EXPERIMENT-8,9

Jay Vikrant
EE22BTECH11025

Problem 1:

Diodes are two-terminal devices primarily designed to allow current flow in one direction while blocking it in the reverse direction. This property makes them ideal for applications like rectifying alternating current (AC) into direct current (DC) and protecting circuits from reverse voltage. Diodes can also perform signal clipping by limiting the amplitude of an input signal. However, they are not typically used for amplification or complex switching logic due to their limited functionality.

Diodes are semiconductors with different characteristics and applications. While diodes have two terminals and can perform rectification and signal clipping, they are not typically used for amplification or complex switching logic because diodes have a forward voltage drop, which means that they consume some of the voltage that is being applied to them. This can be a problem for applications that switch high currents or voltages. They also cannot be used to provide current gain. This means the current flowing through the diode is limited by the current flowing through the input circuit. This can be a problem for applications where we need to amplify a weak signal.

Transistors come in two main types: bipolar junction transistors (BJT) and field-effect transistors (FET), which have three terminals and offer distinct advantages over diodes in various applications.

Amplification: Transistors are designed explicitly for amplification. By controlling the flow of current between two of their terminals (collector and emitter for BJTs, drain and source for FETs) through modulation of the current or voltage at their third terminal (base for BJTs, gate for FETs), they enable voltage or current gain. This property makes them ideal for various amplification applications, from audio amplifiers to radio frequency circuits.

Signal Amplification: While BJTs offer current amplification, FETs provide voltage amplification. Diodes, in contrast, do not possess this inherent capability for signal amplification.

Voltage and Current Control: Transistors control voltage and current in electronic circuits. This control is fundamental to signal processing, amplification, and precise switching. Diodes, lacking the same level of control, are not as versatile in these applications.

Switching Logic: Transistors can switch electronic signals by connecting them in a common emitter configuration or a common collector configuration. In these configurations, the transistor acts as a voltage switch, converting a small input voltage into a larger output voltage. The switching speed of a transistor can be very fast. Whereas Diodes lack this degree of versatility and precise switching capability.

High Gain: Transistors can achieve high voltage and current gain, making them essential for applications where signal amplification is needed, such as power amplifiers and sensors. Diodes, in comparison, have a limited ability to amplify signals.

To sum up, although diodes play an essential role in electronic circuits, particularly in applications that require rectification and clipping of signals, whereas transistors, which have three terminals and can control current or voltage based on input at one terminal, offer a much wider range of functions. They are essential for amplifying and switching logic within electronic circuits, from basic on/off switches to complex signal processing, amplification, etc., which diodes can't do. Three-terminal transistor families continue to play an essential role in the electronics world, enabling innovation and functionality in various electronic products and systems.

Problem 2:

Aim:

To determine the type and polarity of three-terminal devices.

Material Required:

MOSFET (N7000), BJT (BC547), Multimeter.

Theory:

Bipolar Junction Transistor (BJT): BJTs have three terminals - an emitter, a collector, and a base. They're used as current-controlled power sources and come in two types: npn or pnp. we can test them in diode mode, and they'll show positive potential for forward bias and no potential for reverse bias. Usually, the emitter and base junctions will show a slightly higher voltage for forward bias than the collector and base junctions.

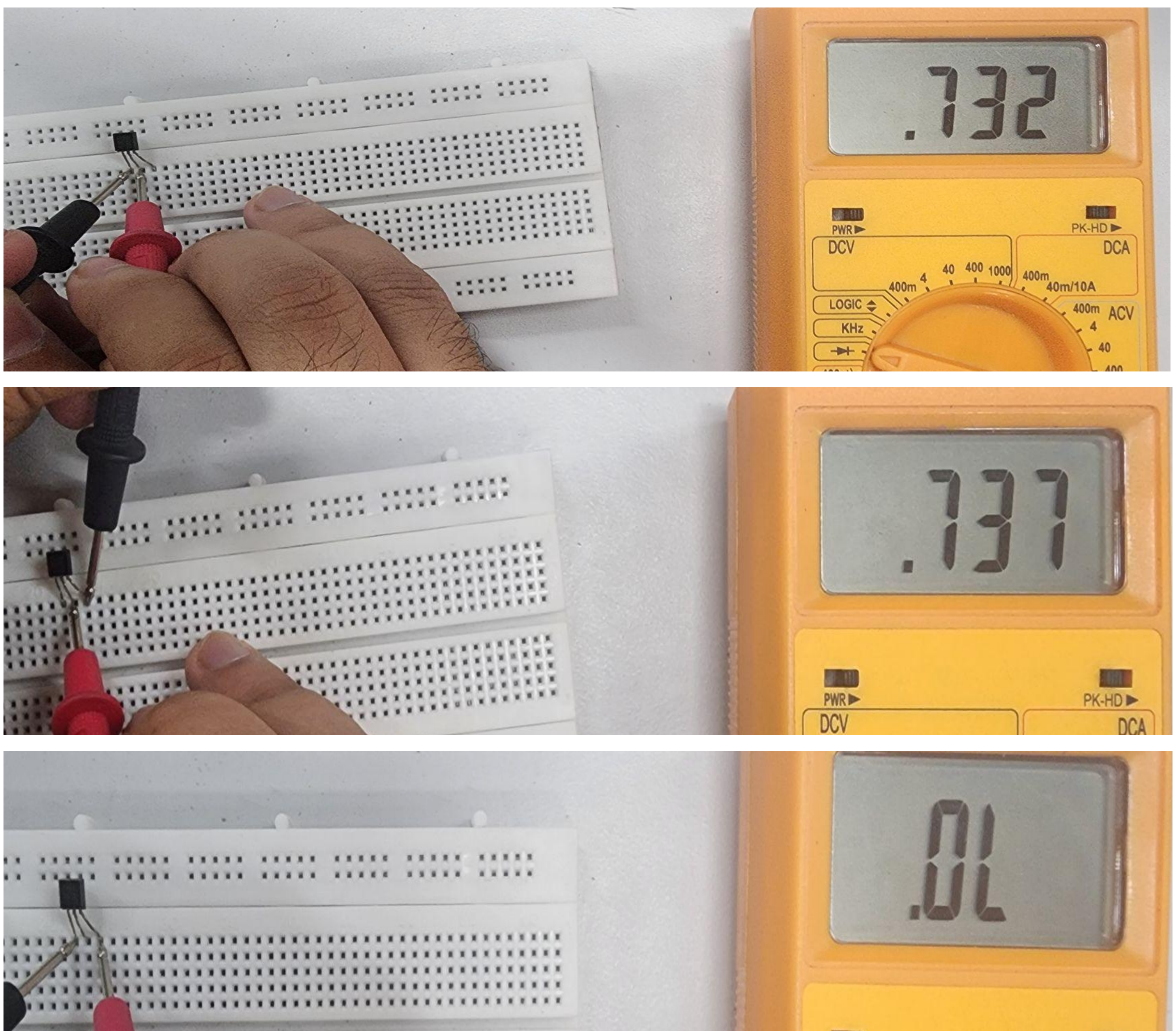
Field Effect Transistor (FET): FETs have three terminals - the gate, the source, and the drain. There are two main types of FETs - Enhance and Depletion - which are divided into n- and p-channel versions. The FET's conduction behaviour is determined by the voltage used on the gate terminal.

