Experiment No.5

JFET Characteristics

Object

The purpose of this experiment is to determine and sketch the characteristics of the JFET and to find its parameters.

Required Parts and Equipment's

1. Electronic Test Board. (M100)
2. Dual Polarity Variable DC Power Supply
3. Digital Multimeters.
4. N-Channel JFET 2N3823/3824
5. Resistors 207KΩ, 220 Ω.

Theory

The Junction Field Effect Transistor (JFET) is a three-terminal device with one terminal (called the gate) capable of controlling the current between the other two terminals (drain and source). The primary difference between FET and BJT transistors is the fact that the BJT transistor is a current-controlled device, while the JFET transistor is a voltage-controlled device. The FET transistor is a unipolar device depending on either electron conduction (N-channel JFET) or hole conduction (P-channel JFET). In contrast, the BJT transistor is a bipolar device, meaning that the conduction depends on two charge carriers (electrons and holes) in the same time.

Another difference between two devices is the high input impedance of the JFET when compared with the BJT. The input impedance is usually larger than 1 MΩ. However, typical AC voltage gains for BJT amplifiers are greater than those for FET amplifiers. Furthermore, FETs are more temperature stable than BJTs and are usually smaller in size, making them particularly useful in integrated circuit chips.

The basic construction of an N-channel JFET is shown in Fig.1 together with its symbol.

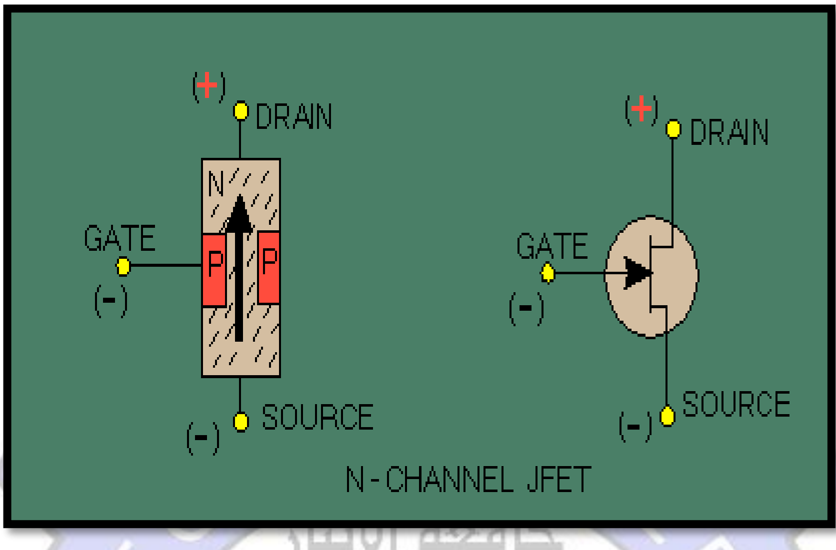


Figure 1: N-Channel JFET Structure and Symbol

The drain current (I_D) of the JFET is controlled by the application of reverse-biased voltage between gate and source terminals (V_{GS}). The relationship between I_D and V_{GS} is defined by the well-known Shockley's equation:

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

Where V_P is called the pinch-off voltage and I_{DSS} is known as the drain saturation current. When $V_{GS} = V_P$ then $I_D = 0$, and the FET is in the cut-off region. Equation (1) indicates that the FET is a square-law device.

The relation between I_D and V_{GS} is also referred as the transfer characteristic of the JFET and is presented in Fig.2. This curve is obtained by varying the negative voltage V_{GS} between V_P and 0 and measuring I_D for a given value of the drain to source voltage (V_{DS}). Equation (1) can approximate this curve to an acceptable level.

