Experiment #: 03

Experiment Title: Characteristic curves of semiconductors

Objectives:

1. Teaching and analyzing of characteristic curves of diode and transistor semiconductor device.

2. To verify the transistor current-voltage (I-V) characteristics of Common Emitter (CE) circuit will be investigated.

Theory:

I-V Characteristic Curves of Semiconductors

Semiconductor devices such as diodes, transistors and thyristors are all constructed using semiconductor PN junctions connected together and as such their I-V characteristics curves will reflect the operation of these PN junctions. Then these devices will have non-linear I-V characteristics, as opposed to resistors which have a linear relationship between the current and voltage.

So for example, the primary function of a semiconductor diode is rectification of AC to DC. When a diode is forward biased (the higher potential is connected to its Anode), it will pass current. When the diode is reverse biased (the higher potential is connected to its Cathode), the current is blocked. Then a PN junction needs a bias voltage of a certain polarity and amplitude for current to flow. This bias voltage also controls the resistance of the junction and therefore the flow of current through it. Consider the diode circuit below.

I-V Characteristic Curve of a Diode

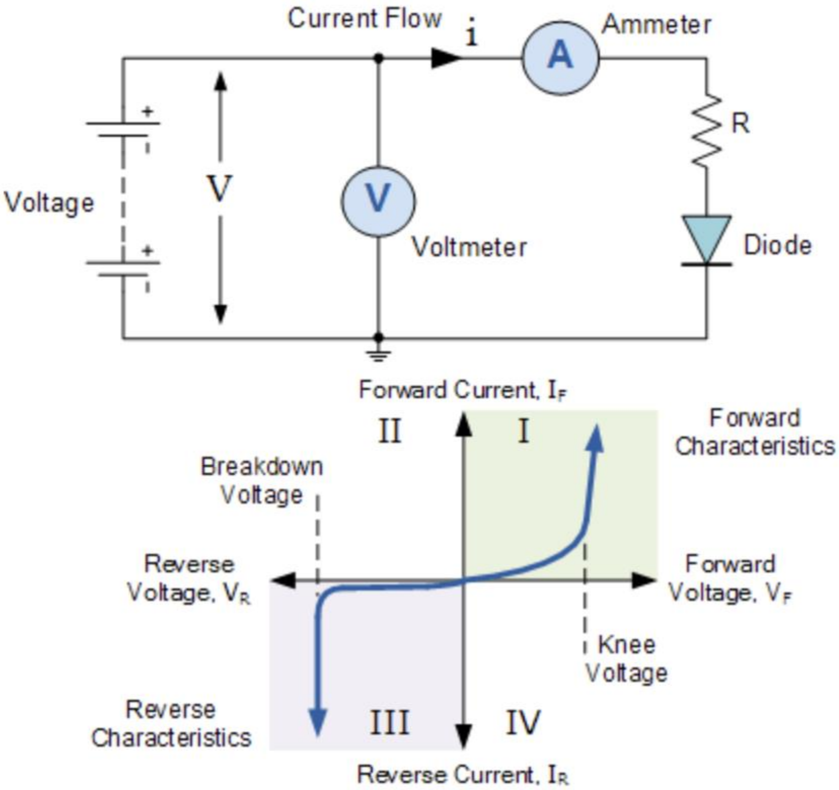


Fig 1. Characteristic Curve of a Diode

When the diode is forward biased, anode positive with respect to the cathode, a forward or positive current passes through the diode and operates in the top right quadrant of its I-V characteristics curves as shown. Starting at the zero intersection, the curve increases gradually into the forward quadrant but the forward current and voltage are extremely small. When the forward voltage exceeds the diodes P-N junctions' internal barrier voltage, which for silicon is about 0.7 volts, avalanche occurs and the forward current increases rapidly for a very small increase in voltage producing a non-linear curve. The "knee" point on the forward curve. Likewise, when the diode is reversed biased, cathode positive with respect to the anode, the diode blocks current except for an extremely small leakage current, and operates in the lower left quadrant of its I-V characteristic curves. The diode continues to block current flow through it until the reverse voltage across the diode becomes greater than its breakdown voltage point resulting in a sudden increase in reverse current producing a fairly straight line downward curve as the voltage losses control. This reverse breakdown voltage point is used to good effect with zener diodes.

Then we can see that the **I-V Characteristic Curves** for a silicon diode are non-linear and very different to that of the previous resistors linear I-V curves as their electrical characteristics are different. Current-Voltage characteristics curves can be used to plot the operation of any electrical or electronic component from resistors, to amplifiers, to semiconductors and solar cells.