Procedure:

- Identify the three terminals of the unknown device. These are usually labelled as emitter (E), base (B), and collector (C) for BJTs, and source (S), gate (G), and drain (D) for FETs
- To determine the type of device, connect the multimeter in diode mode and measure the voltage between the following pairs of terminals:
    - Emitter-base (BJTs) or source-gate (FETs)
    - Emitter-collector (BJTs) or source-drain (FETs)

- To determine the polarity of the device, connect the positive lead of the power supply to the emitter or source terminal, and the negative lead to the collector or drain terminal.
    - If the voltage is positive, the device is NPN or N-channel.
    - If the voltage is negative, the device is PNP or P-channel.

Observations:



Experimental readings:

Pins (+, -)	CTBC547B-BJT
Pin1-pin2	0
Pin2-pin3	0.737V
Pin3-pin1	0
Pin2-pin1	0.732V
Pin3-pin2	0
Pin1-pin3	0

From the above data, we can figure out that there are two pn junctions between terminal “1 & 2” and “2 & 3”.

For the pn junction between terminals 1 & 2, terminal 1 is n-sided and terminal 2 is p-sided, there is an output thus showing it is forward biased. Similarly, we can say, for the pn junction between terminals 2 & 3, terminal 3 is at the n side and 2 is at the p side. Hence, we can say with certainty that the three-terminal device is a npn BJT.

Pins (+, -)	N7000-FET
Pin1-pin2	0
Pin2-pin3	0
Pin3-pin1	0.732
Pin2-pin1	0
Pin3-pin2	0
Pin1-pin3	0

From the above data we can conclude it as an n-channelled FET due to forward bias in the terminal- 3,1.

Problem 3:

Aim:

To measure and plot the transfer (I_D vs. V_G, for two different V_D) and output characteristics (I_D vs. V_D, for six different V_G) of a FET. To extract the threshold voltage, transconductance, sub-threshold slope, on-state and off-state resistance.

Material Required:

MOSFET (N7000), resistors of 1kΩ and 100kΩ, breadboard, connecting wires, and power supply.

Theory:

- **Threshold Voltage (Vth):** The minimum voltage you need to apply at the gate to open the channel between the source and drain. Once this threshold is crossed, the drain current (I_D) starts flowing, transforming the FET from an 'off' to an 'on' state. Think of it as the FET's initiation point.

- **Transconductance (g_m):** This metric measures how responsive the FET is to changes in the gate voltage. It's like the FET's sensitivity dial. Transconductance (g_m) quantifies the relationship between a change in drain current (ΔI_D) and a change in gate-source voltage (ΔV_G).