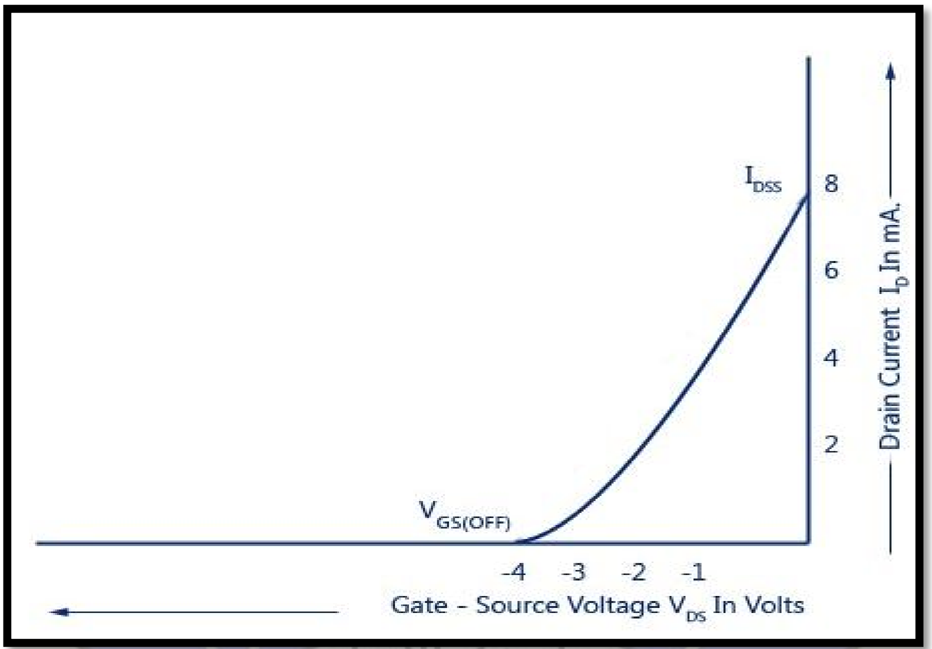


Figure 2: The Transfer Characteristics of the JFET

The circuit used to obtain the JFET characteristics is shown in Fig.3. To obtain the transfer characteristic, the drain supply voltage V_{DD} should be maintained at a certain value, and the gate supply voltage is adjusted to several negative values while recording I_D in each step.