The current-voltage characteristics of an electronic component tells us much about its operation and can be a very useful tool in determining the operating characteristics of a particular device or component by showing its possible combinations of current and voltage, and as a graphical aid can help visually understand better what is happening within a circuit.

The diode is a device formed from a junction of n-type and p-type semiconductor material. The lead connected to the p-type material is called the anode and the lead connected to the n-type material is the cathode. In general, the cathode of a diode is marked by a solid line on the diode.

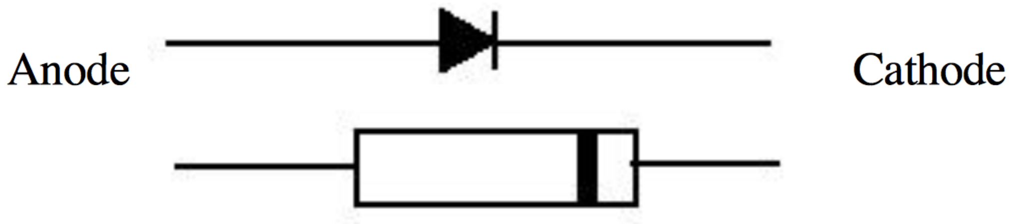


Figure 1.2: The symbol for a diode compared to an actual diode package

Theoretical. Theoretically, the current through many silicon diodes at room temperature is related to the voltage across them by the equation

$$I = I_0\left(e^{\frac{V}{kT}} - 1\right) \approx I_0 \; e^{\frac{V}{26mV}}$$

where k is Boltzman's constant, T is the absolute temperature, and I_0 is the "leakage" current when the diode is reverse biased. This approximation implies a theoretical value for the differential resistance of the forward conducting diode.

The primary function of the diode is the rectification. When it is forward biased (the higher potential is connected to the anode lead), it will pass current. When it is reverse biased (the higher potential is connected to the cathode lead), the current is blocked. The characteristic curves of an ideal diode and a real diode are seen in Figure 1.2.

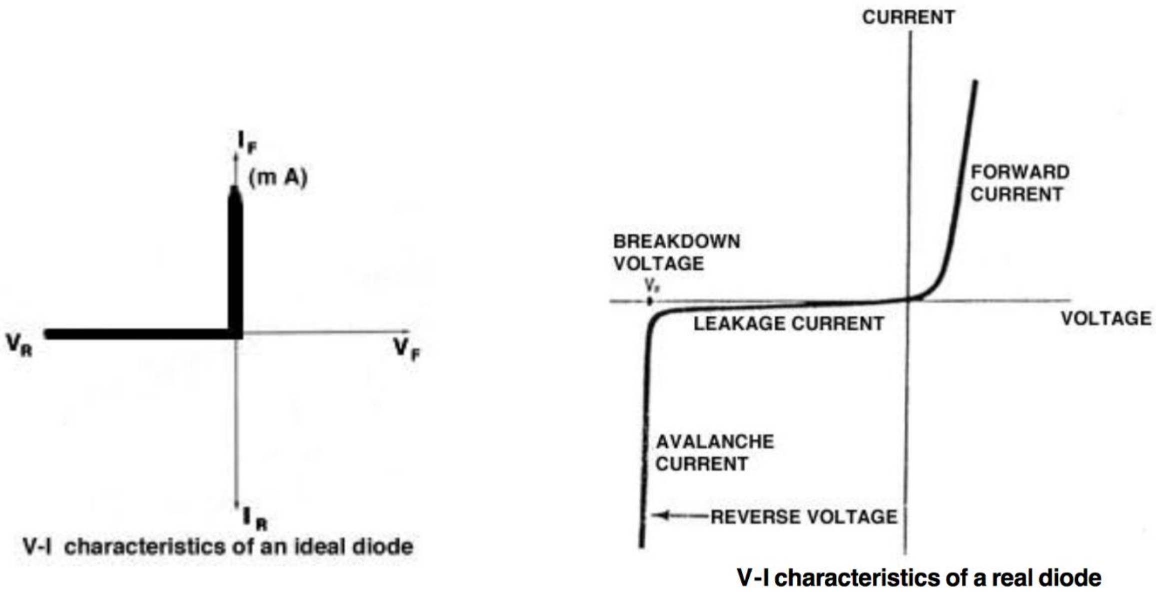


Figure 1.3. The characteristic curves of an ideal diode and a real diode

When analyzing circuits, the real diode is usually replaced with a simpler model. The simplest form , the diode is modeled by a switch(Figure 1.3). The switch is closed when the diode is forward biased and open when the diode is reverse biased.

