UNIT 02: TRANSISTORS

- Unit 02-01: Transistors: Introduction and Types
- Unit 02-02: BJT: Construction, Types and Regions of Operations
- Unit 02-03: CB and CE configurations with their characteristics and current relationships
- Unit 02-04: BJT as Switch, DC Load Line
- Unit 02-05: Voltage Divider Bias Circuit, Single Stage CE Amplifier
- Unit 02-06: Enhancement MOSFET: Types, Construction, Operation and Characteristics

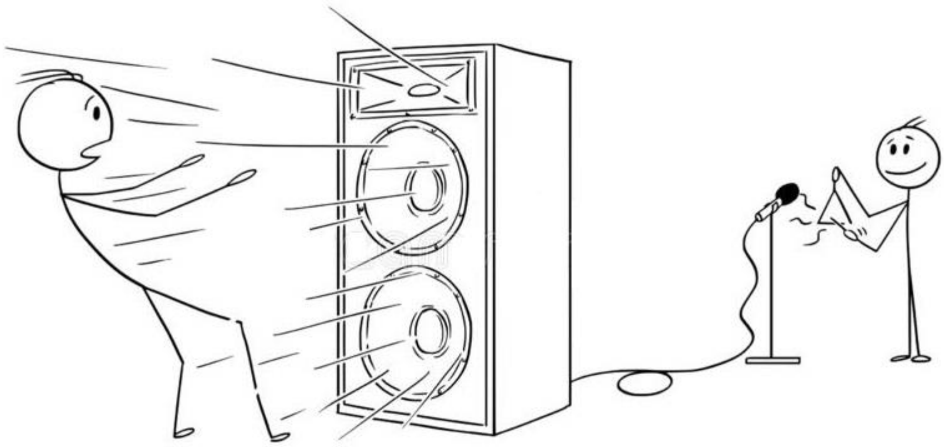
UNIT 02-01: TRANSISTORS: INTRODUCTION AND TYPES

LEARNING OBJECTIVES

After successful completion of this unit, you will be able to

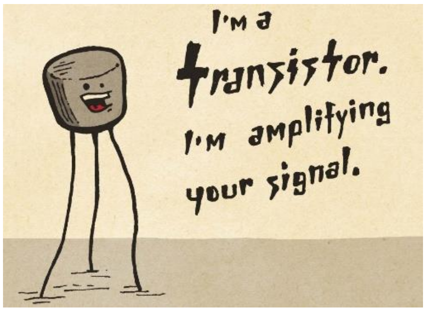
- ❖ Compare vacuum tubes and transistors
- ❖ Elaborate evolution of the transistors
- ❖ Describe different types of the transistors
- ❖ Enlist various applications of the transistors

INTRODUCTION



(Source: Google)

- How the size of computers is reducing over time?
- How the power requirement in computers is decreasing over time?
- How the level of a voice signal is increased using a public address system?
- How does an inverter convert DC signal into AC signal?



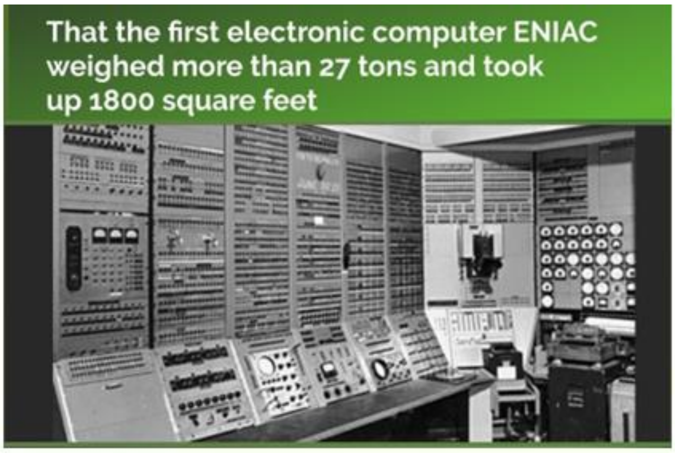
(Source: Google)

01-01: INSTRUCTION TO TRANSISTORS

In any modern-day electrical device, from alarm clocks to phones to computers to televisions, you will find a device called a transistor. In fact, you will find billions of them. Transistors are the basic building blocks of modern-day computing, combining to create the logic gates that enable computation. The invention of the transistor in 1947 opened the door to the information age as we know it.

But computers existed in a rather rudimentary form before transistors did. These massive systems took up entire rooms and weighed thousands of pounds. Rather than being built out of transistors, these computers were made up of something called thermionic valves or vacuum tubes. These light bulb looking devices are now more or less obsolete but they were used to design many electronic systems from radios to telephones to computers.

Vacuum Tube - Triode



(Source: Google)

The basic working principle of a vacuum tube is a phenomenon called thermionic emission. It works like this: you heat up a metal, and the thermal energy knocks some electrons loose. In 1904, English physicist John Ambrose Fleming took advantage of this effect to create the first vacuum tube device which he called an oscillation valve. Fleming's device consisted of two electrodes, a cathode and an anode, placed on either end of an encapsulated glass tube. When the cathode is heated, it gives off electrons via thermionic emission. Then by applying a positive voltage to the anode (also called the plate), these electrons are attracted to the plate and can flow across the gap. By removing the air from the tube to create a vacuum, the electrons have a clear path from the cathode to the anode and a current is created. This type of vacuum tube, consisting of only two electrodes, is called a diode. The term diode is still used today to refer to an electrical component that only allows an electric current to flow in one direction, although today these devices are all semiconductor based. In the case of the vacuum tube diode, a current can only flow from the anode to the cathode (though the electrons flow from the cathode to the anode). Diodes are commonly used for rectification, that is, converting from an alternating current (AC) to a direct current (DC).

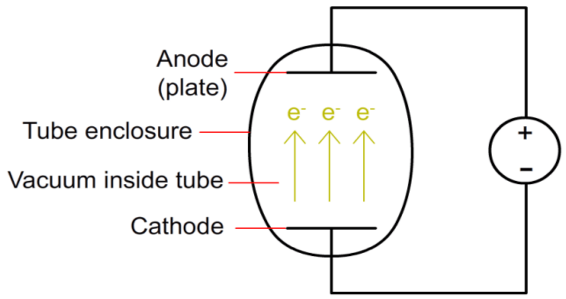


Fig 1.1.1: Simplified structure of a vacuum tube diode

In 1907, American inventor Lee de Forest added a third electrode to the mix, creating the first triode tube. This third electrode, called the control grid, enabled the vacuum tube to be used not just as a rectifier but as an amplifier of electrical signals. The control grid is placed between the cathode and anode, and is in the shape of a mesh (the holes allow electrons to pass through it). By adjusting the voltage applied to the grid, you can control the number of electrons flowing from the cathode to the anode. If the grid is given a strong negative voltage, it repels the electrons from the cathode and chokes the flow of current. The more you increase the grid voltage, the more electrons can pass through it, and the higher your current. In this way, the triode can serve as an ON / OFF switch for an electrical current as well as a signal amplifier.

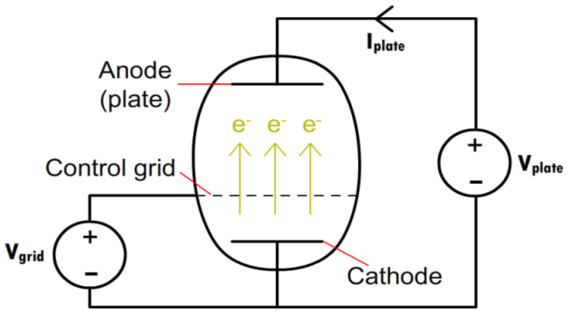
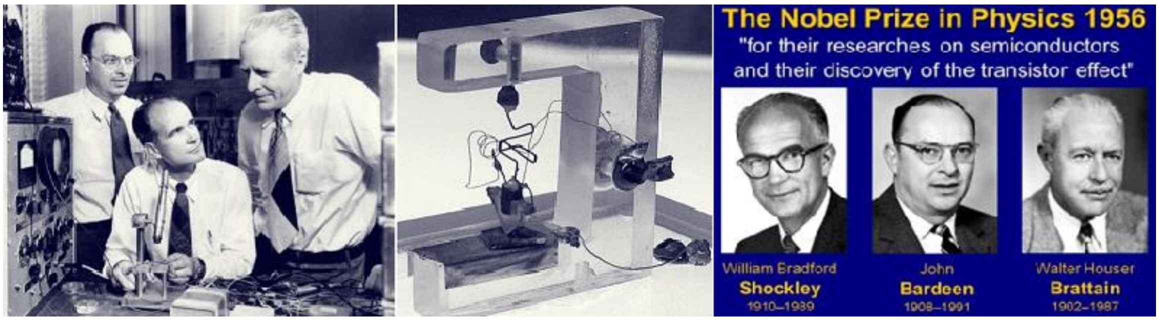
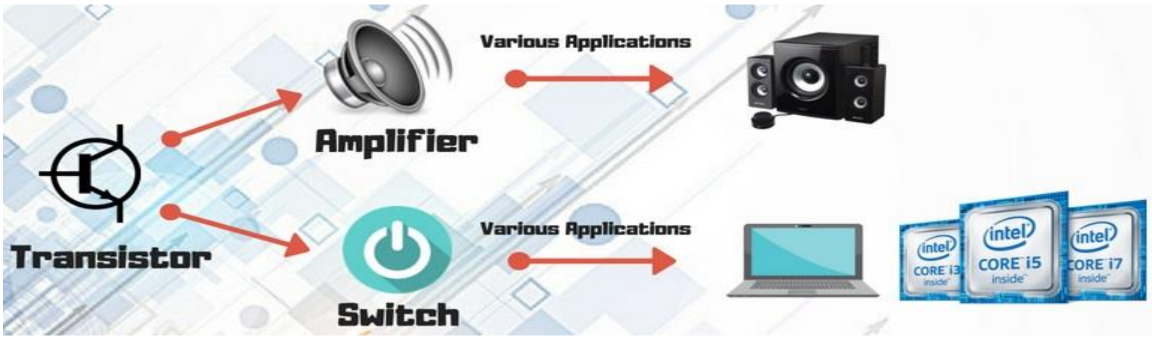


Fig 1.1.2: Simplified structure of a vacuum tube triode

These vacuum tubes are very bulky and large in size. Also, they are delicate as they are made up of glass material. They require high voltages to operate. They consume more power and generate more heat. Their failure rate is high.

In 1947, the trio of physicists William Shockley, Walter Brattain and John Bardeen created the world’s first transistor and marked the beginning of the end for the vacuum tube. The transistor could replicate all the functions of tubes like switching and amplification, but was made out of semiconductor materials.