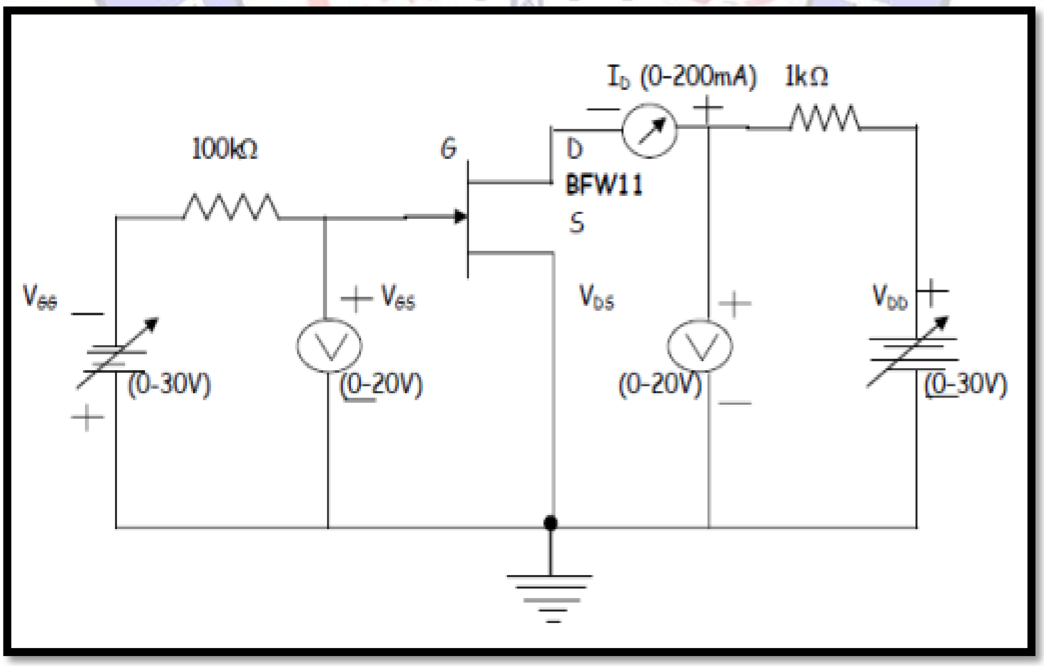
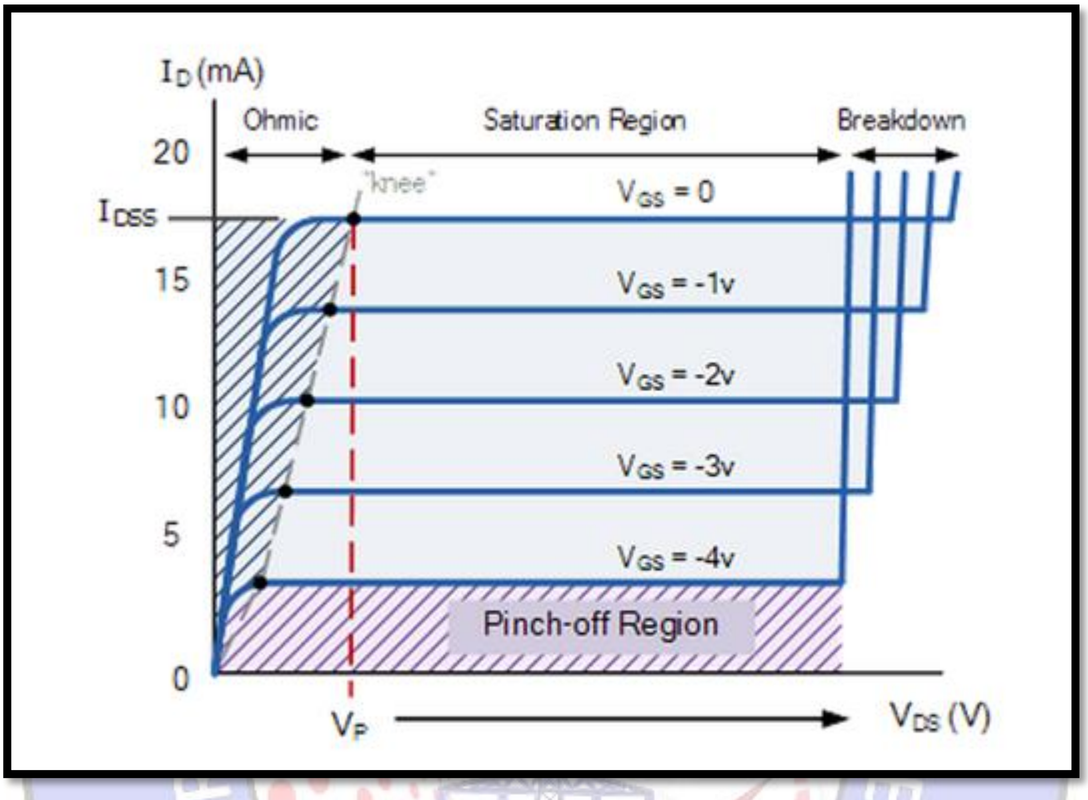


Figure 3: A Test Circuit for Getting JFET Characteristics

On the other hand, to sketch the drain characteristic, the gate-source voltage V_{GS} must be kept at a certain level while varying V_{DS} in several steps and recording I_D in each step. Figure 4 shows the drain (or output) characteristics of the JFET.



As shown from Fig.4, for small values of V_{DS} ($V_{DS} < |V_P|$) the drain current increases linearly with V_{DS}. This region is called the linear or Ohmic region in which the JFET behaves as a voltage-controlled resistor. For larger values of V_{DS} ($V_{DS} > |V_P|$), the drain current (I_D) is approximately constant and enters the saturation region.

The transconductance of the JFET (g_m) is defined as the change in drain current (ΔI_D) for a given change in gate-to-source voltage (ΔV_{GS}) with the drain-to-source voltage (V_{DS}) kept constant. It has the unit of siemens (S).

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right) \quad \text{.................................(2)}$$

Because the transfer characteristic curve for a JFET is nonlinear, gm varies in value depending on the location on the curve as depicted in Fig.5. A datasheet normally gives the value of g_m measured at $V_{GS} = 0$, which is referred as g_{mo}.