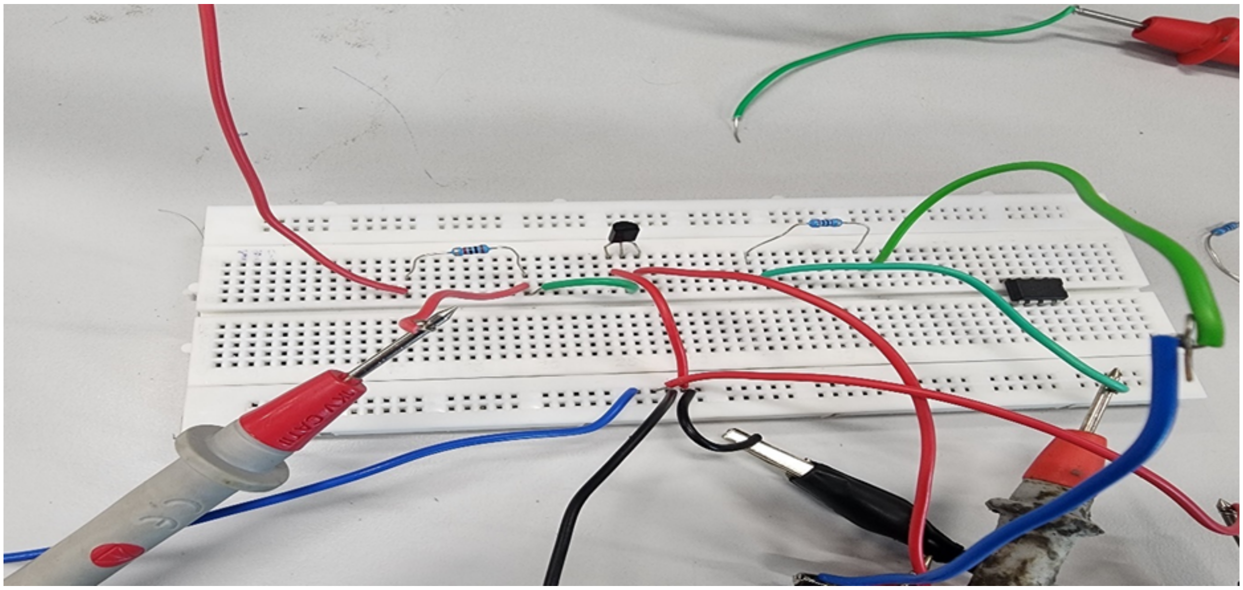
$$gm = \frac{\Delta Ids}{\Delta Vgs}$$

- **Sub-threshold Slope (S):** Imagine this as the FET's efficiency gauge. Sub-threshold slope refers to the slope of a particular curve, and it tells us how efficiently the transistor can switch between its 'off' and 'on' states. A smaller 'S' value means it's more energy efficient.

- **On-State Resistance (R_{on}):** It is a vital parameter that reveals the FET's performance in its 'on' state. You can derive this from the output characteristics. When the output curve is in the linear saturation region, R_{on} becomes apparent. It's the measure of resistance when the transistor is actively conducting.
- **Off-state Resistance:** When the FET is not conducting, there is a very high resistance between the drain and source terminals, and the current does not flow between the drain and source.

Procedure:

- Connect the FET in the common-source configuration as shown in the diagram.
- Set the DC power supply to provide a constant V_D voltage.
- Vary the V_G voltage in steps of 1 V and measure the corresponding drain current (I_D).
- Plot the transfer characteristic (I_D vs. V_G) for the two different V_D voltages.
- Repeat steps 3 and 4 for different V_D voltages (6 different values in total) to obtain the output characteristics.
- To extract the threshold voltage, transconductance, sub-threshold slope, on-state resistance, and off-state resistance, use the following equations from the theory section above.



Observations:

Experimental readings for six different V_D:


100.000 000 0 kHz
Agilent U1242A
50.08
Agilent U1242A
58.55
0.00A
10.18


100.000 000 0 kHz
Agilent U1242A
100.17
Agilent U1242A
70.66
0.01A
10.16


Tektronix
100.000 000 0 kHz
Agilent U1242A
125.1
Agilent U1242A
84.89
0.01A
10.13


100.000 000 0 kHz
Agilent U1242A
150.2
Agilent U1242A
103.13
0.01A
10.16

Experimental readings for two different V_G:

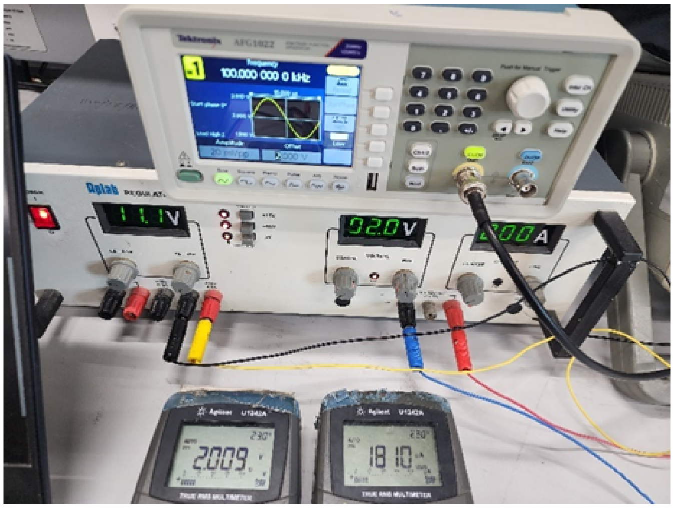
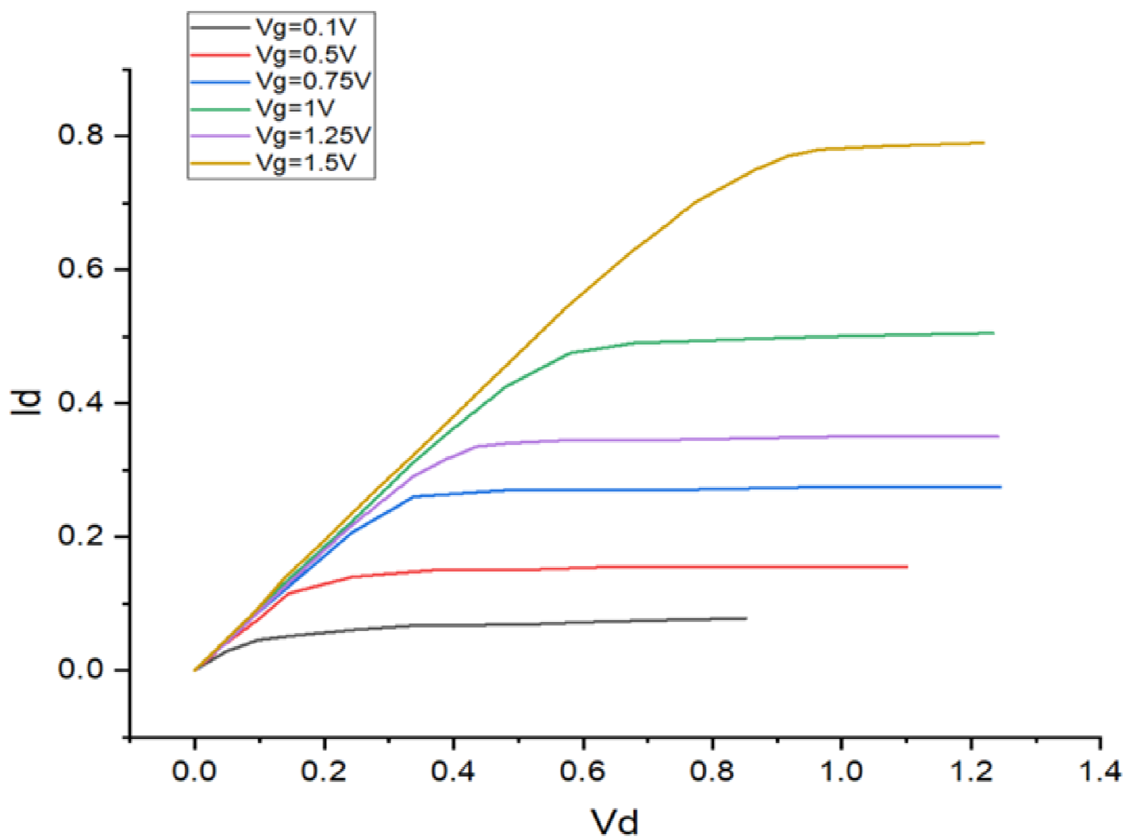
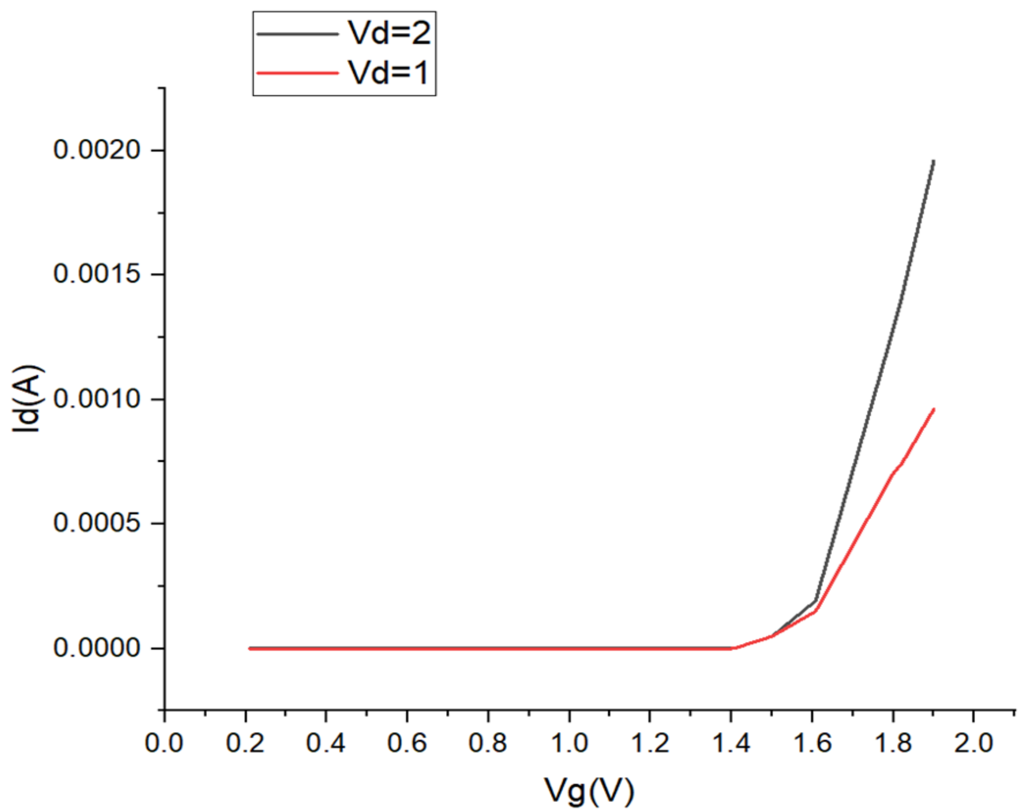


Table and plot of above readings:

	A(X1)	B(Y1)	C(X2)	D(Y2)	E(X3)	F(Y3)	G(X4)	H(Y4)	I(X5)	J(Y5)	K(X6)	L(Y6)
Long Name	Id	Vd	Id	Vd	Id	Vd	Id	Vd	Id	Vd	Id	Vd
Units												
Comments	Vg=0.1V	Vg=0.1V	Vg=0.5V	Vg=0.5V	Vg=0.75V	Vg=0.75V	Vg=1V	Vg=1V	Vg=1.25V	Vg=1.25V	Vg=1.5V	Vg=1.5V
F(x)=												
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0.0485	0.02815	0.048	0.04	0.0475	0.04	0.0475	0.045	0.0475	0.04	0.0475	0.045
3	0.0975	0.04505	0.096	0.075	0.0955	0.085	0.1435	0.135	0.1445	0.13	0.095	0.09
4	0.1475	0.0512	0.1445	0.115	0.2405	0.205	0.2395	0.22	0.24	0.215	0.14	0.14
5	0.248	0.0608	0.244	0.14	0.3385	0.26	0.288	0.265	0.337	0.29	0.19	0.185
6	0.3485	0.0674	0.369	0.15	0.489	0.27	0.336	0.31	0.386	0.315	0.2375	0.23
7	0.499	0.0682	0.495	0.15	0.64	0.27	0.384	0.35	0.4345	0.335	0.285	0.275
8	0.5995	0.07185	0.6455	0.155	0.74	0.27	0.481	0.425	0.485	0.34	0.3355	0.32
9	0.75	0.07575	0.897	0.155	0.991	0.275	0.5795	0.475	0.585	0.345	0.3835	0.365
10	0.851	0.0776	1.1	0.155	1.245	0.275	0.679	0.49	0.7365	0.345	0.431	0.41
11							0.8295	0.495	0.9875	0.35	0.4795	0.455
12							0.98	0.5	1.241	0.35	0.5275	0.5
13							1.2335	0.505			0.5755	0.545
14											0.672	0.625
15											0.7205	0.66
16											0.7715	0.7
17											0.8665	0.75
18											0.916	0.77
19											0.966	0.78
20											1.068	0.785
21											1.2185	0.79