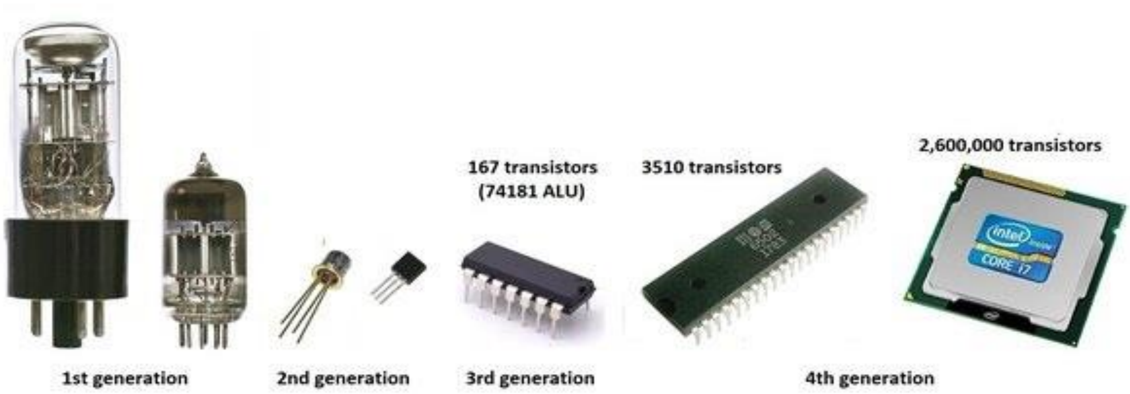




(Source: Google)

Transistor is a semiconductor device which is used to either amplify the signals or to act as an electrically controlled switch. Hence it is an active electronic component. A transistor is a three terminal device and a small current / voltage at one terminal (or lead) will control a large flow of current between the other two terminals (leads). Transistor is an essential component is almost every electronic circuit like amplifiers, switching, oscillators, voltage regulators, power supplies and digital logic ICs. The word transistor is a combination of transfer and resistance. This is because it transfers the resistance from one end of the device to the other end.

The first generation of computers depended upon the invention of vacuum tubes; for the second generation it was transistors; for the third, it was the integrated circuit; and the fourth generation of computers came about after the invention of the microprocessor.



(Source: Google)

Once the transistor cat was let out of the bag, vacuum tubes were on their way to extinction in all but the most specific of applications. Despite the emergence of the transistor, vacuum tubes aren't completely extinct, and they remain useful in some applications. For example, vacuum tubes are still used in high power RF transmitters, as they can generate more power than modern semiconductor equivalents. For this reason, you will find vacuum tubes in particle accelerators, MRI scanners, and even microwave ovens.

Vacuum tubes and transistors compared

Vacuum tubes: advantages

- Highly linear without negative feedback, especially some small-signal types.
- Clipping is smooth, which is widely considered more musical than transistors.
- Tolerant of overloads and voltage spikes.
- Characteristics highly independent of temperature, greatly simplifies biasing.
- Wider dynamic range than typical transistor circuits, thanks to higher operating voltages.
- Device capacitances vary only slightly with signal voltages.
- Capacitive coupling can be done with low-value, high-quality film capacitors.
- Circuit designs tend to be simpler than semiconductor equivalents.
- Operation is usually in Class A or AB, which minimizes crossover distortion.
- Output transformer in power amp protects speaker from tube failure.
- Maintenance tends to be easier because tubes can be replaced by user.

Vacuum tubes: disadvantages

- Bulky, hence less suitable for portable products.
- High operating voltages required.
- High power consumption; needs heater supply.
- Generate lots of waste heat.
- Lower power efficiency than transistors in small-signal circuits.
- Low-cost glass tubes are physically fragile.
- More prone to microphonics than semiconductors, especially in low-level stages.
- Cathode electron-emitting materials are used up in operation, resulting in short lifetimes (typically 1–5 years for power tubes).
- High-impedance devices that usually need a matching transformer for low-impedance loads, like speakers.
- Usually higher cost than equivalent transistors.

Transistors: advantages

- Usually lower cost than tubes, especially in small-signal circuits.
- Smaller than equivalent tubes.
- Can be combined in one die to make integrated circuit.
- Lower power consumption than equivalent tubes, especially in small-signal circuits.
- Less waste heat than equivalent tubes.
- Can operate on low-voltage supplies, greater safety, lower component costs, smaller clearances.
- Matching transformers not required for low-impedance loads.
- Usually more physical ruggedness than tubes (depends on chassis construction).

Transistors: disadvantages

- Tendency toward higher distortion than equivalent tubes.
- Complex circuits and considerable negative feedback required for low distortion.
- Sharp clipping, in a manner widely considered non-musical, due to considerable negative feedback commonly used.
- Device capacitances tend to vary with applied voltages.
- Large unit-to-unit variations in key parameters, such as gain and threshold voltage.
- Stored-charge effects add signal delay, which complicates high-frequency and feedback amplifier design.
- Device parameters vary considerably with temperature, complicating biasing and raising the possibility of thermal runaway.
- Cooling is less efficient than with tubes, because lower operating temperature is required for reliability.
- Power MOSFETs have high input capacitances that vary with voltage.
- Class B totem-pole circuits are common, which can result in crossover distortion.
- Less tolerant of overloads and voltage spikes than tubes.
- Nearly all transistor power amplifiers have directly-coupled outputs and can damage speakers, even with active protection.
- Capacitive coupling usually requires high-value electrolytic capacitors, which give inferior performance at audio-frequency extremes.
- Greater tendency to pick up radio-frequency interference, due to rectification by low-voltage diode junctions or slew-rate effects.
- Maintenance more difficult; devices are not easily replaced by user.
- Older transistors and ICs often unavailable after 20 years, making replacement difficult or impossible.

(Source: IEEE & Eric Barbour)

SOLVED PROBLEMS 01

NA

SELF-TEST 01

1) The first electronic computer ENIAC was designed using ______.

   a) Transistors

   b) Microprocessor

c) Integrated Circuits

d) Vacuum Tubes

2) The working principle of a vacuum tube is known as _____.

a) Thermionic Emission

b) Radio Frequency Emission

c) Photonic Emission

d) Radionic Emission

3) The transistor can be used as a _____.

a) Switch

b) Amplifier

c) Switch or Amplifier

d) Sensor

Short Answer Questions 01

1) Explain the working of a vacuum tube triode as an amplifier.

2) Compare the vacuum tubes and transistors.

3) How the transistor is an active electronic component?

01-02: Types of Transistors

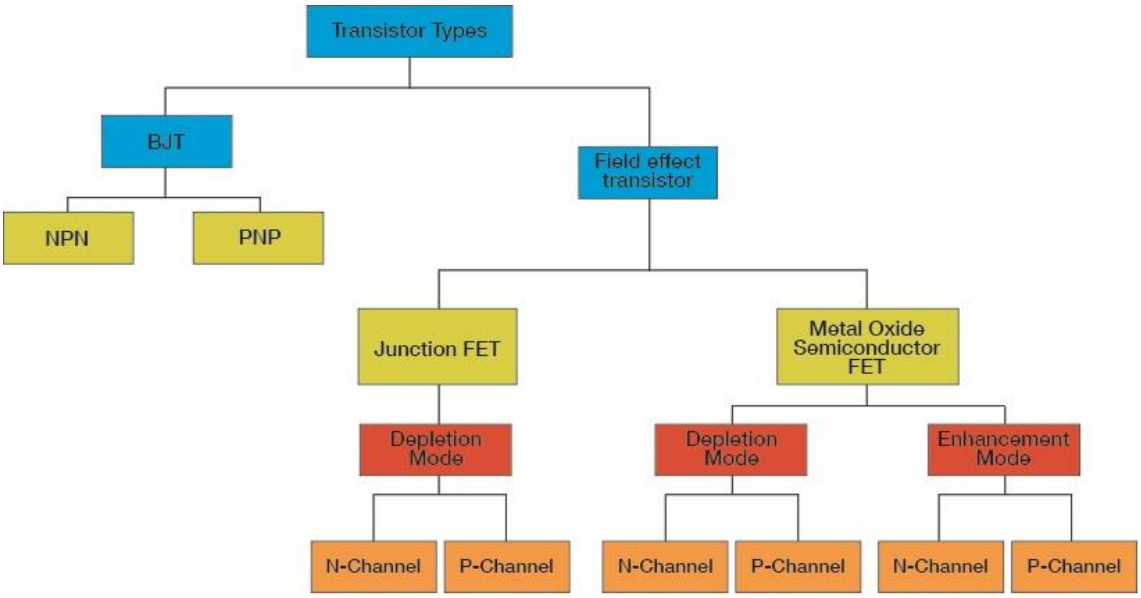


Fig 1.2.1: Classification of Transistors

Transistors are basically classified into two types, namely Bipolar Junction Transistors (BJT) and Field Effect Transistors (FET). The BJTs are classified into NPN and PNP transistors. The FETs are classified into JFET and MOSFET. JFETs are further classified into N-Channel JFET and P-Channel JFET depending on their construction. MOSFETs are classified into Depletion Mode MOSFET and Enhancement Mode MOSFET. Again, Depletion and Enhancement mode MOSFETs are further classified into respective N-Channel and P-Channel MOSFETs.

As mentioned earlier, on a broader scale, the major families of transistors are BJT and FET. Irrespective of the family they belong to, all transistors have proper / specific arrangement of different semiconductor materials. Commonly used semiconductor materials for manufacturing transistors are Silicon, Germanium and Gallium-Arsenide. Basically, the transistors are classified depending on their structure. Each type of transistors has their own characteristics, advantages and disadvantages. Physically and structurally speaking, the difference between BJT and FET is that the current flow in BJT is due to both electrons and holes, whereas the current flow in FET is due to only majority charge carriers. Hence BJTs are the bipolar devices while FETs are the unipolar devices.

The BJTs have three terminals named Emitter (E), Base (B) and Collector (C). There are two PN junctions in a BJT. The BJTs are classified into NPN and PNP transistors depending on the construction. BJTs are essentially current-controlled devices. If a small amount of current flows through the Base of a BJT, then it causes a flow of large current between Collector and Emitter.