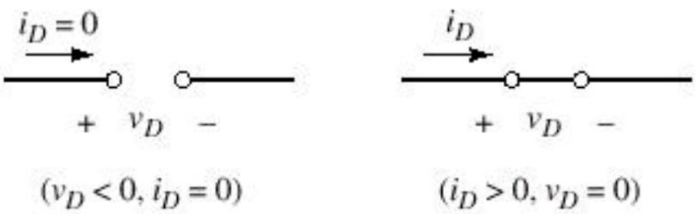
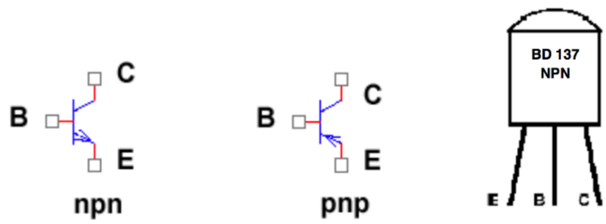


Figure 1.4. Equivalent Circuit of Diode

The bipolar junction transistor (BJT) can be modeled as a current controlled current source. The circuit symbol and the pin out for the actual device can be seen in Figure 1.



How to Test a Transistor ?

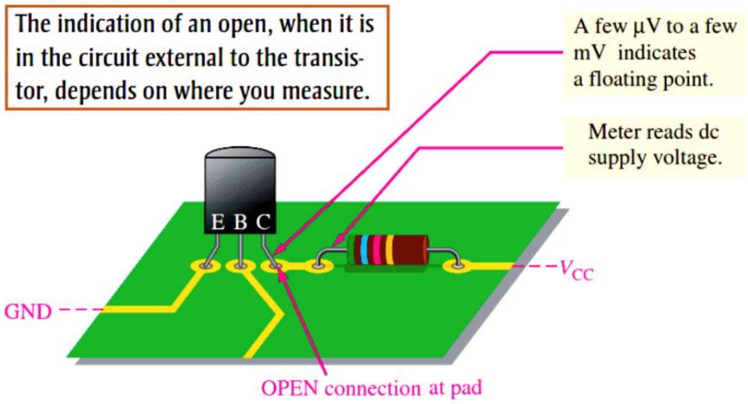


Figure 1.5.

Principles

Transistors are among the most important semiconductor components in electronic circuit technology. The electrodes of a bipolar transistor are called the emitter (E), the base (B) and the collector (C). Electrons and holes are both involved in conducting current. The transistor consists of a total of three n-conducting and p-conducting layers, in the order npn or pnp. The base layer, located in the middle, is so thin that charge carriers originating at one junction can cross to the other junction. The experiment examines the properties of an npn-transistor on the basis of its characteristics. This experiment measures the output characteristic:

The collector current I_C as a function of the collector emitter voltage V_{CE} at a constant base current I_B

As an aid in visualizing the current/voltage relationships and transistor operation, a family of static characteristics plots of collector current versus collector-emitter voltage for several values of base current is plotted in Figure 2.

