To Study the Characteristics Of a Common Emitter npn (Or pnp) Transistor & to Find Out the values Of Current & Voltage Gains

Aim

To study the characteristics of a common emitter npn (or pnp) transistor and to find out the values of current and voltage gains.

Apparatus

An n-p-n transistor, a three volt battery, a 30 volt battery, two high resistance rheostats, one 0-3 volt voltmeter, one 0-30 volt voltmeter, one 0-50 μA micro-ammeter, one 0-50 mA milli-ammeter, two one way keys, connecting wires.

Theory

In common-emitter circuit of a transistor, emitter-base make input section and emitter-collector make output section. As usual, base junction (input junction) is forward biased and collector junction (output junction) is reverse biased. ,
Resistance offered by base junction, is called input resistance (R_I) It has a very small resistance due to forward biasing.
Resistance offered by collector junction, is called output resistance (R_0). It has a high value due to reverse biasing.
Due to high output resistance (resistance in output section), a high resistance can be used as load resistance (R_L). Generally $R_L = R_0$.

The ratio $\frac{R_L}{R_I} = \frac{R_0}{R_I}$ measures resistance gain of the common emitter transistor. It is of the order of one thousand. The current equation, $I_e = I_b + I_c$.

Also emitter current (I_e) divides itself into base current (I_b) and collector current (I_c). In n-p-n transistor, I_c is about 98% of I_e, base current I_b remains only 2% of I_e. A little change in I_b causes a large change (about 49 times) in I_c. The ratio of change in collector current to the corresponding change in base current, measures current gain in common emitter transistor. It is represented by symbol β.

i.e.

$$\beta = \frac{\Delta I_c}{\Delta I_b}$$

For the example given above, β becomes 49.

For the example given above, P becomes 49.
The product of current gain and the resistance gain measures voltage gain of the common emitter transistor. It is about fifty times the resistance gain.

Formula used

Input resistance, $R_I = \dfrac{\Delta V_b}{\Delta I_b}$

Output resistance, $R_o = \dfrac{\Delta V_c}{\Delta I_c}$

Resistance gain, $= \dfrac{R_0}{R_I}$

Current gain, $\beta = \dfrac{\Delta I_c}{\Delta I_b}$

Voltage gain = Current gain × Resistance gain

i.e. $$A_V = \beta \cdot \frac{R_0}{R_I}$$

Diagram

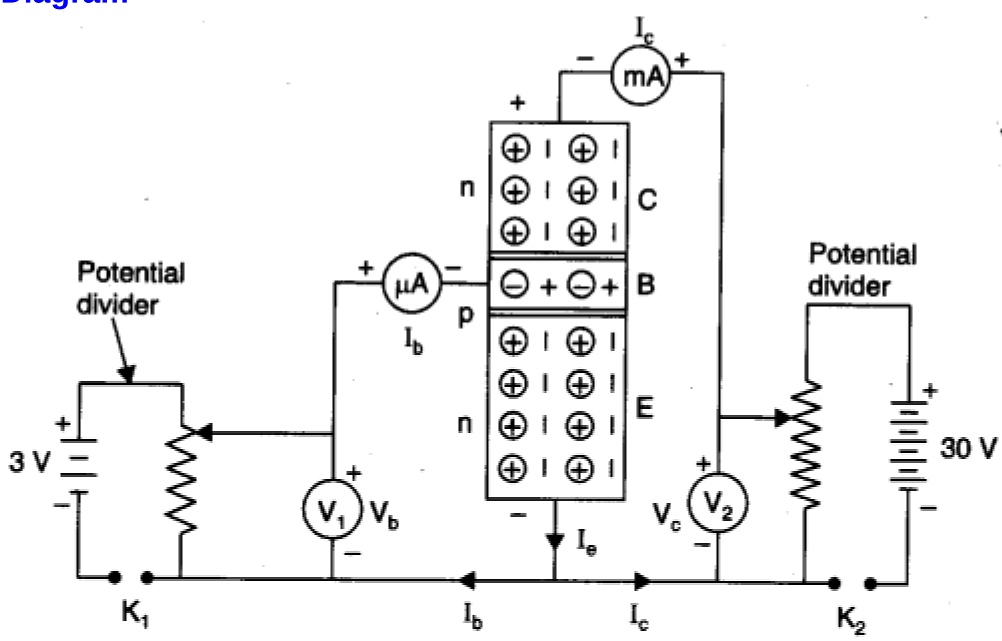

Fig. Common-emitter transistor circuit.