	A(X)	B(Y)	C(Y)
Long Name	Vg	Id	Id
Units			
Comments		Vd=1V	Vd=2V
F(x)=			
1	0.101	3.609E-7	1.25E-6
2	0.2095	3.627E-7	1.25E-6
3	0.3055	3.658E-7	1.25E-6
4	0.419	3.722E-7	1.26E-6
5	0.54	3.855E-7	1.26E-6
6	0.628	4.017E-7	1.28E-6
7	0.731	4.297E-7	1.298E-6
8	0.816	4.579E-7	1.323E-6
9	0.9037	4.874E-7	1.353E-6
10	1.024	5.382E-7	1.401E-6
11	1.213	6.291E-7	1.487E-6
12	1.389	7.243E-7	1.581E-6
13	1.406	1E-6	1E-6
14	1.5	5E-5	5E-5
15	1.608	1.501E-4	1.92E-4
16	1.799	7.024E-4	0.00128
17	1.822	7.468E-4	0.00142
18	1.9	9.622E-4	0.00196



From the above measurements,

Threshold Voltage: From the transfer characteristics graph, the threshold voltage is 1V and 2V.

Transconductance: This is the slope of the linear part of the graph.

- For 1V, Transconductance = 23.58mS
- For 2V, Transconductance = 49.31mS

Sub-Threshold Slope – This is the slope of the linear part of the graph in the log(I_D) vs V_G

- For 1V, Sub-Threshold slope = 3.354decades/V
- For 2V, Sub-Threshold slope = 4.508decades/V

On-Resistance – Slope of the linear part of the I_D vs V_D graph.

- For V_g=0.1V, 5.88kΩ
- For V_g=0.5V, 3.48kΩ
- For V_g=0.75V, 1.69kΩ
- For V_g=1V, 1.3kΩ
- For V_g=1.25V, 1.26kΩ
- For V_g=1.50V, 1.12kΩ

NOTE: for off-resistance there was practically no current flow, thus can be taken as **infinite**

Problem 4:

Aim:

- To measure and plot the I-V characteristics of a BJT in forward biased Collecter-Emitter configuration.
- To extract the Early voltage, V_A, and output resistance, R_{out}, of a BJT.
- To measure and plot the frequency response of the amplification factor, β, of a BJT and determine the cutoff frequency, f_T.

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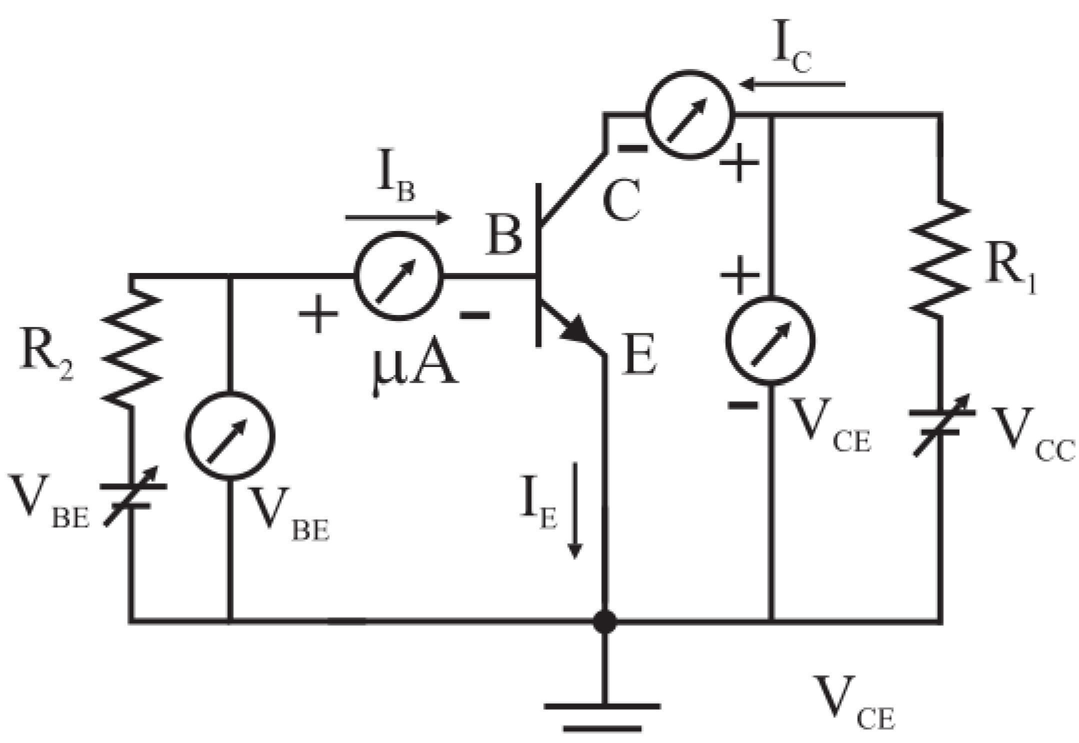
Material Required:

Breadboard, Resistor(1kΩ nad 100kΩ), BJT(BC547),DC supply, DSO.