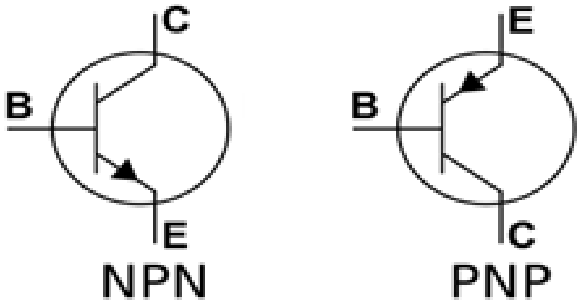


Fig 1.2.2: Symbols of BJTs

The FETs also have three terminals named Source (S), Gate (G) and Drain (D). FETs are essentially voltage-controlled devices. The voltage applied between Gate and Source controls the flow of electric current between Drain and Source of the transistor. The switching speed of FET is greater than BJT. It has good thermal stability as compared to BJT.

The Junction Field Effect Transistors (JFETs) are the earliest and simplest type of FETs. In N-Channel JFET, the current flow is due to the electrons. When voltage is applied between Gate and Source, a channel is formed between source and drain for current flow. This channel is called N-Channel. In P-Channel JFET, the current flow is due to the holes.

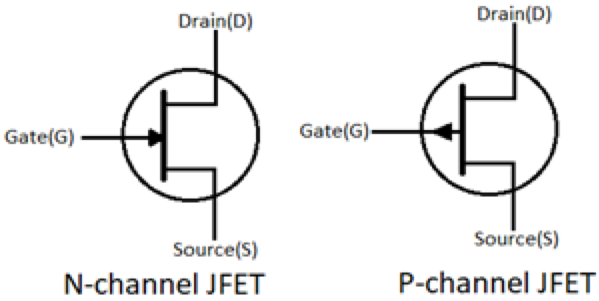


Fig 1.2.3: Symbols of JFETs

In Metal Oxide Semiconductor Field Effect Transistors (MOSFETs), the metal region of Gate and the semiconductor region are separated by a thin layer of metal oxide (usually, SiO2). Hence, MOSFET is also known as Insulated Gate FETs as the Gate region is completely insulated from the Source and Drain region. The additional fourth terminal of the MOSFET is called Substrate (SS) and is not normally used as either an input or an output connection but instead it is used for grounding the substrate. MOSFET has many advantages over BJT and JFET, mainly it offers high input impedance and low output impedance. The MOSFETs are available in Depletion and Enhancement types. Further, the Depletion and Enhancement MOSFETs are classified into N–Channel and P–Channel types. In Depletion MOSFET, the channel between Drain and Source is permanently present. Hence it can conduct even if Gate to Source voltage is zero. While in Enhancement MOSFET, such a channel is created temporarily after applying Gate to Source voltage. Hence it can not conduct if Gate to Source voltage is zero.

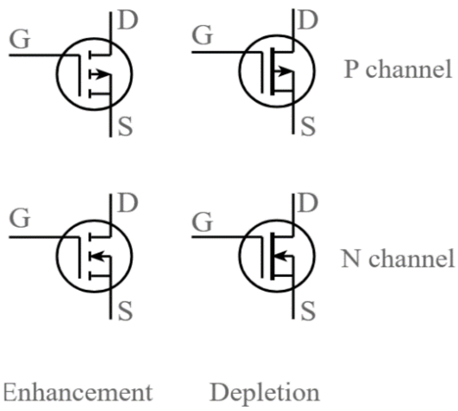


Fig 1.2.4: Symbols of MOSFETs

Solved Problems 02

NA

Self-Test 02

4) BJT is a _____ controlled device.

    a) Field

    b) Voltage

    c) Resistor

    d) Current

5) In FETs, the current flow is due to _____.

    a) minority charge carriers

    b) majority charge carriers

    c) both minority and majority charge carriers

    d) either minority or majority charge carriers

6) In E-MOSFET, the channel is _____.

    a) not required

    b) present initially in unbiased condition

    c) always present

    d) created later after biasing

Short Answer Questions 02

4) Explain the different types of transistors.

5) Compare the BJTs and FETs.

Summary

- Vacuum tubes were used for switching and amplification purposes in electronic circuits before the invention of transistors.
- Transistors are semiconductor-based devices which are small in size, light weight and they require low power.
- Transistors are the basic building blocks of both digital and analog ICs.
- The size and power requirement of transistors are reducing with time.
- BJTs are the bipolar devices while FETs are the unipolar devices.
- BJTs are the current controlled devices while FETs are the voltage controlled.

Key Words

Switching, Amplification, Vacuum Tubes, Transistors, BJT, JFET, MOSFET

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Course Companion Website

Visit Here for Course Companion website for this course:

- https://www.electronicshub.org/transistors-classification-and-types/

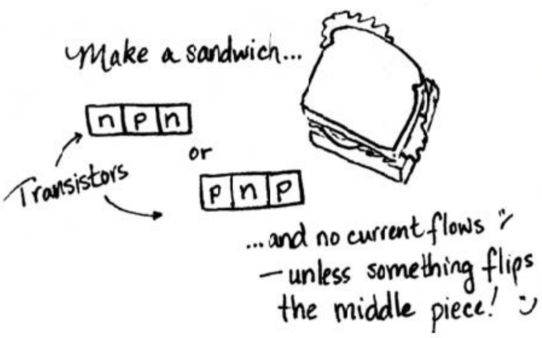
UNIT 02-02: BJT: CONSTRUCTION, TYPES AND REGIONS OF OPERATIONS

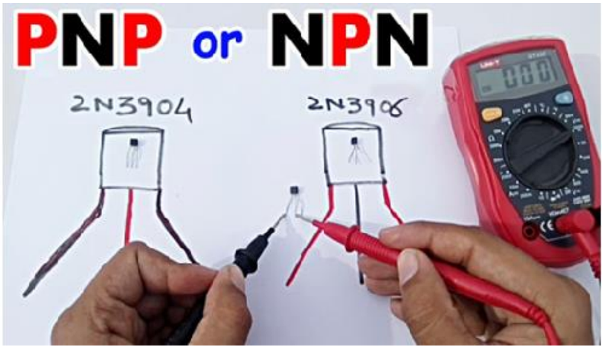
LEARNING OBJECTIVES

After successful completion of this unit, you will be able to

- ❖ Explain the construction of BJT
- ❖ Describe two diode analogy of BJT
- ❖ Identify the terminals of BJT
- ❖ Identify the different types of transistor packages
- ❖ Explain the different regions of operation and applications of a BJT based on biasing of its two PN junctions

INTRODUCTION





(Source: Google)

- The structure of a BJT is similar to a sandwich.
- The BJT has two PN junctions connected back-to-back.
- The BJT has different physical looks.
- DMM can be used to test a BJT.

02-01: BJT: CONSTRUCTION AND TYPES

The BJT is constructed with three doped semiconductor regions separated by two PN junctions, as shown in the epitaxial planar structure in Fig 2.1.1(a). The three regions are called Emitter, Base and Collector. Physical representations of the two types of BJTs are shown in Fig 2.1.1(b) and (c). NPN type consists of a P region sandwiched between two N regions and PNP type consists of a N region sandwiched between two P regions. The term bipolar refers to the use of both holes and electrons as current carriers in the transistor structure. Electrons are the majority charge carriers in a NPN type while holes are the majority charge carriers in PNP type. As the mobility of electrons is higher than the mobility of holes, the NPN transistors are widely used. The PN junction joining the Base region and the Emitter region is called the Base-Emitter junction or simply the Emitter junction. The PN junction joining the Base region and the Collector region is called the Base-Collector junction or simply the Collector junction, as indicated in Fig 2.1.1(b). A single PN junction is equivalent to a diode. Thus, a BJT can be considered to be equivalent to two diodes, connected back-to-back as shown in Table 2.1.1. A wire lead connects to each of the three regions, as shown. These leads are labeled E, B and C for Emitter, Base and Collector respectively. The Base region is lightly doped and very thin compared to the heavily doped Emitter and the moderately doped Collector regions.

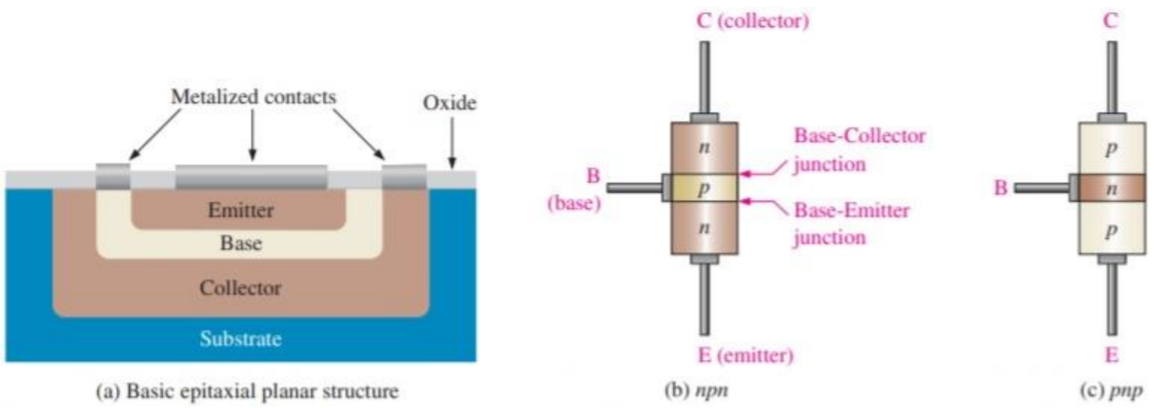


Fig 2.1.1: Basic BJT construction

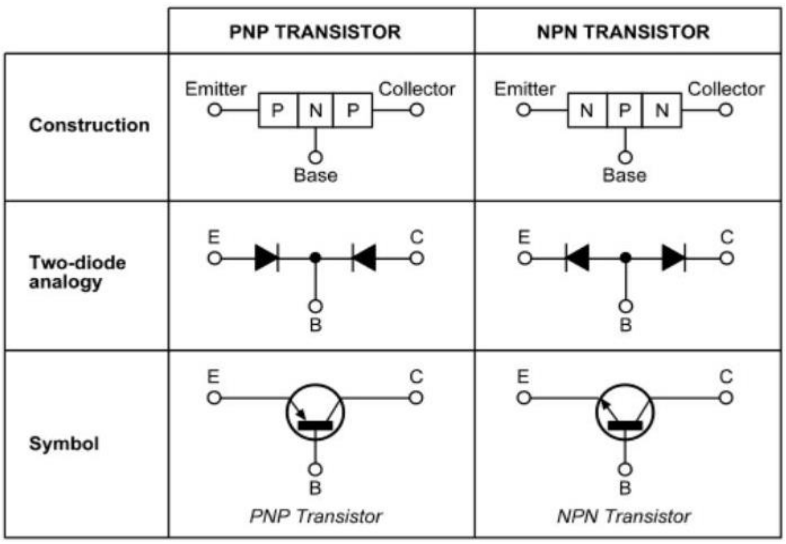
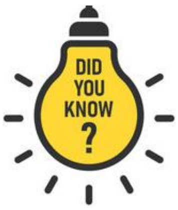