Theoretically, g_m can be calculated at any point on the transfer characteristic curve from the following equation:

$$g_m = g_{mo}\left(1 - \frac{V_{GS}}{V_P}\right) \qquad \text{.......(3)}$$

Where g_{mo} is found from:

$$g_{mo} = \frac{2I_{DSS}}{|V_P|} \qquad \text{.......(4)}$$

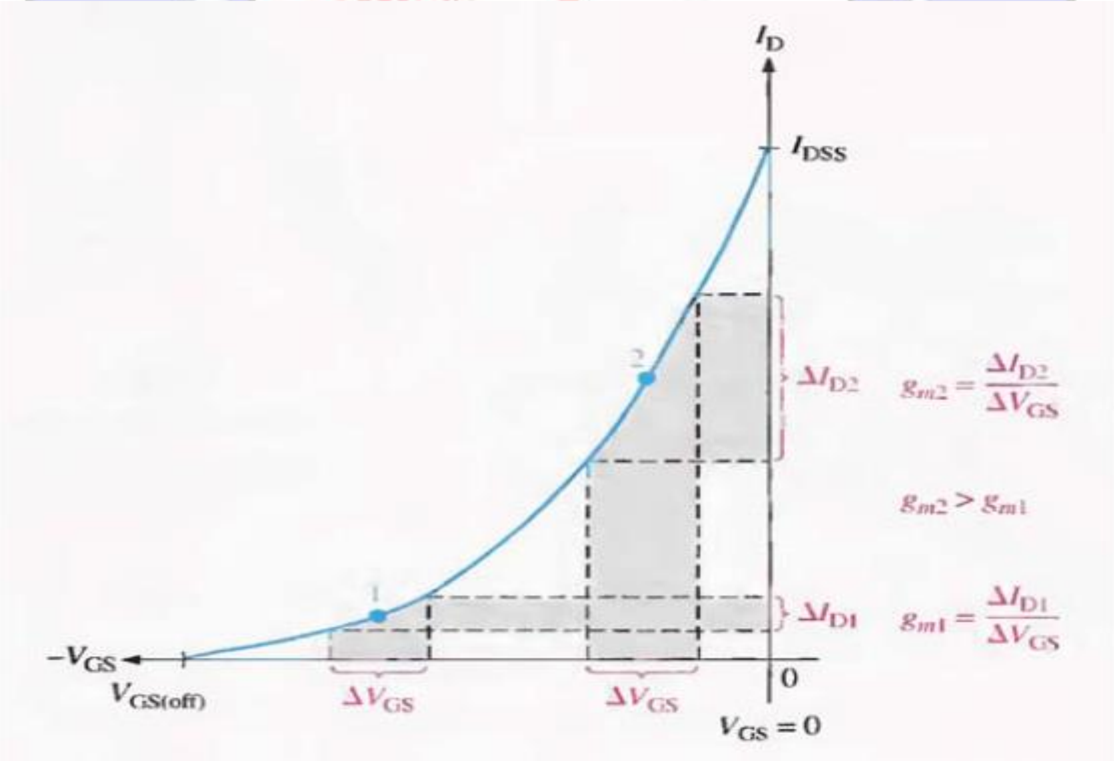


Figure 5: Graphical Determination of the JFET Transconductance

Procedure

1. Connect the circuit shown in Fig.6.

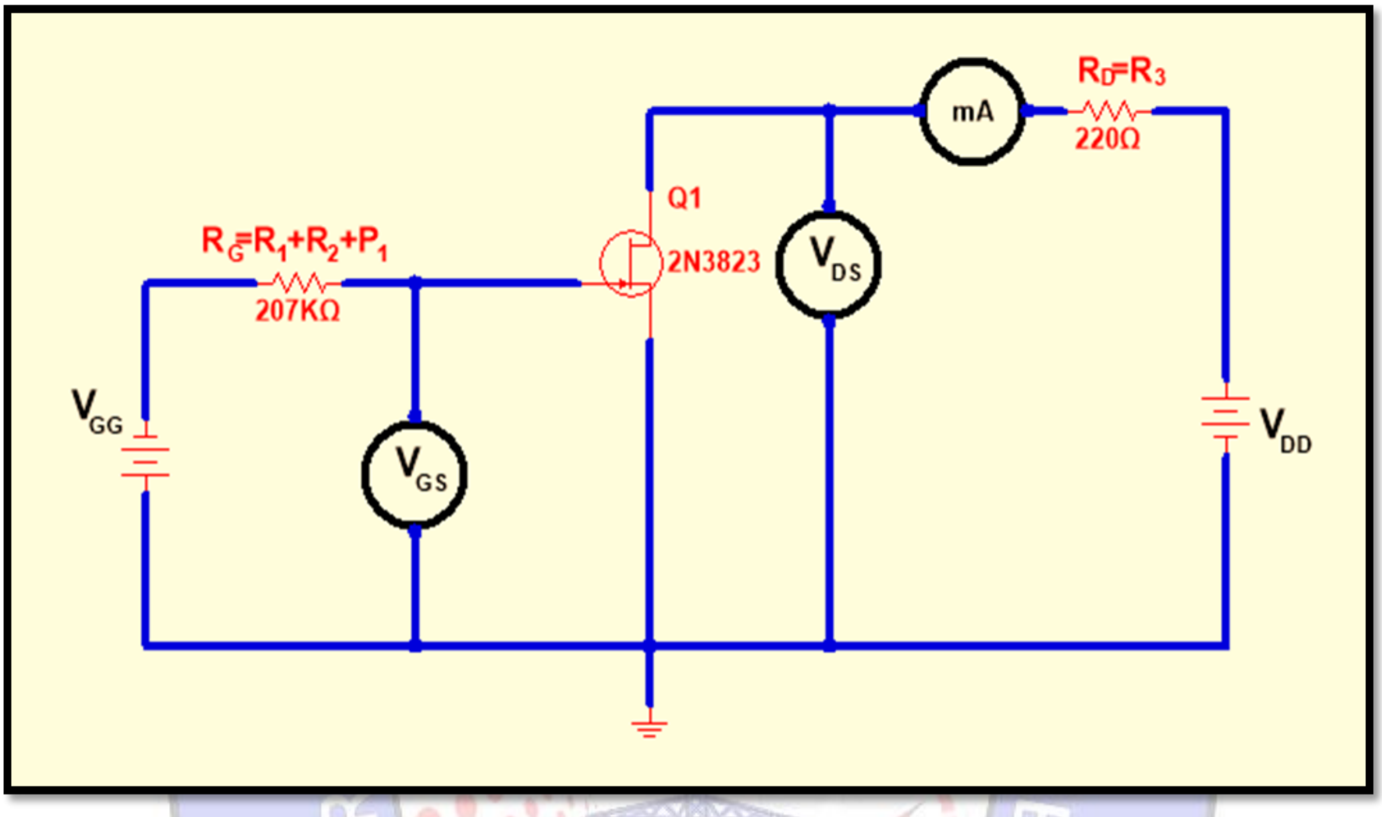


Figure 6: The Test Circuit for Getting JFET Characteristics

2. Adjust V_{DD} so that V_{DS} = 5V, and vary V_{GG} to change V_{GS} from 0V to -3V in different steps recording I_D for each step. Repeat with V_{DS} = 10V. Tabulate your results as shown in Table-1.
3. Set V_{GG} to 0V so that V_{GS} = 0V and vary V_{DD} so that V_{DS} changes in several steps recording I_D in each step. Repeat with V_{GS} = -1V. Tabulate your results as illustrated in Table 2.

Table 1: Recorded Data for the JFET Transfer Characteristics

VDS = 5V		VDS = 10V	
V_{GS}(V)	I_D (mA)	V_{GS}(V)	I_D (mA)
0		0	
-0.25		-0.25	
-0.5		-0.5	
-0.75		-0.75	
-1		-1	
-1.25		-1.25	
-1.5		-1.5	
-1.75		-1.75	
-2		-2	
-2.25		-2.25	
-2.5		-2.5	
-2.75		-2.75	
-3		-3	

Table 2: Recorded Data for the JFET Drain Characteristics

VDS = 0V		VDS = -1V	
VGS(V)	ID (mA)	VGS(V)	ID (mA)
0		0	
0.5		0.5	
1		1	
1.5		1.5	
2		2	
2.5		2.5	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
9		9	
10		10	

Discussion

1. From the obtained data, sketch the transfer characteristics of the JFET.
2. Determine the values of V_P and I_{DSS} from the plot.
3. Calculate theoretically the value of g_m at V_{GS} = -1V and V_{GS} = -2V when V_{DS} = 10V and compare them with the measured quantities.
4. Sketch the drain characteristics of the JFET from the obtained data.
5. From the linear region of the drain characteristic, determine the value of the drain to source resistance r_{ds} when V_{GS} = 0V.
6. Compare between the JFET and the BJT.