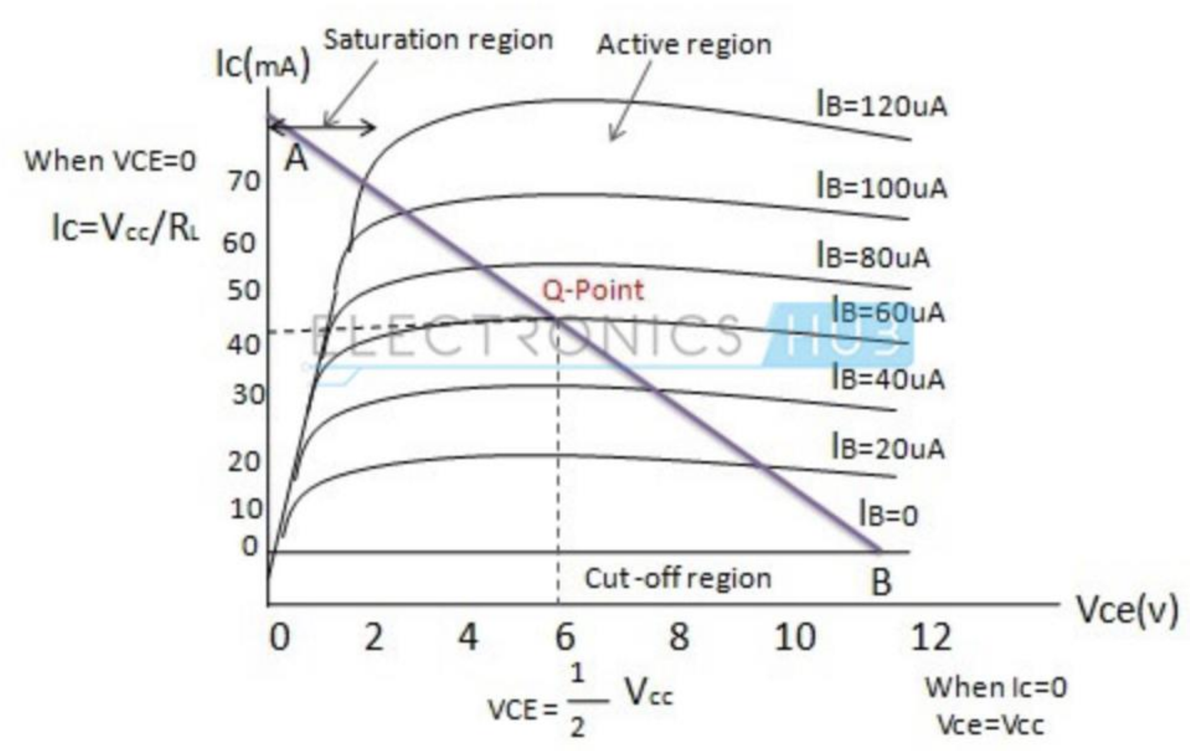


Figure 2: Characteristic curves for the BJT transistor.(CE)

These curves in Figure 2 can be used to calculate the large signal current gain βDC (or hFE) and the small signal current gain, βAC(or hfe). These values are in general calculated for a given bias point ICQ, VCEQ using the following equations: βDC = ICQ / IBQ

βAC = | ICQ - ICQ' |/| IBQ- IBQ'|

From this, one can see that a large signal gain depends only on the Q point and the small signal gain depends only on small deviations around the Q point.

List of Equipment:

Apparatus

1. Resistor 1 kΩ
2. Resistor 3.3 kΩ
3. Resistor 47 kΩ Potentiometer 220 Ω Transistor BD 137 or BC 237, NPN
4. DC power supply, 0...15 V 3 Multimeters

Circuit Diagram:

Transistor Common-Emitter Collector Characteristics using IV Measurement

a) Set the DC power supply at 5 V and connect the circuit shown in Figure 3 below.

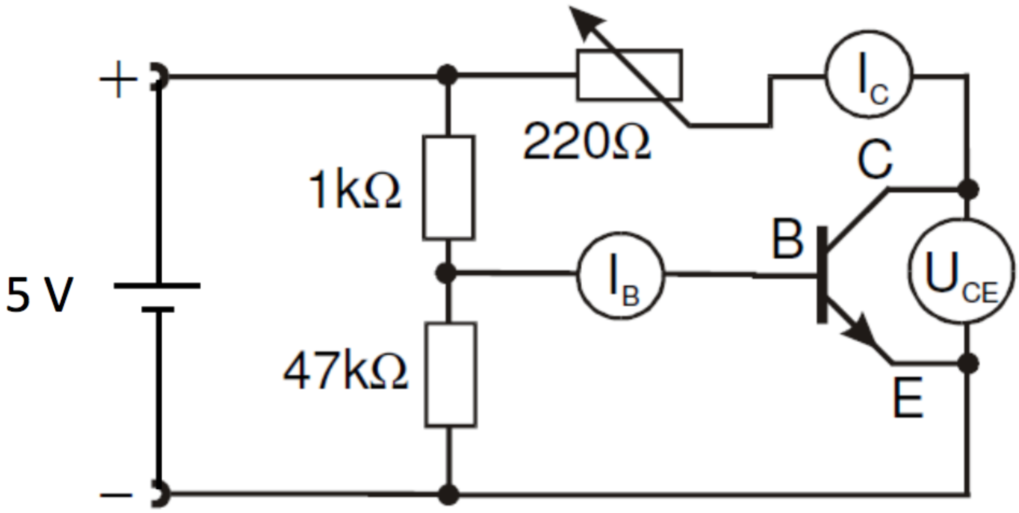


Figure 3 I-V Measurement Set-up

Procedure:

1)Finding Diode specifications

Look up the characteristics of the diodes in your kit using the reference provided. The specifications for different kinds of diodes vary. For this reason, the reference is broken into sections which group together similar diode types (for example, Zener diodes). At the beginning of each section are the definitions of the specifications for a particular type of diode. Copy all of the specifications for each diode as well as of the specification definitions.