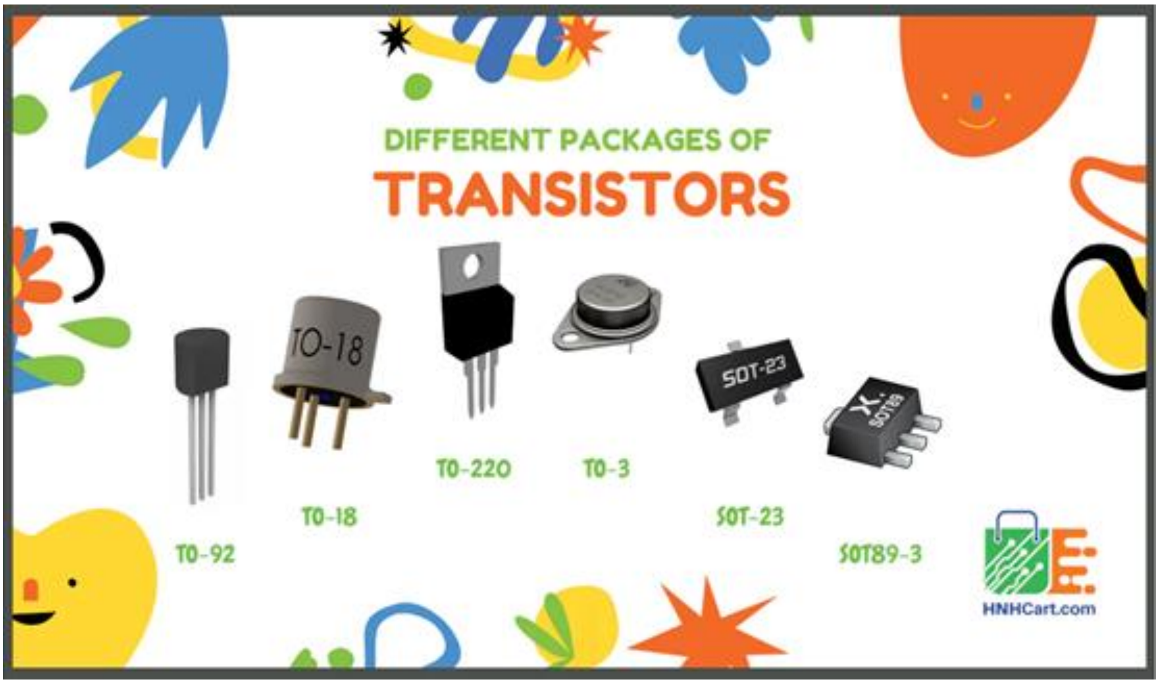
Table 2.1.1: Two diode analogy of BJT



Transistor packages are the styles of the case used to house transistor components, providing the connection between the internal and the external circuit, as well as protection for the delicate internal part and perhaps capacity for removal of heat via heatsinks to avoid thermal damage. Standards for transistor packages are, "TO" (transistor outline); other standards sometimes use "SOT" (small-outline transistor) for surface mount devices.

The transistor packages are varied according to their applications. Low power transistor packages will be different from the packaging of the high-power transistor. Low power transistor packaging is made of plastic material having a characteristic surface that is flat, while those made of metal have a tag on the plate underneath.

Transistors with a higher power are usually made of plastic packaging, metal, or a mixture of plastic and metal. Metals in the body transistor generally signify a collector terminal and specialized in high power transistors, the metal tag is useful for attaching a heat sink or appliance exhaust heat dissipation that occurs during the process.



(Source: www.hnhcart.com/blogs/learn/different-packages-of-transistors)

SOLVED PROBLEMS 01

NA

SELF-TEST 01

7) The three terminals of a BJT are called ______.

   a) P, N, P

b) N, P, N

c) Input, Output, Ground

d) Emitter, Base, Collector

8) In a PNP transistor, the P regions are _____.

a) Base and Emitter

b) Base and Collector

c) Emitter and Collector

d) Only Base

9) Base region of the transistor is always _____ and _____ doped.

a) thick, lightly

b) thin, lightly

c) thick, heavily

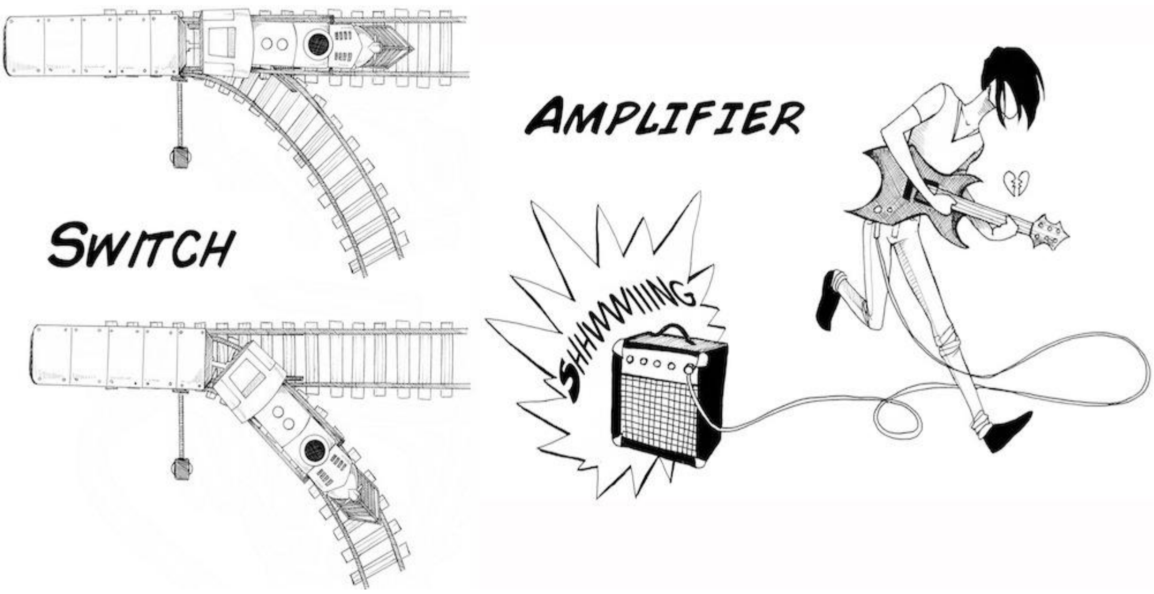
d) thin, heavily

SHORT ANSWER QUESTIONS 01

6) Explain the construction of BJT.

7) Why is the Base a thin and lightly doped region in BJT?

02-02: BJT: REGIONS OF OPERATIONS



(Source: Google)

B-E Junction	B-C Junction	Region of Operation	Application of BJT
Forward Biased	Forward Biased	Saturation	ON Switch
Forward Biased	Reversed Biased	Active	Amplifier
Reversed Biased	Forward Biased	Reverse Active	Not Used
Reversed Biased	Reversed Biased	Cut-off	OFF Switch

Table 2.2.1: Regions of operation and applications of BJT

When both B-E junction as well as B-C junction are forward biased then the BJT operates in the saturation region and it operates as a fully ON switch. When both B-E junction as well as B-C junction are reverse biased then the BJT operates in the cut-off region and it operates as a fully OFF switch. When the B-E junction is forward biased and the B-C junction is reverse biased then the BJT operates in the active region and it operates as an amplifier. When the B-E junction is reverse biased and the B-C junction is forward biased then the BJT operates in the reverse active region. The gain of the BJT in the reverse active region is very low. Hence operating thy BJT in this region is not useful.

SOLVED PROBLEMS 02

NA

SELF-TEST 02

10) For operating a BJT in the active region, the emitter junction should be _____ biased and collector junction should be _____ biased.

    a) forward, forward

    b) reverse, reverse

    c) forward, reverse

    d) reverse, forward

11) For operation as an amplifier, the Base of a NPN transistor must be _____.

    a) Positive with respect to the Emitter

    b) Negative with respect to the Emitter

    c) Positive with respect to the Collector

    d) 0 V

SHORT ANSWER QUESTIONS 02

8) Explain the different regions of operation of a BJT.

9) What will happen if the B-E junction of a BJT is reverse biased and the B-C junction is forward biased?

SUMMARY

- BJT is constructed with three doped semiconductor regions separated by two PN junctions.
- The three regions in the BJT are called Emitter, Base and Collector.
- There are two types of the BJT namely NPN and PNP.
- Base is the lightly doped and very thin region.
- Transistor packages are the styles of the case used to house transistor components.
- The terminals and the type of the BJT can be identified using DMM.
- The BJT can be used as a switch or as an amplifier based on its biasing.

KEY WORDS

NPN, PNP, Emitter, Base, Collector, Saturation, Active, Reverse Active, Cut-off

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Course Companion Website

Visit Here for Course Companion website for this course:

https://www.electroniclinic.com/bipolar-junction-transistor-construction-and-working/

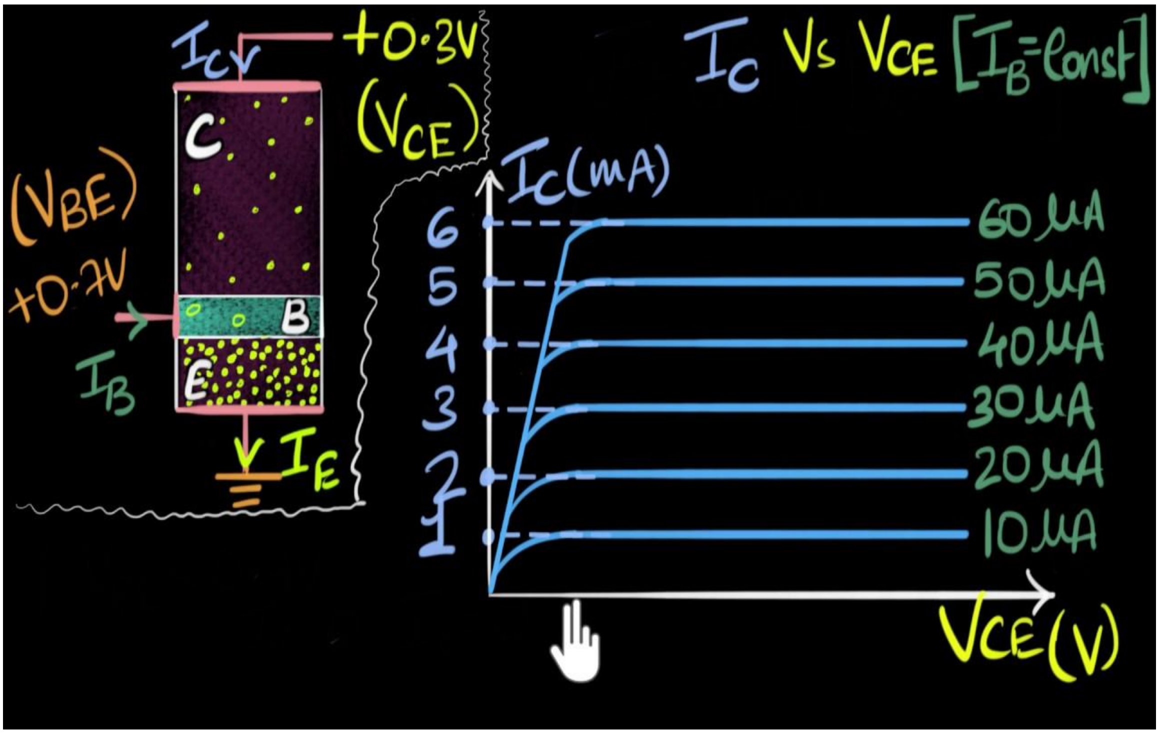
UNIT 02-03: CB AND CE CONFIGURATIONS WITH THEIR CHARACTERISTICS AND CURRENT RELATIONSHIPS

LEARNING OBJECTIVES

After successful completion of this unit, you will be able to

- ❖ Elaborate the current flow in the BJT.
- ❖ Explain the current relationships in the BJT.
- ❖ Describe the characteristics of CB and CE configurations of the BJT.
- ❖ Determine the region of operation of the BJT.

INTRODUCTION



(Source: Khan Academy)

DID YOU KNOW?

- How does the current flow in the BJT?
- How the three terminal BJT is connected in a circuit having four terminals?
- The BJT can be used as a constant current source.
- BJT also has alpha (α) and beta (β) associated with it.

03-01: Configurations of BJT

The BJT has three terminals - Emitter (E), Base (B) and Collector (C). But in the circuit connections, we need four terminals, two terminals for input side and another two terminals for output side. To overcome this problem, we use one terminal as common for both input and output sides.

Using this property, we construct the BJT circuits under DC operating conditions which are called BJT configurations. There are three different configurations of the BJT and they are Common Base (CB) configuration, Common Emitter (CE) configuration and Common Collector (CC) configuration.

03-02: CB configuration with its characteristics and current relationships

In CB configuration, Base is the common terminal between input and output sides. Input is applied between Emitter and Base terminals while the output is taken between Collector and Base terminals. The input voltage is V_{EB} while the output voltage is V_{CB}. The B-E junction is forward biased while the B-C junction is reverse biased by properly adjusting polarities and magnitudes of the DC sources V_{EE} and V_{CC} respectively. The input current is Emitter current (I_E) while the output current is Collector current (I_C). The circuit diagram of the CB configuration is shown in Fig 3.2.1.

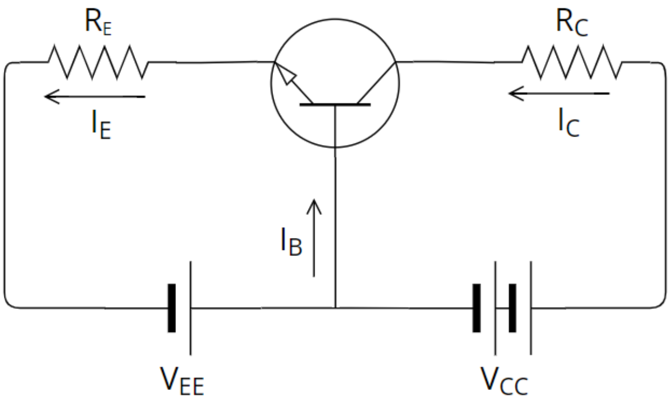


Fig 3.2.1: Circuit diagram of CB configuration

In BJT, the Base current (I_B) is very small because the Base region is lightly doped and very thin. In BJT Emitter current (I_E) is always equal to Collector current (I_C) plus Base current (I_B).

$$I_E = I_C + I_B \qquad ..... (3.2.1)$$

The current gain or current amplification factor is defined as the ratio of the output current to the input current. The current gain of CB configuration is denoted by symbol alpha (α).

$$\alpha = \frac{I_C}{I_E} \qquad \text{..... (3.2.2)}$$

α is always less than unity. Its typical value ranges from 0.95 to 0.995.

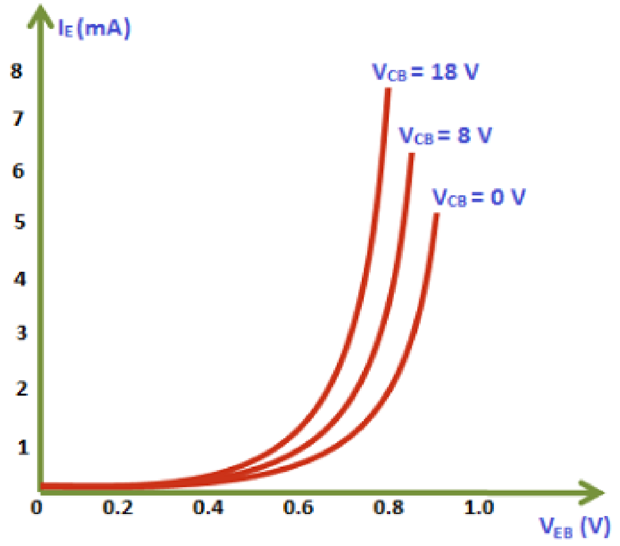


Fig 3.2.2: Input characteristics of CB configuration

Input characteristic is the graph of input current on Y-axis verses input voltage on X-axis at constant output voltage. The input characteristics of CB configuration are shown in Fig 3.2.2. In CB configuration, input is applied between Emitter and Base terminals and the B-E junction is forward biased. Hence its input characteristics look like the VI characteristic of a forward biased PN junction. The input current I_E increases with increase in the output voltage V_{CB} at constant value of the input voltage V_{EB}.

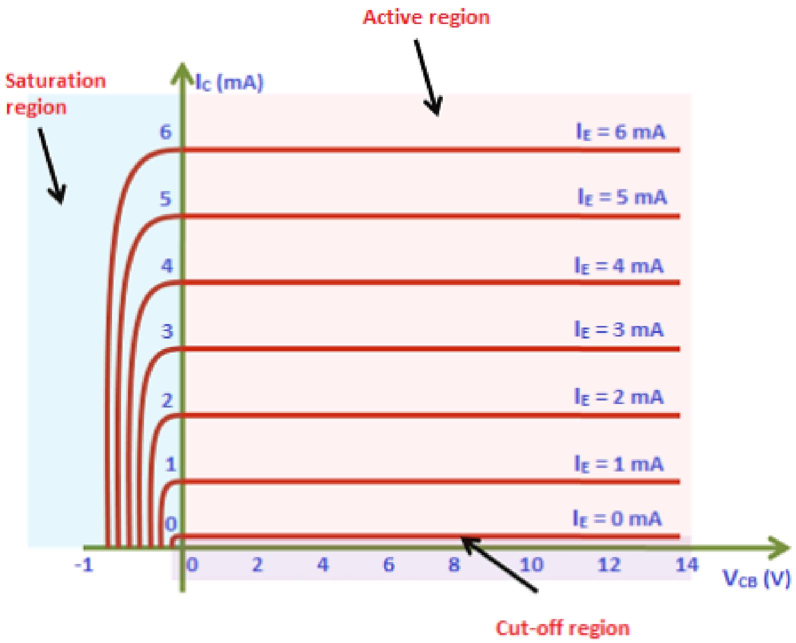


Fig 3.2.3: Output characteristics of CB configuration

Output characteristic is the graph of output current on Y-axis verses output voltage on X-axis at constant input current. The output characteristics of CB configuration are shown in Fig 3.2.3. The three regions of operation of the BJT are shown in these characteristics. In active region, the output current I_C is almost constant. It is not dependent on output voltage V_{CB}. Its value is almost same as that of input current I_E in the active region. Thus, the BJT acts as a constant current source within this region. If the Emitter terminal is kept open then the input current I_E will be zero and the B-E junction will be reverse biased. The BJT will operate in the cut-off region which is shown below I_E = 0 in the output characteristics. For negative values of the output voltage V_{CB}, the B-C junction will be forward biased and the BJT will operate in the saturation region. This region is on the left-hand side of vertical axis the output characteristics.

SOLVED PROBLEMS 01

1) Determine α and I_B for a transistor where I_E = 3.7 mA and I_C = 3.65 mA.

Solution:

$$\alpha = \frac{I_C}{I_E} = \frac{3.65}{3.7} = 0.9864$$

$$I_B = I_E - I_C = 3.7 - 3.65 = 0.05\ mA$$

SELF-TEST 01

12) The α is always _____.

  a) unity
  b) less than unity
  c) greater than unity
  d) greater than or equal to unity

13) The input characteristics of the CB configuration is the graph of _____.

  a) V_{CE}, I_C
  b) V_{EB}, I_E
  c) I_E, V_{EB}
  d) V_{EB}, I_B

SHORT ANSWER QUESTIONS 01

10) Explain the input characteristics of the CB configuration of transistor.

11) Explain the output characteristics of the CB configuration of transistor.

03-03: CE CONFIGURATION WITH ITS CHARACTERISTICS AND CURRENT RELATIONSHIPS

In CE configuration, Emitter is the common terminal between input and output sides. Input is applied between Base and Emitter terminals while the output is taken between Collector and Emitter terminals. The input voltage is V_{BE} while the output voltage is V_{CE}. The B-E junction is forward biased while the B-C junction is reverse biased by properly adjusting polarities and magnitudes of the DC sources V_{BB} and V_{CC} respectively. The input current is Base current (I_B) while the output current is Collector current (I_C). The circuit diagram of the CE configuration is shown in Fig 3.3.1.

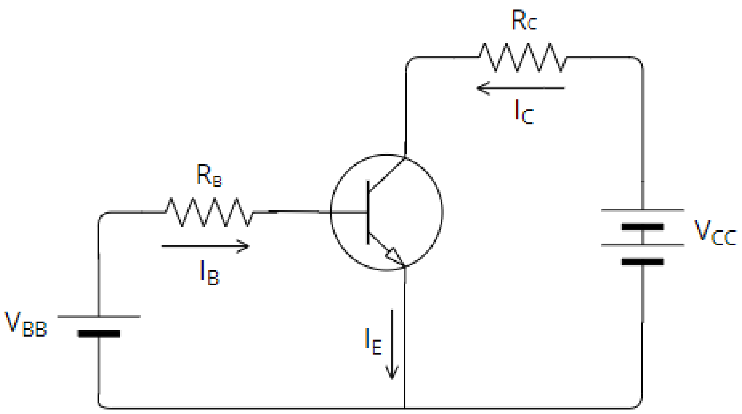


Fig 3.3.1: Circuit diagram of CE configuration

The current gain of CE configuration is denoted by symbol beta (β).

$$\beta = \frac{I_C}{I_B} \quad . \qquad \text{.... (3.3.1)}$$

The typical value of β ranges from 20 to 200 or even high. It is dependent on the effective Base width. If the effective Base width is increased (by reducing V_{CE}) then the I_B will be increased and β will be decreased.

Dividing numerator and denominator by I_B on right hand side of Eq 3.2.2, we get

$$\alpha = \frac{I_C/I_B}{I_E/I_B} \qquad \text{..... (3.3.2)}$$

Using Eq 3.2.1 in Eq 3.3.2, we get

$$\alpha = \frac{\frac{I_C}{I_B}}{\frac{I_B + I_C}{I_B}}$$

$$\alpha = \frac{\frac{I_C}{I_B}}{\frac{I_B}{I_B} + \frac{I_C}{I_B}} \qquad \text{..... (3.3.3)}$$

Using Eq 3.3.1 in Eq 3.3.3, we get

$$\alpha = \frac{\beta}{1+\beta} \qquad \text{..... (3.3.4)}$$

By applying Kirchhoff's voltage law to the B-E junction of the CE configuration circuit of the BJT shown in Fig 3.3.1, we get

$$V_{BB} - I_B R_B - V_{BE} = 0$$

Solving for I_B, we get

$$I_B = \frac{V_{BB}-V_{BE}}{R_B} \qquad \text{..... (3.3.5)}$$

By applying Kirchhoff's voltage law to the B-C junction of the CE configuration circuit of the BJT shown in Fig 3.3.1, we get

$$V_{CC} - I_C R_C - V_{CE} = 0$$

Solving for I_C, we get

$$I_C = \frac{V_{CC}-V_{CE}}{R_C} \qquad \text{..... (3.3.6)}$$

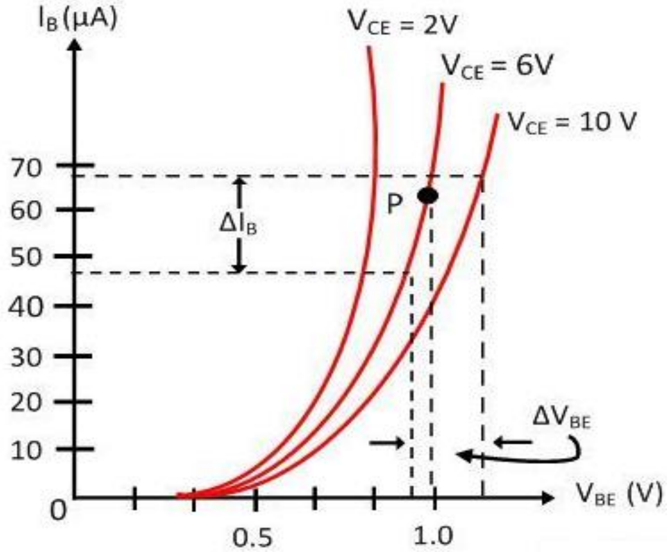


Fig 3.3.2: Input characteristics of CE configuration

The input characteristics of CE configuration are shown in Fig 3.3.2. In CE configuration, input is applied between Base and Emitter terminals and the B-E junction is forward biased. Hence its input characteristics look like the VI characteristic of a forward biased PN junction. At constant input voltage V_{BE}, the input current I_B decreases with increase in the output voltage V_{CE}. Because the effective Base width decreases with increase in the output voltage V_{CE}.

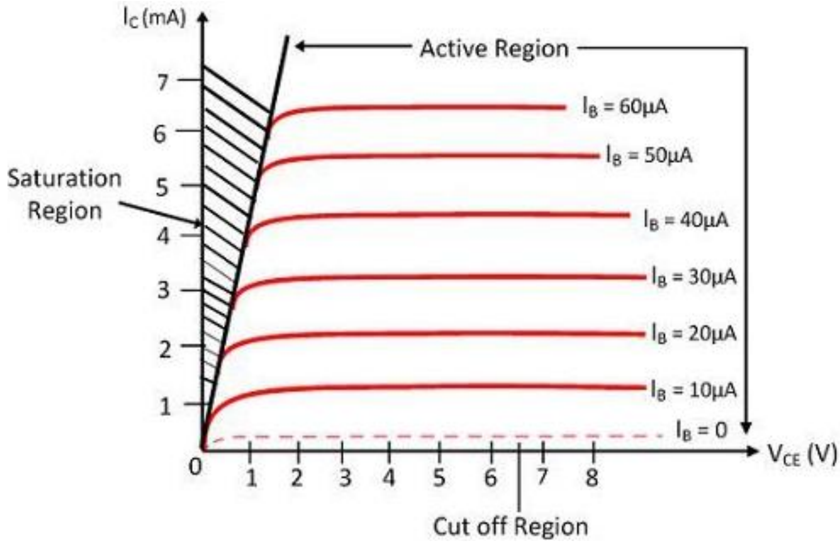


Fig 3.3.3: Output characteristics of CE configuration

The output characteristics of CE configuration are shown in Fig 3.3.3. As the Collector is the output terminal in CE configuration, its output characteristics are also known as the Collector characteristics curves. The three regions of operation of the BJT are shown in these characteristics. In active region, the output current I_C is almost constant. It is not dependent on output voltage V_{CE}. Thus, the BJT acts as a constant current source within this region.

If the Base terminal is kept open then the input current I_B will be zero and the B-E junction will be reverse biased. The BJT will operate in the cut-off region which is shown below $I_B = 0$ in the output characteristics. If I_B is zero I_C also becomes zero because $I_C = \beta I_B$. Thus, from Eq 3.3.6, we get

$$V_{CE(cut-off)} = V_{CC} \qquad \text{..... (3.3.7)}$$

If the I_B is increased then I_C also increases ($I_C = \beta I_B$) and V_{CE} decreases as a result of more voltage drop across R_C ($V_{CE} = V_{CC} – I_C R_C$). When V_{CE} reaches its saturation value, $V_{CE(sat)}$, the B-C junction becomes forward biased and I_C can increase no further even with a continued increase in I_B. At the point of saturation, the relation $I_C = \beta I_B$ is no longer valid. The saturation region is near to the vertical axis the output characteristics.

$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C} \qquad \text{..... (3.3.8)}$$

The minimum value of I_B needed to produce saturation is

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta} \qquad \text{..... (3.3.9)}$$

I_B should be significantly greater than $I_{B(min)}$ to keep the BJT well into the saturation.

Solved Problems 02

2) Determine α and β for a transistor for which $I_B = 0.02$ mA and $I_C = 4.9$ mA.

Solution:

$$\beta = \frac{I_C}{I_B} = \frac{4.9}{0.02} = 245$$

$$\alpha = \frac{\beta}{1+\beta} = \frac{245}{1+245} = 0.996$$

3) For the CE configuration circuit of the BJT shown in Fig 3.3.1 if $V_{BB} = 5$ V, $V_{CC} = 10$ V, $R_B = 10$ kΩ, $R_C = 100$ Ω and β = 150 then determine I_B, I_C and V_{CE}.

Solution:

Assume $V_{BE} = 0.7$ V

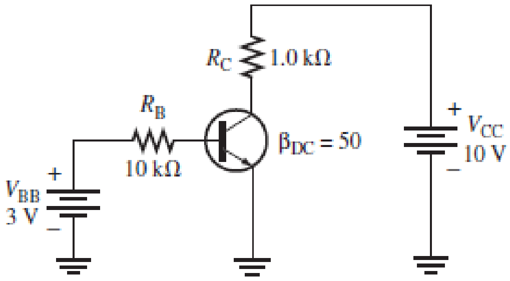
$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5 - 0.7}{10k} = 430\ \mu A$$

$$I_C = \beta I_B = 150 \times 430\mu = 64.5\ mA$$

$$I_E = I_C + I_B = 64.5\ mA + 430\ \mu A = 64.9\ mA$$

$$V_{CE} = V_{CC} - I_C R_C = 10 - (64.5m \times 100) = 3.55\ V$$

4) Determine whether or not the transistor shown below is in saturation. Assume $V_{CE(sat)} = 0.2$ V.



Solution:

$$I_{C(sat)} = \frac{10 - 0.2}{1k} = 9.8\ mA$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{3 - 0.7}{10K} = 0.23\ mA$$

The minimum value of I_B needed to produce saturation is

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta} = \frac{9.8\ mA}{50} = 0.196\ mA$$

As I_B is greater than $I_{B(min)}$, the transistor is in saturation.

Self-Test 02

14) If I_C is 50 times larger than I_B then β is _____.

    a) 0.02
    b) 100
    c) 50
    d) 500

15) In cut-off region, V_{CE} is _____.

    a) V_{CC}
    b) 0 V
    c) floating
    d) 0.2 V

16) In saturation region, V_{CE} is _____.

    a) 0.7 V
    b) Equal to V_{CC}
    c) minimum
    d) maximum

Short Answer Questions 02

12) Explain the input and output characteristics of the CE configuration of transistor.

13) What will happen with the Collector current if the Base current is further increased after saturation of the transistor? Why?

14) Why is the CE configuration most widely used?

15) Compare the CB and CE configurations of the transistor.

Summary

- There are three different configurations of the BJT - CB, CE and CC.
- The three currents in the transistor are I_B, I_C and I_E.
- I_B is very small as compared to I_C and I_E.
- α is the current gain of CB configuration. Its typical value ranges from 0.95 to 0.995.
- β is the current gain of CE configuration. Its typical value ranges from 20 to 200 or even high.

- The output characteristics of the CE configuration are also known as the Collector characteristics curves.
- The BJT acts as a constant current source in the active region.

Key Words

Common Base, Common Emitter, Input Characteristics, Output Characteristics, Gain, Alpha (α), Beta (β), Saturation, Active, Cut-off

References

MOOCs

- Khan Academy Course: "Class 12 Physics (India) – Semiconductors – Transistor Working and Transistor Characteristics"

  https://www.khanacademy.org/science/in-in-class-12th-physics-india/in-in-semiconductors

YouTube Videos

- BJT: Common Base Configuration Explained

  https://www.youtube.com/watch?v=NMD4KECE-7I

- BJT: Common Emitter Configuration Explained

  https://www.youtube.com/watch?v=KynKHr2cXgk&t=8s

Wikipedia

- https://en.wikipedia.org/wiki/Bipolar_junction_transistor

OER

- IIT Kharagpur's Basic Electronics Virtual Laboratory

  1) BJT Common Base Characteristics

     http://vlabs.iitkgp.ac.in/be/exp12/index.html

  2) BJT Common Emitter Characteristics

     http://vlabs.iitkgp.ac.in/be/exp11/index.html

Books

- Thomas. L. Floyd, "Electronics Devices", 9th Edition, Pearson

Course Companion Website

Visit Here for Course Companion website for this course:

https://www.electronicshub.org/different-configurations-of-transistors/

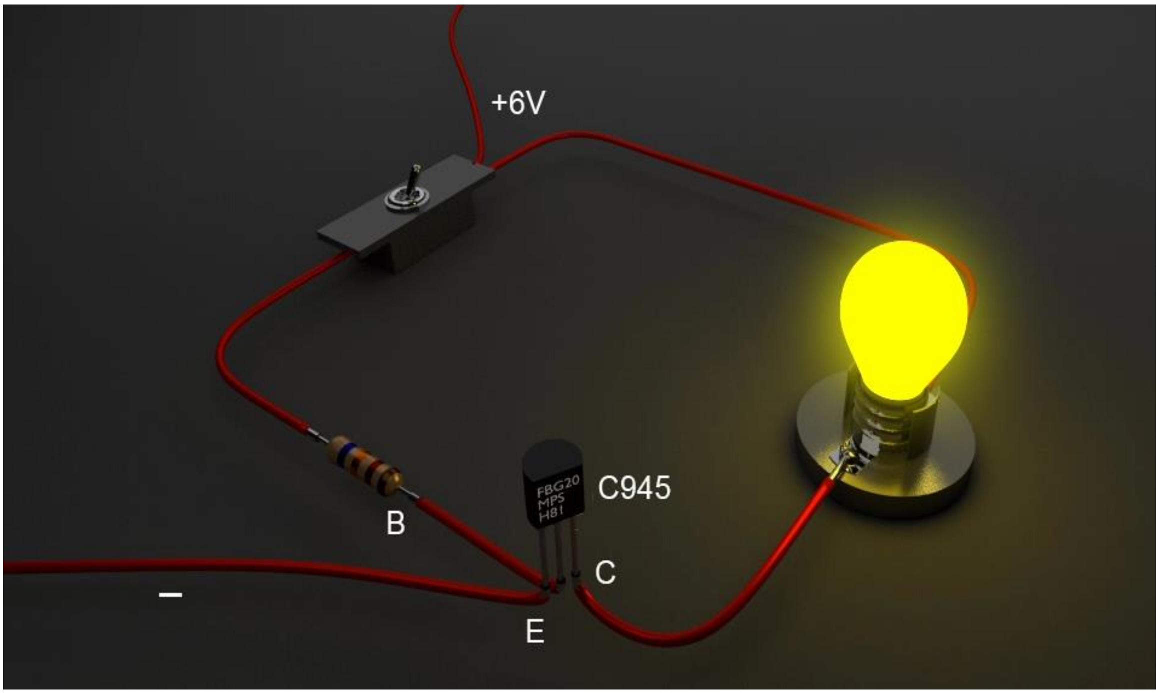
UNIT 02-04: BJT as Switch, DC Load Line

LEARNING OBJECTIVES

After successful completion of this unit, you will be able to

- ❖ Explain BJT switching operation.
- ❖ Describe a basic application of a BJT switching circuit.
- ❖ Analyze a BJT switching circuit for cutoff and saturation.
- ❖ Explain the purpose of DC bias in a BJT circuit.
- ❖ Discuss and determine the Q-point / DC operating point of a BJT circuit.
- ❖ Draw a DC load line for a given biased BJT circuit.
- ❖ Discuss the reasons for output waveform distortion.

INTRODUCTION



(Source: Google)

A transistor is like a miniature on-off switch that allows a computer to process information. A computer can't operate without an integrated circuit (chip), and a chip can't operate without a transistor. Transistors have shrunk in size with a factor of 222 since the first Intel 4004 chip was introduced in 1971. The first Intel computer chip had 2,300 transistors, while the latest one has 820 million.

04-01: BJT AS SWITCH

Fig 4.1.1 illustrates the basic operation of a BJT as a switching device. In part (a), the transistor is in the cut-off region because the Base-Emitter junction is not forward biased. In this condition, there is an open between Collector and Emitter, as indicated by the switch equivalent. In part (b), the transistor is in the saturation region because the Base-Emitter junction and the Base-Collector junction are forward biased and the Base current is made large enough to cause the Collector current to reach its saturation value. In this condition, there is a short between Collector and Emitter, as indicated by the switch equivalent. Actually, a small voltage drop across the transistor of up to a few tenths of a volt normally occurs, which is the saturation voltage, $V_{CE(sat)}$. The conditions in cut-off and saturation are given in Eq 3.3.7 to Eq 3.3.9.

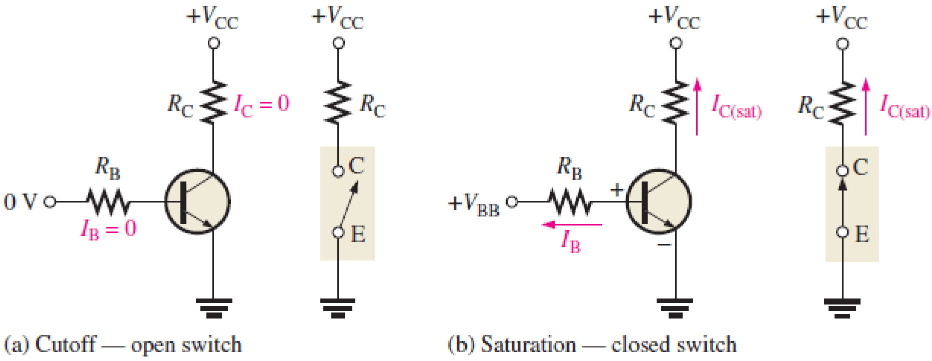


Fig 4.1.1: Switching action of a BJT

The transistor in Fig 4.1.2 is used as a switch to turn the LED on and off. A square wave input voltage with a period of 2 s is applied to the input as indicated. When the square wave is at 0 V, the transistor is in cutoff and since there is no collector current, the LED does not emit light. When the square wave goes to its high level, the transistor saturates. This forward-biases the LED, and the resulting collector current through the LED causes it to emit light. Thus, the LED is on for 1 second and off for 1 second.

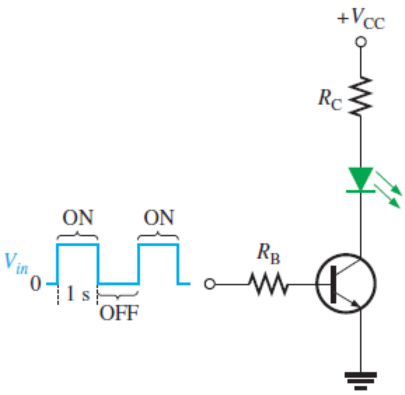


Fig 4.1.2: BJT used to switch a LED on and off

04-02: TROUBLESHOOTING A BIASED BJT

Several faults can occur in a simple transistor bias circuit. Possible faults are open bias resistors, open or resistive connections, shorted connections, and opens or shorts internal to the transistor itself.

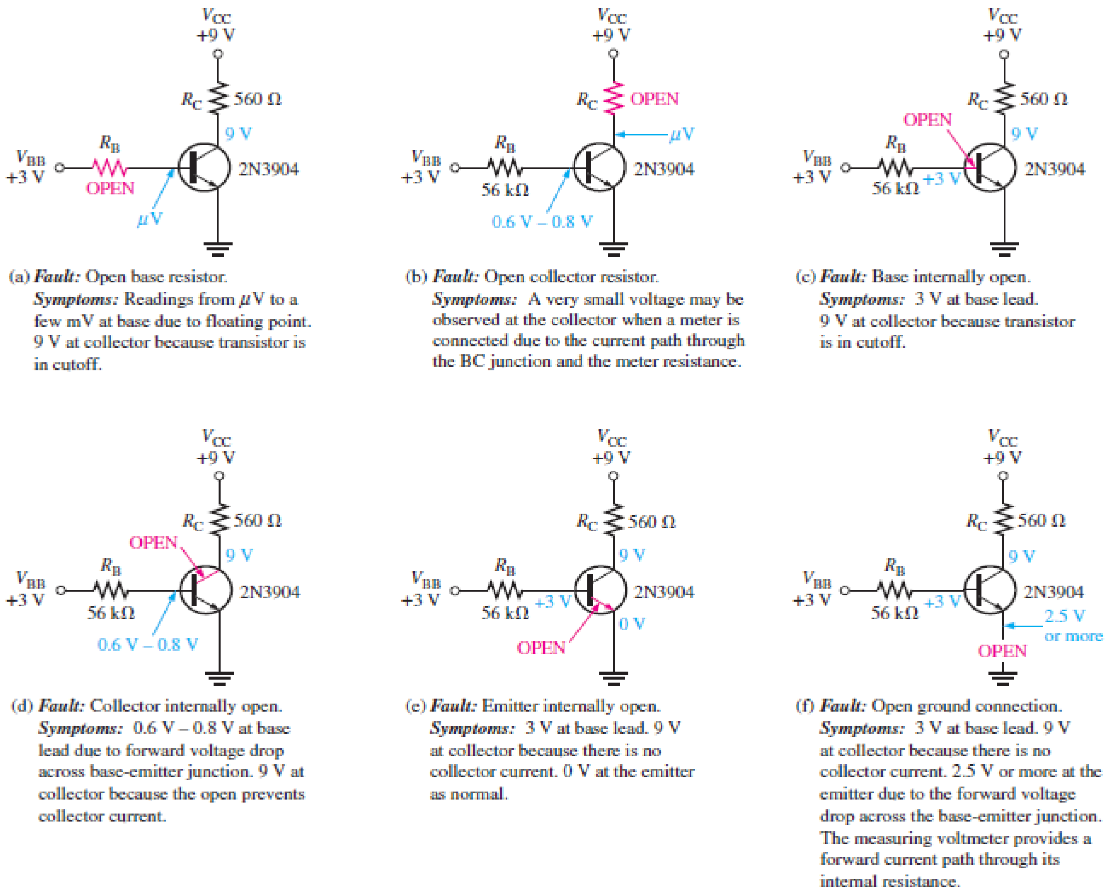
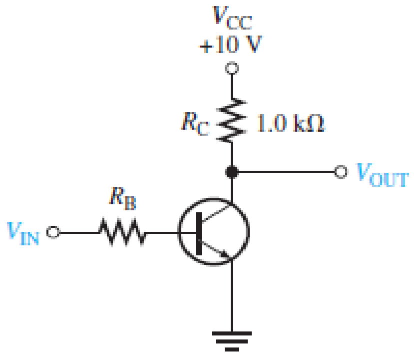


Fig 4.2.1 Examples of faults and symptoms in the basic BJT bias circuit

Different faults that can occur in the circuit and the accompanying symptoms are illustrated in Fig 4.2.1. Symptoms are shown in terms of measured voltages that are incorrect. If a transistor circuit is not operating correctly, it is a good idea to verify that V_{CC} and ground are connected and operating. A simple check at the top of the Collector resistor and at the Collector itself will quickly ascertain if V_{CC} is present and if the transistor is conducting normally or is in cutoff or saturation. If it is in cutoff, the Collector voltage will equal V_{CC}; if it is in saturation, the Collector voltage will be near zero. Another faulty measurement can be seen if there is an open in the Collector path. The term **floating point** refers to a point in the circuit that is not electrically connected to ground or a "solid" voltage. Normally, very small and sometimes fluctuating voltages in the mV to low mV range are generally measured at floating points. The faults in Fig 4.2.1 are typical but do not represent all possible faults that may occur.