Procedure

1. Make circuit diagram as shown in figure.
2. Make all connections neat, clean and tight.

3. Note least count and zero errors of voltmeters and ammeters.
4. Make voltmeter readings zero in V_1 and V_2 and insert the keys.
   For input characteristics
5. Apply forward bias voltage on base junction. Read base voltage (V_b) from and base
   current (I_b) from μA.
6. Go on increasing V_b till I_b rises suddenly. Note corresponding values of I_b for each value of V_b.
7. Make collector voltage V_c = 10 V and repeat steps 5 and 6.
8. Repeat step 7 with V_c = 20 V and 30 V.
9. Make all readings zero.
   For output characteristics
10. Keep collector voltage (V_c) zero. Adjust base voltage Vb to make base current I_b = 10 μA. Though collector voltage V_c is zero ; but there is collector current I_c. Note it.
11. Make collector voltage 10 V, 20 V and 30 V and note the corresponding collector currents.
12. Repeat steps 10 and 11 with I_b = 20μA, 30 μA, and 40 μA.
13. Record your observations as given below :

Observations

Least count of voltmeter,	V_1 = ... V
Zero error of voltmeter,	V_1 = ... V
Least count of voltmeter,	V_2 = ... V
Zero error of voltmeter,	V_2 = ... V
Least count of milli-ammeter	= ...... mA
Zero error of milli-ammeter	= ..... mA
Least count of micro-ammeter	= ...... μA
Zero error of micro-ammeter	= ...... μA.

1. Table for base voltage and base current

Serial No. of Obs. (1)	Base voltage (V_b) (V) (2)	Base current (I_b) for collector voltage			
		$V_c = 0$ V (μA) (3a)	$V_c = 10$ V (μA) (3b)	$V_c = 20$ V (μA) (3c)	$V_c = 30$ V (μA) (3d)

2. Table for collector voltage and collector current

Serial No. of Obs. (1)	Collector voltage (V_c) (V) (2)	Collector current (I_c) for base current			
		$I_b = 10$ μA (mA) (3a)	$I_b = 20$ μA (mA) (3b)	$I_b = 30$ μA (mA) (3c)	$I_b = 40$ μA (mA) (3d)

Calculations

1. Calculation for input resistance (R_I)
   Plot a graph between base voltage V_b (column 2—table 1) and base current I_b (column 3a—table 1) for zero collector voltage V_c, taking Vb along X-axis and I_b along Y-axis. Plot graphs for different values of V_c. The graphs come as shown. These graphs are called 'input characteristics' of the transistor.

The slope of graphs becomes large at the ends. The slope gives value of $\frac{\Delta I_b}{\Delta V_b}$. Its reciprocal $\frac{\Delta V_b}{\Delta I_b}$ gives input resistance R_I. As graphs run parallel near the ends, all give same value of R_I.