2) Diode V-I Characteristics

The V-I characteristics for a diode can be displayed on Two-Wire Current-Voltage Analyzer.

1. a) Connect the anode of the diode to the CURRENT HI terminal on the prototyping board and the cathode to the CURRENT LO terminal.
2. b) Open the Two-Wire Current-Voltage Analyzer.
3. c) Set the start voltage to -3V, stop voltage to 4V and the increment to 0.1
4. d) Run the process.
5. e) The current plot is displayed for the varying voltage across the diode.
6. f) From this graph, obtain the cut - in voltage for the diode.
7. g) Study the characteristics of various diodes provided.
8. h) Repeat the procedure for 1N5404,1N34 (germanium diode).

3) Zener Diode Characteristics

The Zener diode has the unique property of maintaining a desired reverse biased voltage. This makes it useful in voltage regulatio n. In this exercise, you are to tabulate the regulating properties of the Zener diode.

1. a) Connect the circuit as in Figure1.4.
2. b) Use 100 resistor and 1N4730 Zener diode.
3. c) Measure the diode properties, by the varying the input voltage and measuring the voltage across the diode and the current.
4. d) From your observations obtain the VZ.

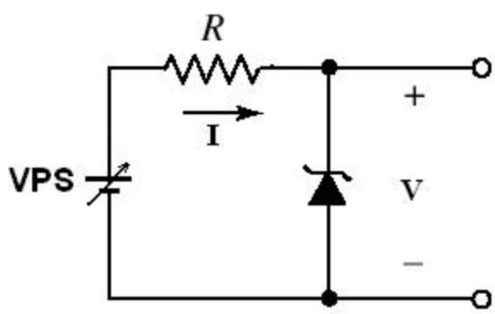


Fig. 1.4 Zener diode circuit

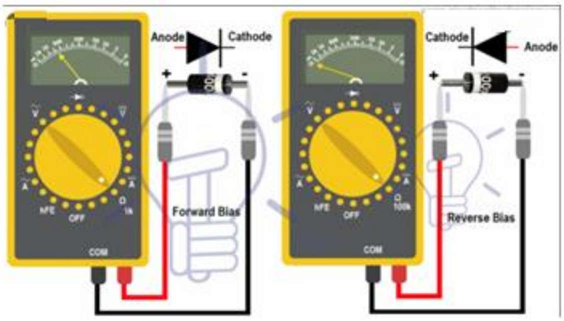
Questions for the Lab Report

1) Compare the important features of a silicon versus a germanium diode.

2) What are the possible applications for the half wave rectifier circuit.

3) Define voltage regulation, cut-in voltage and all the terms in the diode equation.

How to test a diode



Data Collection:

b) By turning the 220 potentiometer carefully increase voltage V_{CE}. Fill in pairs of voltage V_{CE} and current I_C in the Table 1 below.

measure the base current I_{B1} = ... (this value must be constant)

V_{CE} (Volts)	I_C(mA)		V_{CE} (Volts)	I_C(mA)
0.02			0.6	
0.03			0.9	
0.08			2.0	
0.11			3.0	
0.2			4.0	
0.4			4.8	

Table 1: Measurement of V_{CE} and I_C for a constant base current I_{B1}

c) Repeat the procedure for another value of IB (replace the 1 kΩ by 3.3 kΩ). Fill the table 2 below.

measure the base current I_{B2} = ... (this value must be constant)

V_{CE} (Volts)	I_C(mA)		V_{CE} (Volts)	I_C(mA)
0.02			0.6	
0.03			0.9	
0.08			2.0	
0.11			3.0	
0.2			4.0	
0.4			4.8	

Table 1: Measurement of V_{CE} and I_C for a constant base current I_{B2}

Questions for the Lab Report

1) Plot the two V-I characteristics on the same figure, with I_C on Y-axis and V_{CE} on X- axis.

2) Calculate the current gains β_1 and β_2 from the curves when the voltage V_{CE} = 3.0 V.

Calculation:

Result: