the channel increases but at the same time the channel starts to narrow near the drain side. Ultimately, beyond a certain value of V_{DS}, the channel is pinched off near the drain end. Hence, there is no increase in current, for a small increase in voltage. This is shown in the I-V characteristics in the next section. JFET has two characteristics namely

1. Drain characteristics
2. Transfer characteristics

The circuit connections to find the drain and transfer characteristics is shown in figure 4. By changing V_{GG}, the voltage applied at the gate to source V_{GS} is changing. It is to note that no gate current flows in JFET. The V_{DS} and I_D are changed by changing V_{DD}.

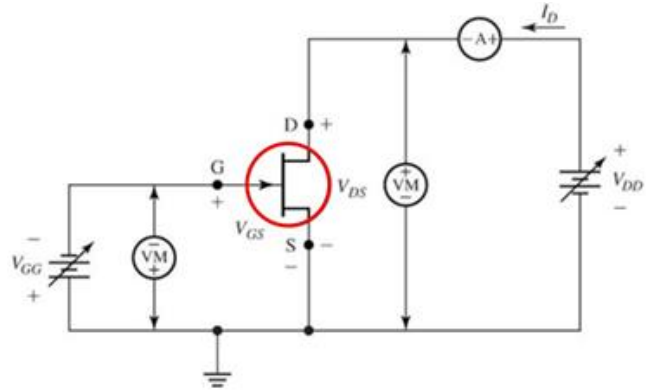

Figure 4. Connection diagram to determine the characteristics curves

1. Drain or V-I characteristics

Drain characteristics is also known as Output characteristics. It gives the relationship between Drain current (I_D) and Drain to source voltage (V_{DS}) for different values of gate to source voltage (V_{GS}).

With $V_G = 0$,

As shown in Figure 5(a), when no external Gate voltage ($V_{GS} = 0$), and a small voltage (V_{DS}) is applied between the Drain and the Source, the drain current increases linearly (Refer curve in the top with $V_{GS} = 0$). It grows lineraly till knee point and then it becomes nonlinear curve due to increase in width of the depletion layer. It reaches a point called pinch-off where both the depletion regions are coming closed without touching each other. The drain to source voltage at which this occurs is called as pinch-off voltage. As the voltage V_{DS} is increased further, the JFET enters the saturation region and operates as a constant current device. Because, the channel resistance increases proportional to the increase in V_{DS} which maintains I_D constant at I_{DSS}. If V_{DS} is increased beyond certain value, the JFET device will breakdown.

With V_G <0,

Now, the voltage (for example, -2V or -4V) as shown in Figure 5(b), is applied to the gate-source junction. Because of a small negative voltage ($-V_{GS}$), the size of the depletion region begins to increase. This reduces the overall effective area of the channel and thus reducing the current flowing through it. So, applying a reverse bias voltage increases the width of the depletion region which in turn reduces the conduction of the channel. Therefore, the characteristic curve corresponding to V_{GS}=-2V or -4V, has less current I_{DS}.

The result is that the FET acts more like a voltage controlled resistor which has zero resistance when $V_{GS} = 0$ and maximum "ON" resistance (R_{DS}) when the Gate voltage is very negative. Under normal operating conditions, the JFET gate is always negatively biased relative to the source. It is essential that the Gate voltage is never positive since if it is all the channel current will flow to the Gate and not to the Source, the result is damage to the JFET.

Further increase in V_{DS} beyond Pinch off point, has no effect in drain current. The drain current is maintained constant.

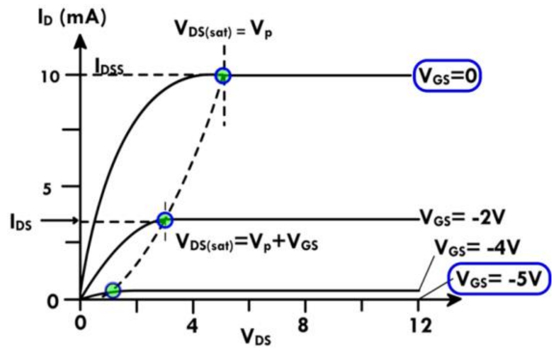

Figure 5(a). The drain characteristics curves

Important terms in JFET characteristics

Knee Point: Where the variation of drain current with drain-source voltage appears to be linear. But beyond this point, the linearity changes into a curve.

Channel Ohmic Region: The region to the left of the knee point in the characteristics curve.

Pinch-off point: The point in the curve beyond which the drain current will not increase further no matter how much we are increasing the drain to source voltage.

Pinch-off Voltage: The voltage at the pinch-off point is termed as pinch-off voltage because at this voltage, the current is completely turned to be constant.

Drain-Source Saturation Current: The drain to source saturation current is the current which becomes constant and enters into a saturation state.

Various operating regions in the drain characteristics such as Ohmic region, saturation region and breakdown region are clearly shown in Figure 5(b).

Session 2

BALAJI C

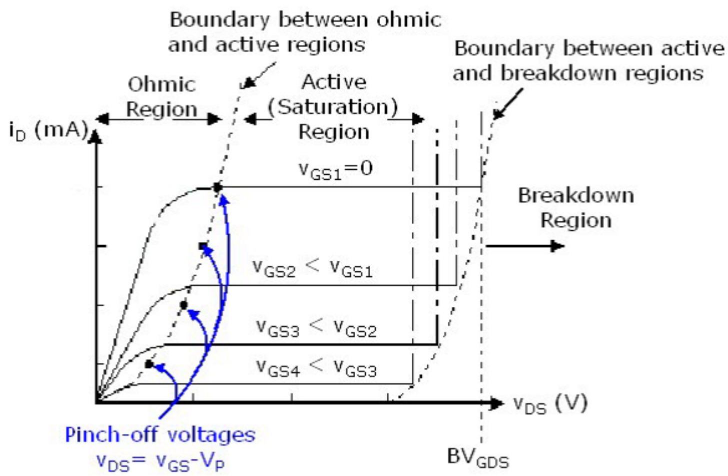

Figure 5.(b) The drain characteristics curves

2. Transfer characteristics

The transfer characteristics is drawn between input voltage and output current. Therefore, for an n-channel common source amplifier, it is the plot of the drain current Vs Gate source voltage for different values of drain to source voltage (V_{DS}).

From Figure 6, it is observed that when $V_{GS} = 0$, $I_D = I_{DSS}$ and when $I_D = 0$, $V_{GS} = V_P$. The transfer characteristic approximately follows the equation.

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

Using the drain characteristics, by reading V_{GS} and I_{DSS} values for different values of V_{DS} , the transfer characteristic can be drawn.

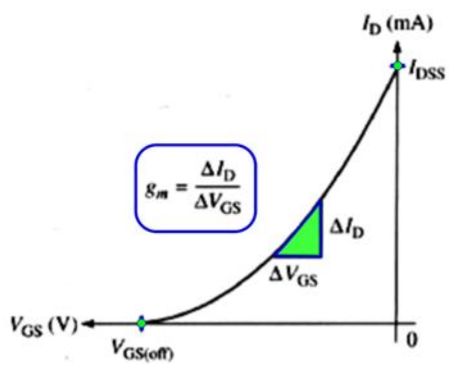

Figure 6. The transfer characteristics curves

It is observed that the value of drain current varies **inversely** with respect to gate-source voltage when the drain-source voltage is constant.

Similar procedure adopted in CS amplifier can be used to obtain the characteristics of CD and CG amplifiers. The basic circuit diagram, the transfer and drain characteristics are presented in Figure 7(a), (b) and (c) respectively.

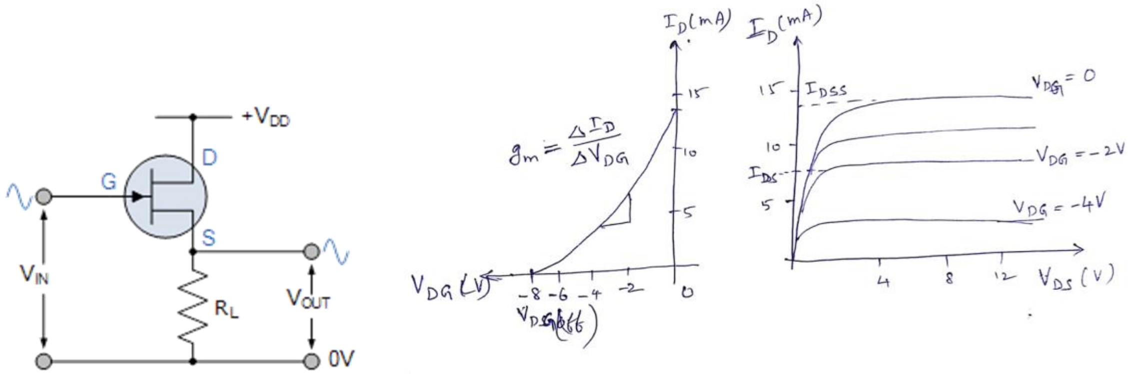

Figure 7. (a) Basic circuit of CD amplifier, (b) transfer characteristic and (c) drain characteristics

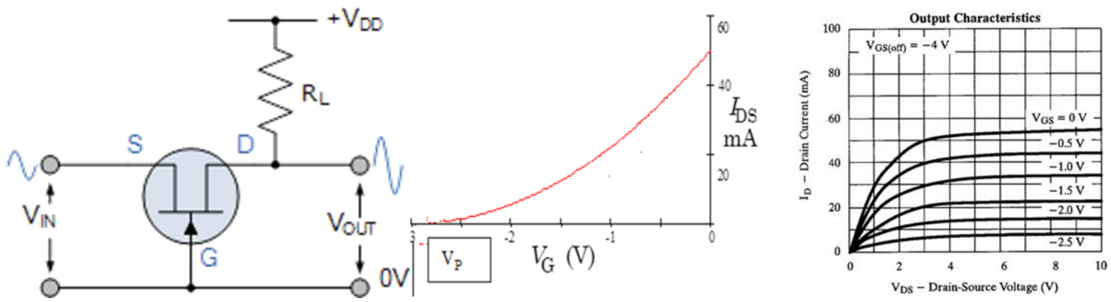

Figure 7.(a) Basic circuit of CG amplifier, (b) transfer characteristic and (c) drain characteristics

The basic circuit diagram of CG amplifier, the transfer and drain characteristics are presented in Figure 8(a), (b) and (c) respectively.

Session 2

BALAJI C

Comparison between BJT and JFET

BJT	JFET
Bipolar device (current condition, by both types of carriers, i.e. majority and minority-electrons and hole).	Unipolar device (current conduction is only due to one type of majority carrier either electron or hole).
The operation depends on the injection of minority carries across a forward biased .junction.	The operation depends on the control of a junction depletion width under reverse bias.
Current controlled device. The base current controls the output current.	Voltage controlled device. The gate voltage controls output current.
High noise level. (current conduction through junctions)	Low noise level. (current conduction is through n-channel or p-channel and no junction crossing)
Low input impedance (due to forward bias at input side).	High input impedance (due to reverse bias).
Gain is characterized by voltage gain.	Gain is characterised by transconductance.
Low thermal stability. (positive temperature coefficient at high current levels lead to thermal breakdown)	Better thermal stability.(NTC at high current levels prevent thermal breakdown)
Cheaper	Relatively costly