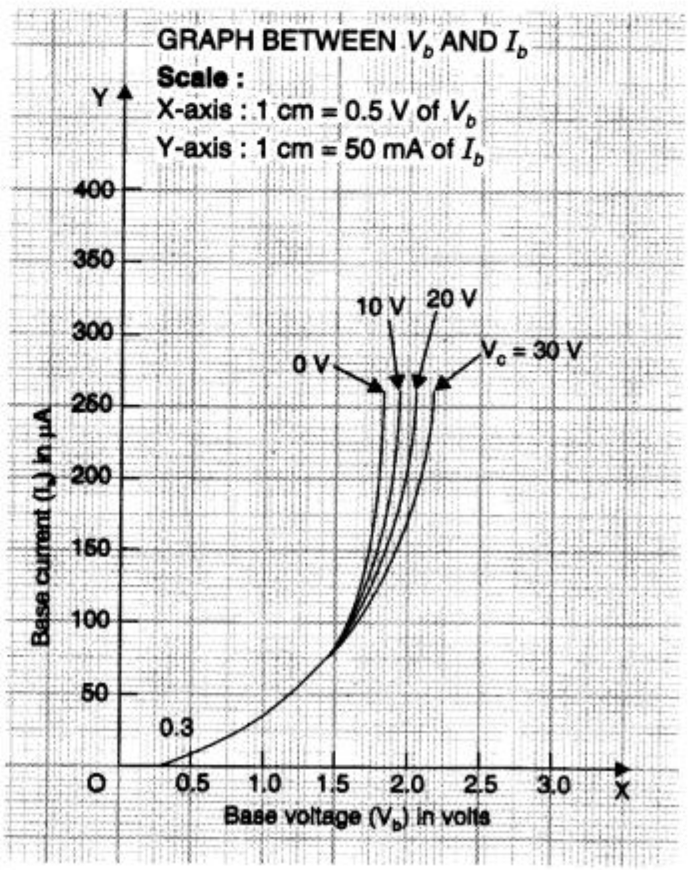

Fig. Input characteristics of a common emitter transistor.

2. Calculation for output resistance (R_0)
   Plot a graph between collector voltage V_c (column 2—table 2) and collector current I_c (column 3a – table 2) for 10 μA base current I_b, taking V_c along X-axis and I_c along Y-axis. Plot graphs for different values of I_b.

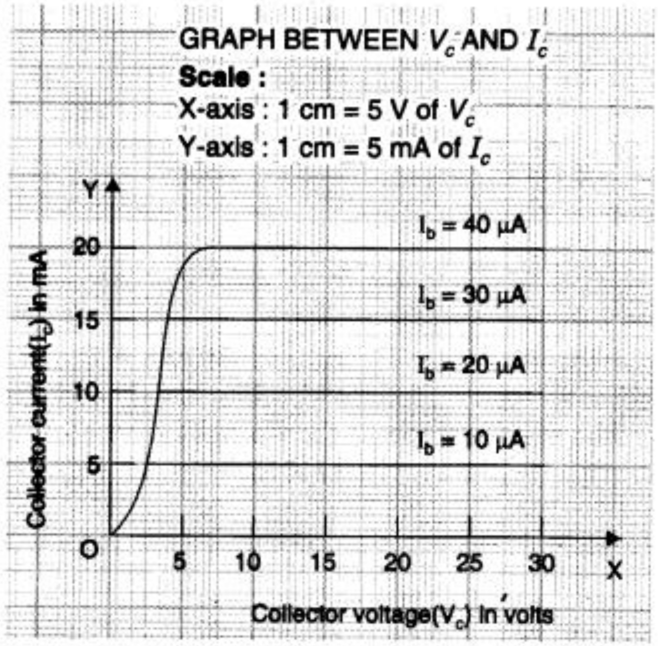

Fig. **Output characteristics of a common emitter transistor.**

These graphs are called 'output characteristics' of the transistor.

The slope of graphs becomes almost zero at ends. The slope gives value of $\frac{\Delta I_c}{\Delta V_c}$. Its reciprocal $\frac{\Delta V_c}{\Delta I_c}$ gives output resistance R_o. As graphs run parallel near the ends, all give same value of R_o.

3. Calculation for current gain (β)
   Plot a graph between base current I_b (columns 3a, 36, 3c and 3d—table 2) and corresponding collector current I_c (from same columns) for 30 volts collector voltage V_c, taking I_b along X-axis and $I_c$along Y-axis. The graph comes to be a straight line. The graph is called current gain characteristic of the common emitter transistor.

The slope of the straight line gives value of $\frac{\Delta I_c}{\Delta I_b}$ which is the value of current gain β of the common emitter transistor.

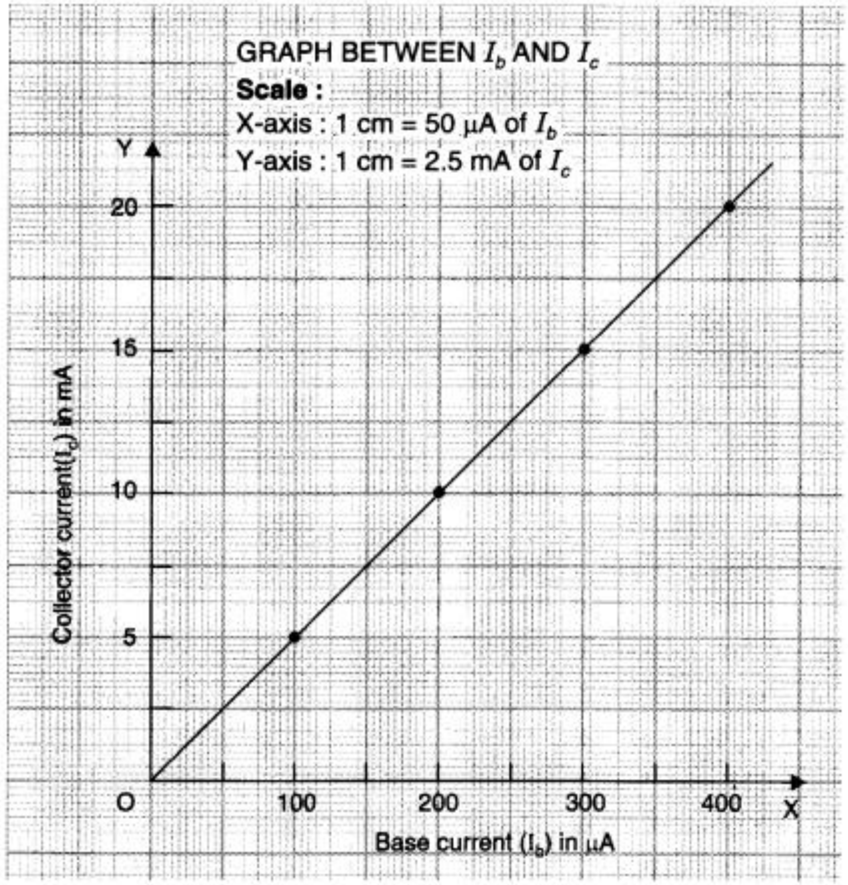

Fig. Current gain characteristics of a common emitter transistor. It is a straight line.

4. Calculation for voltage gain A_v

From relation, Voltage gain = Current gain × Resistance gain

$$A_v = \beta \times \frac{R_0}{R_I}$$

Result

For the given common emitter transistor,

Current gain, $\beta = \ldots\ldots$

Voltage gain, $A_v = \ldots\ldots$.

Precautions

Same as given in Experiment 8.

Sources of error

Same as given in Experiment 8.

Viva Voce

Question. 1. What is a semiconductor junction triode or transistor?
Answer. It is a semiconductor device having three sections which are (i) emitter (E), (ii) base (B) and (iii) collector (C).

Question. 2. How are the three sections arranged in a transistor?
Answer. The base is a thin layer of one type extrinsic semiconductor between two other sections of second type extrinsic semiconductors on either side of it.

Question.3. Are the emitter and the collector sections (made of same type of extrinsic semi-conductor) alike?
Answer. No. Emitter section is heavily doped, narrow and longer. It is done to provide more free charge carriers.
Collector section is moderately doped, broad and shorter. It is done for providing easy passage to free charge carriers from emitter section.

Question.4. What is the order of thickness of base section and what is reason for it?
Answer. The base thickness is of the order of 10 micron (10^{-5} m). The small thickness allows the recombination of only 2 to 5 per cent of charge carriers during their passage through it.

Question.5. In how many ways a transistor can be used?
Answer. A transistor can be used in three ways:

1. common base circuit;
2. common emitter circuit and
3. common collector circuit.

Question.6. How are the two junctions used?
Answer. One junction is used as input junction and the other as output junction.

Question.7.How are the two junction biased?
Answer. Generally, input junction is forward biased to offer less resistance and output junction is reverse biased to offer more resistance. Reverse is also possible.

Question.8.Why is the semiconductor junction triode called a transistor?
Answer. It can be used to transform a low resistance of a forward-biased junction into a high resistance of a reverse-biased junction or vice-versa. Thus, it works as a Transformer of resistor, which has been shortened to transistor.

Question.9.What is current gain of a common base transistor?
Answer. It is the ratio of change in collector current to the corresponding change in emitter current. It is represented by the symbol α.

i.e. $$\alpha = \frac{\Delta I_c}{\Delta I_e} \Rightarrow \alpha < 1.$$

It is about 0.98.

Question.10.What is current gain of a common emitter transistor?
Answer. It is the ratio of change in collector current to the corresponding change in base current. It is represented by the symbol β.

i.e. $$\beta = \frac{\Delta I_c}{\Delta I_b}$$

It is about 49.

Question.11.What makes 'p' so much more than 'α'?
Answer.

In a transistor, $$I_e = I_c + I_b$$
$$I_c = 0.98\, I_e,\ I_b = 0.02\, I_e$$

It makes $$\Delta I_b = 0.02\, \Delta I_e$$

or $$\frac{\Delta I_e}{\Delta I_b} = 50$$

Since $$\beta = \frac{\Delta I_c}{\Delta I_b} \quad \text{and} \quad \alpha = \frac{\Delta I_c}{\Delta I_e}$$

β becomes 50 times more than α.

Question.12.What is the order of magnitude of emitter current and base current?
Answer. Emitter current has magnitude upto 50 mA. Base current has magnitude upto 100 μA.

Question.13.Why a common emitter circuit is preferred over a common base circuit in amplifiers?
Answer. It is due to large current gain from common emitter circuit.

Question.14.What is resistance gain of a transistor?
Answer. The ratio of load resistance (R_L) used in output circuit to the input resistance (R_I) of input junction, is called resistance gain of a transistor.
Since load resistance used has value equal to output resistance (R_g) of output junction, the resistance gain is measured as R_o /R_I

Question.15.What is input characteristic of a common emitter transistor?
Answer. A graph between base voltage (V_b) and base current (I_b) for fixed value of collector voltage (V_c), is called the input characteristic of the common emitter transistor.

Question.16.What is the importance of the input characteristic? ,
Answer. It helps in calculating input resistance of the transistor.

By definition, $$R_I = \frac{\Delta V_b}{\Delta I_b}$$

It is equal to the reciprocal of the slope of the input characteristic and can be found.

Question.17.What is output characteristic of a common emitter transistor?
Answer. A graph between collector voltage (V_c) and collector current (I_c) for a fixed value of base current (I_b), is called the output characteristic of the common emitter transistor.

Question.18.What is the importance of the output characteristic?
Answer. It helps in calculating output resistance of the transistor.

By definition, $$R_o = \frac{\Delta V_c}{\Delta I_c}$$

It is equal to the reciprocal of the slope of the output characteristic and can be found.

Question.19.How to determine current gain of a common emitter transistor?
Answer. A graph can be plotted between base current (I_b) and collector current (I_c) taking I_b

along X-axis and I_c along Y-axis. The slope of this graph $\frac{\Delta I_c}{\Delta I_b}$ will give current gain (β) of the common emitter transistor.

Question.20.How do we calculate resistance gain?
Answer. We find input resistance Rb from input characteristics and output resistance R_o from output characteristics.

The ratio $\frac{R_0}{R_1}$ gives resistance gain.

Question.21.How do we calculate voltage gain?
Answer. Voltage gain is calculated by multiplying current gain by resistance gain.

Question.22.Write the three application of a transistor.
Answer. (i) Amplifier (ii) Switch (iii) Oscillator.

Question.23.Define the trans conductance of a transistor.
Answer. It is the ratio of change in collector current to the change in base-emitter voltage. It is denoted by g_m .

$$g_m = \frac{\Delta I_C}{\Delta V_{BE}}$$

Question.24.How does the collector current changes in a junction transistor of the base region has (i) large size (ii) large doping.
Answer. The collector current shall decrease in both cases.

Question.25.Why a common emitter transistor amplifier is preferred over a common base transistor amplifier?
Answer. Because the current gain in CE mode is much larger than CB mode.

Question.26.Can two p-n junction diodes placed back to back work as a p-n-p transistor?
Answer. No. In this device, the base region will be quite thick and highly doped. The base current will become equal to emitter due to neutralisation of majority carriers coming from emitter to collector.

Question.27.Why is the base region of a transistor made thin and lightly doped?
Answer. It is to reduce the base current and to increase both collector current and current gain.

Question.28.Why a transistor cannot be used as a rectifier?
Answer. To use a transistor as a rectifier, either its emitter-base portion or collector base portion has to be used. As the base is thin and lightly doped, then it will not work as a p-n junction.

Question.29.Which one of the transistors p-n-p and n-p-n is more useful and why?
Answer. n-p-n transistor is better than p-n-p transistor. It is because that electrons are majority carrier in n-p-n transistor while holes are majority carrier in p-n-p transistor. The mobility of electrons is much larger than that of holes due to small mass.

Question.30.How would you test in a simple way whether the transistor is spoiled or in working order?
Answer. The resistance of input section of a transistor is low as compared the output sector. In a spoiled transistor, the resistance is low for both sections.