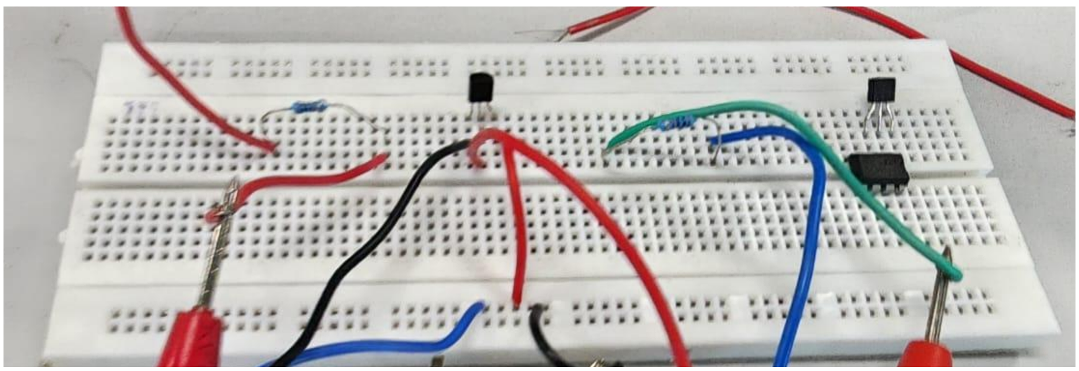
Procedure:



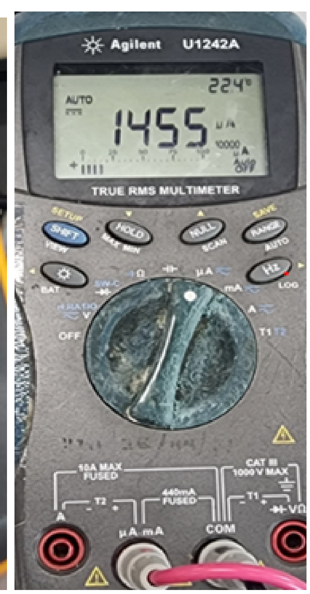
- Connect the BJT in common emitter configuration as shown in the schematic diagram above.
- Vary the base current, I_B, and measure the corresponding collector current, I_C.
- Plot the I_C vs V_{CE} characteristics of the BJT.

Now, for small signal analysis part,

- Add a small sinusoidal signal to the base of the BJT.
- Measure the amplitude of the input and output signals using the oscilloscope.
- Repeat steps 1-3 for different frequencies and plot the frequency response of β.
- The cutoff frequency, f_T, of the BJT is the frequency at which β drops to 1.



Observations:



NOTE; These are only some of the readings as there were many

Table and Plot of above readings:

V_{ce} in V	I_{ce} in A	I_{be} in uA
0	0	
0.037	6.20E-05	
0.078	1.82E-04	
0.1	4.50E-04	
0.12	6.00E-04	
0.155	1.00E-03	10
0.2	1.25E-03	
0.356	1.34E-03	
0.602	1.34E-03	
0.858	1.35E-03	
1.105	1.35E-03	

Vce in V	Ice in A	Ibe in uA
0	0	
0.038	6.00E-05	
0.078	2.90E-04	
0.1	7.20E-04	
0.132	1.48E-03	
0.2	2.09E-03	12
0.3	2.22E-03	
0.55	2.23E-03	
0.772	2.24E-03	
1	2.25E-03	

V_{ce} in V	I_{ce} in A	I_{be} in uA
0.00E+00	0	
0.038	7.48E-06	
7.30E-02	2.46E-04	
1.00E-01	1.11E-03	
1.47E-01	2.30E-03	
1.99E-01	3.01E-03	15
2.51E-01	3.20E-03	
0.452	3.29E-03	

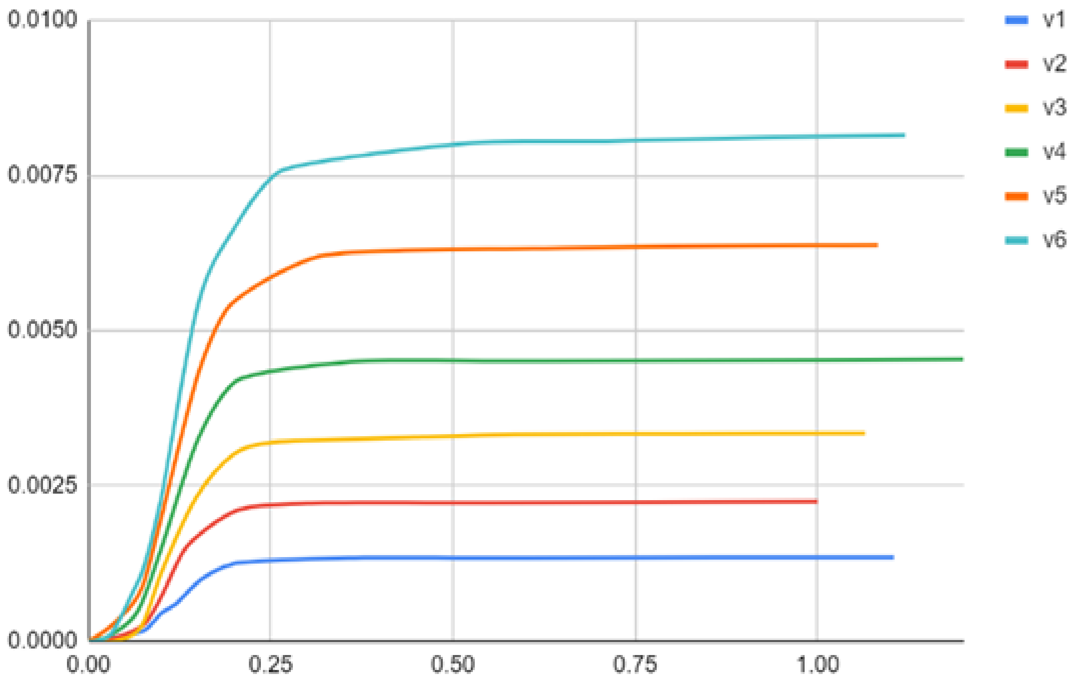
0.585	3.33E-03	
0.817	3.34E-03	
1.065	3.35E-03	

V_{ce} in V	I_{ce} in A	I_{be} in uA
0	0	20
0.026	7.00E-05	
0.068	4.90E-04	
0.1	1.50E-03	
0.15	3.25E-03	
0.2	4.17E-03	
0.36	4.50E-03	
0.58	4.51E-03	
V	4.52E-03	
1.2	4.54E-03	

V_{ce} in V	I_{ce} in A	I_{be} in uA
0	0	
0.036	2.99E-04	
0.073	8.50E-04	
0.1	2.00E-03	

0.15	4.29E-03	25
0.19	5.35E-03	
0.311	6.18E-03	
0.65	6.33E-03	
1.083	6.38E-03	

V_{ce} in V	I_{ce} in A	I_{be} in uA
0	0	30
0.03	1.06E-04	
0.06	7.70E-04	
0.075	1.16E-03	
0.1	2.32E-03	
0.15	5.41E-03	
0.2	6.65E-03	
0.26	7.55E-03	
0.525	8.02E-03	
0.71	8.05E-03	
0.92	8.11E-03	
1.12	8.15E-03	



Output resistance,

For I_{BE}= 10uA, 0.714kΩ

For I_{BE}= 12uA, 0.377kΩ

For I_{BE}= 15uA,   0.262kΩ

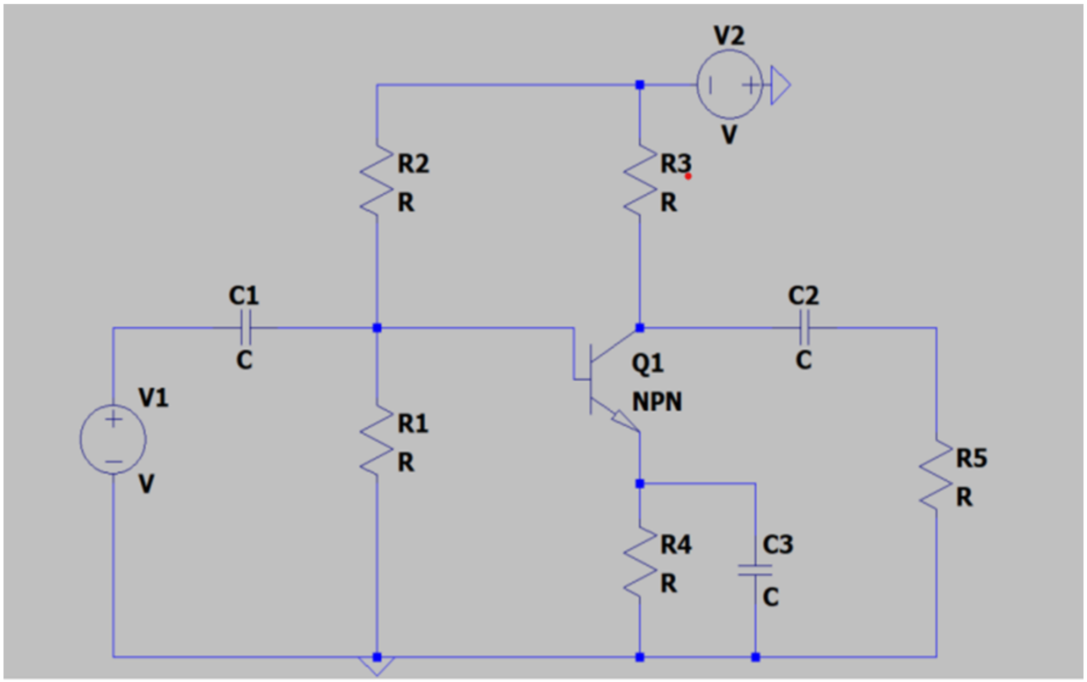
For I_{BE}= 20uA, 0.190kΩ

For I_{BE}= 25uA,   0.177kΩ

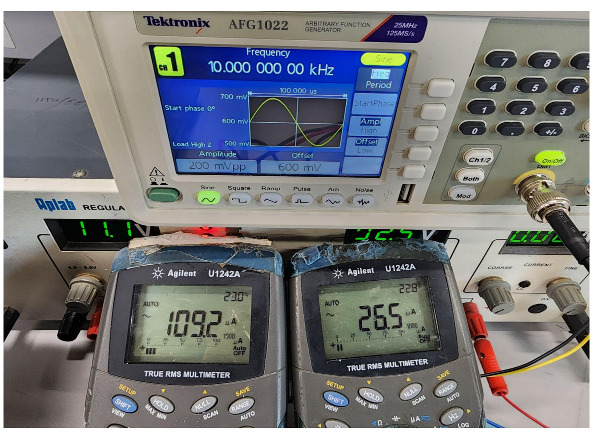
For I_{BE}= 30uA,   0.150kΩ

The **early voltage** is the average of all intercepts is -1.342V

For small signal analysis:



Observation:



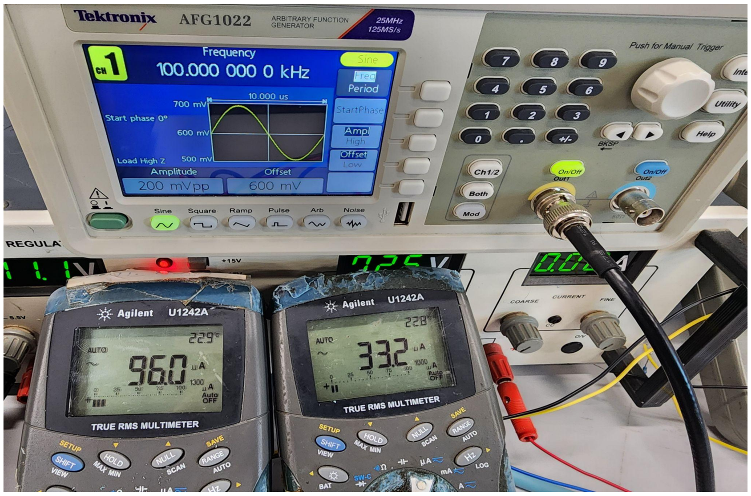


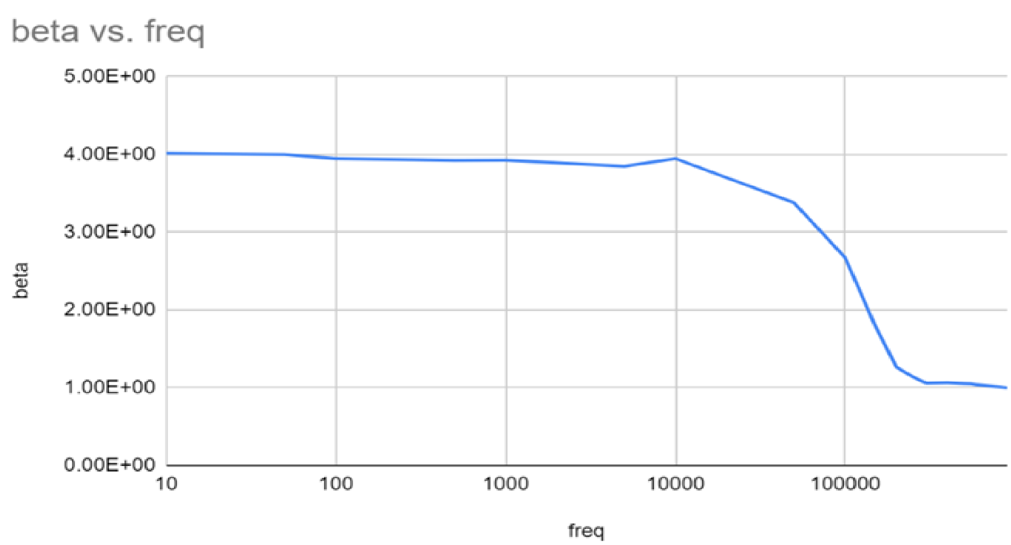
Table and plot of above readings

frequency	I_c	I_b	β
10	107.2	2.67E+01	4.01E+00
50	105.6	2.64E+01	4.00E+00
100	105.8	2.68E+01	3.95E+00
500	105.9	2.70E+01	3.93E+00
1000	105.9	2.70E+01	3.93E+00
5000	1.06E+02	2.75E+01	3.85E+00
1.00E+04	1.05E+02	2.67E+01	3.95E+00
50000	100.4	2.97E+01	3.38E+00
1.00E+05	90.7	3.39E+01	2.68E+00
1.50E+05	60.5	3.36E+01	1.80E+00
2.00E+05	42.6	33.6	1.27E+00
2.50E+05	34.8	30.5	1.14E+00

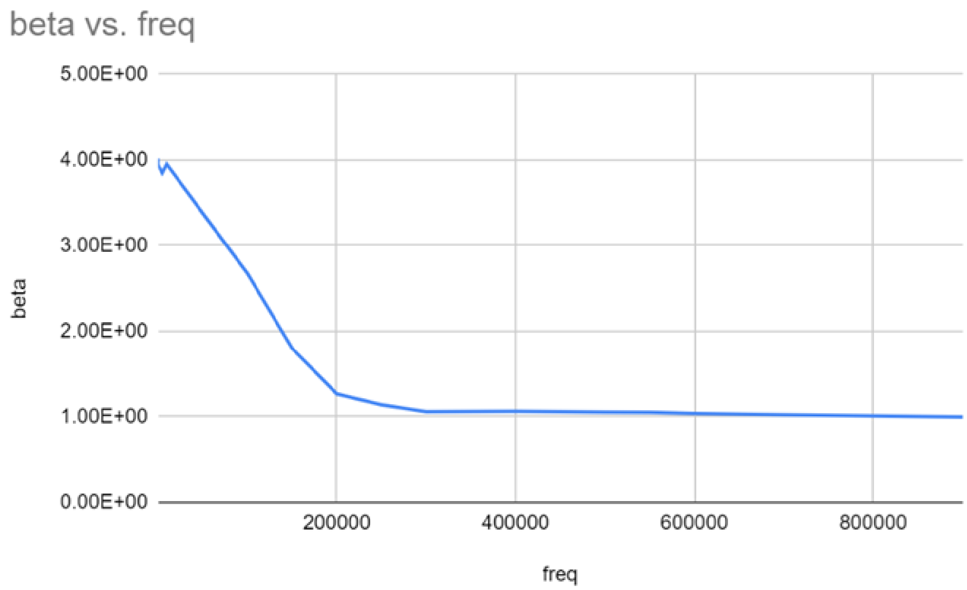
3.00E+05	30.4	28.7	1.06E+00
4.00E+05	28.3	26.6	1.06E+00
5.00E+05	26.7	25.3	1.06E+00
5.50E+05	26.3	25	1.05E+00
6.00E+05	25.6	24.8	1.04E+00
7.00E+05	25.2	24.6	1.02E+00
8.00E+05	24.7	24.4	1.01E+00
9.00E+05	24.3	24.3	1.00E+00

Graph:

LOG SCALE



NORMAL SCALE



For lower frequency beta is high, which decrease on increasing the frequency and will tend to unity at which we get out cutoff frequency.

Cutoff frequency(f_T)=350kHz