5) For the transistor circuit shown below, what is V_{CE} when V_{IN} 0 V? What minimum value of I_B is required to saturate this transistor if β is 200? Neglect $V_{CE(sat)}$. Calculate the maximum value of R_B when V_{IN} = 5 V.



Solution:

When V_{IN} 0 V, the transistor is in cutoff (acts like an open switch) and

$$V_{CE} = V_{CC} = 10\ V$$

$$I_{C(sat)} = \frac{V_{CC} - V_{CE(sat)}}{R_C} = \frac{10 - 0}{1\ k} = 10\ mA$$

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta} = \frac{10\ m}{200} = 50\ \mu A$$

This is the value of I_B necessary to drive the transistor to saturation.

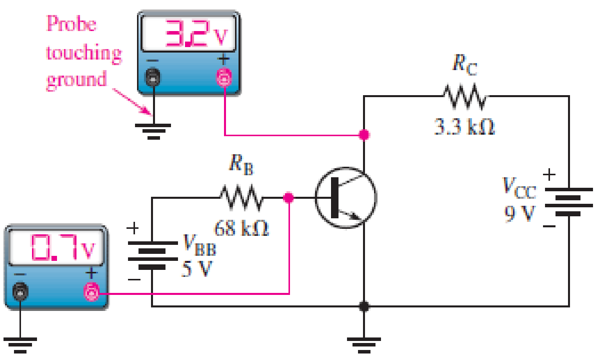
When the transistor is on, V_{BE} = 0.7 V and the voltage across R_B is

$$V_{R_B} = V_{IN} - V_{BE} = 5 - 0.7 = 4.3\ V$$

The maximum value of R_B needed to allow a minimum I_B of 50 μA is

$$R_{B(max)} = \frac{V_{R_B}}{I_{B(min)}} = \frac{4.3}{50\ \mu A} = 86\ k\Omega$$

6) What is the value of the β of transistor shown below?



Solution:

From the given circuit V_C = 3.2 V and V_B = 0.7 V

$$I_C = \frac{V_{CC} - V_C}{R_C} = \frac{9 - 3.2}{3.3\ k} = 1.76\ mA$$

$$I_B = \frac{V_{BB} - V_B}{R_B} = \frac{5 - 0.7}{68\ k} = 63.23\ \mu A$$

$$\beta = \frac{I_C}{I_B} = \frac{1.76\ m}{63.23\ \mu} = 27.83$$

SELF-TEST 01

17) To saturate a BJT _____.

a) $I_B = I_{C(sat)}$

b) $I_B > I_{C(sat)} / \beta$

c) V_{CC} must be at least 10 V

d) the Emitter must be open

18) Once in saturation, a further increase in the Base current will _____.

a) cause the Collector current to increase

b) cause the Collector current to decrease

c) not affect the Collector current

d) turn the transistor off

19) When operated in cutoff and saturation, the transistor acts like _____.

a) a linear amplifier

b) a variable capacitor

c) a variable resistor

d) a switch

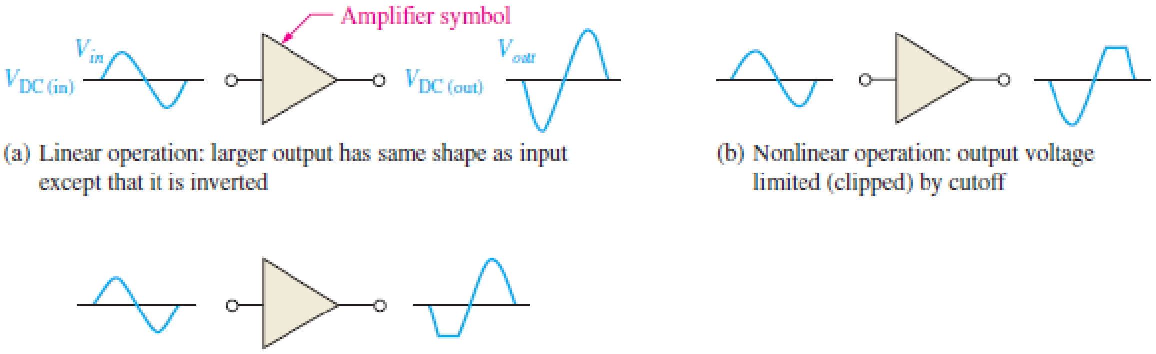
SHORT ANSWER QUESTIONS 01

16) How the BJT can be used as a switch?

17) A transistor has a β = 50, V_{CC} = 15V and R_C =1.2 kΩ. Determine the value of R_B required to ensure saturation when V_{IN} is 5 V. What must V_{IN} be to cut off the transistor? Assume $V_{CE(sat)}$ = 0 V.

04-03: DC LOAD LINE

DC bias establishes the **DC operating point (Q-point)** for proper linear operation of an amplifier. If an amplifier is not biased with correct DC voltages on the input and output, it can go into saturation or cutoff when an input signal is applied. Fig 4.3.1 shows the effects of proper and improper DC biasing of an inverting amplifier. In part (a), the output signal is an amplified replica of the input signal except that it is inverted, which means that it is 180^{O} out of phase with the input. The output signal swings equally above and below the DC bias level of the output, $V_{DC(out)}$. Improper biasing can cause distortion in the output signal, as illustrated in parts (b) and (c). Part (b) illustrates limiting of the positive portion of the output voltage as a result of a Q-point (DC operating point) being too close to cutoff. Part (c) shows limiting of the negative portion of the output voltage as a result of a dc operating point being too close to saturation.



(a) Linear operation: larger output has same shape as input except that it is inverted

(b) Nonlinear operation: output voltage limited (clipped) by cutoff

(c) Nonlinear operation: output voltage limited (clipped) by saturation

Fig 4.3.1: Examples of linear and nonlinear operation of an inverting amplifier

The DC operation of a transistor circuit can be described graphically using a **DC load line**. DC load line is drawn on the output characteristics of CE configuration of the transistor. It is the locus of Q-points. It is a straight line drawn on the Collector characteristic curves from the saturation value where $I_C = I_{C(sat)}$ on the y-axis to the cutoff value where $V_{CE} = V_{CE(cut\text{-}off)}$ on the x-axis as shown in Fig 4.3.2.

From Fig 3.3.1, the equation for I_C is

$$I_C = \frac{V_{CC} - V_{CE}}{R_C}$$

$$I_C = \frac{V_{CC}}{R_C} - \frac{V_{CE}}{R_C}$$

$$I_C = \left(-\frac{1}{R_C}\right)V_{CE} + \frac{V_{CC}}{R_C} \qquad .....(4.3.1)$$

This is the equation of a straight line with a slope of $-1/R_C$, an x intercept of $V_{CE(cut\text{-}off)} = V_{CC}$ and a y intercept of $I_{C(sat)} = V_{CC}/R_C$.

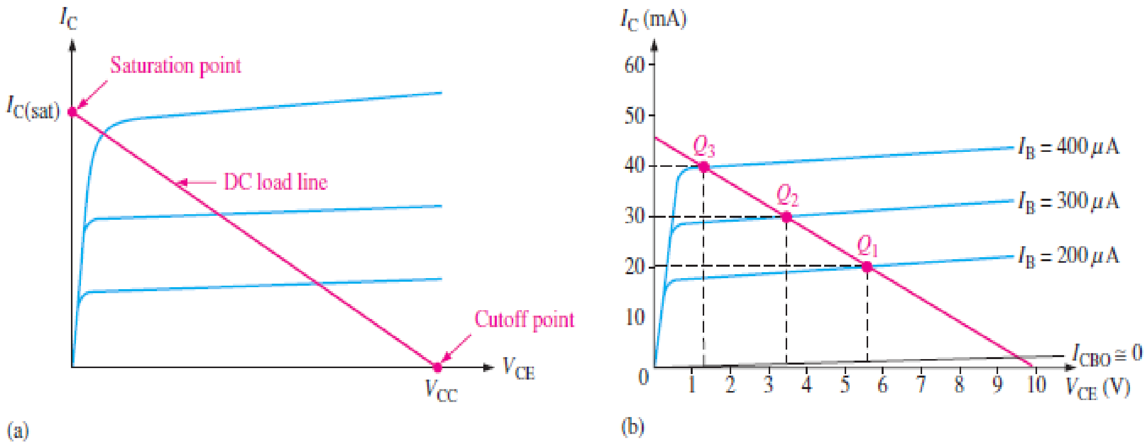


Fig 4.3.2: DC load line

The point at which the load line intersects a characteristic curve represents the Q-point for that particular value of I_B. Fig 4.3.2 (b) illustrates the Q-point on the DC load line for different values of I_B. The coordinates of Q-point are (V_{CEQ}, I_{CQ}).

The region along the load line including all points below saturation and above cutoff is generally known as the **linear region** of the transistor's operation. As long as the transistor is operated in this region, the output voltage is ideally a linear reproduction of the input. Fig 4.3.3 shows an example of the linear operation of a transistor. AC quantities are indicated by lowercase italic subscripts. Point A on the DC load line in Fig 4.3.3 corresponds to the positive peak of the sinusoidal input voltage. Point B corresponds to the negative peak and point Q corresponds to the zero value of the sine wave, as indicated. V_{CEQ}, I_{CQ}, and I_{BQ} are DC Q-point values with no input sinusoidal voltage applied.

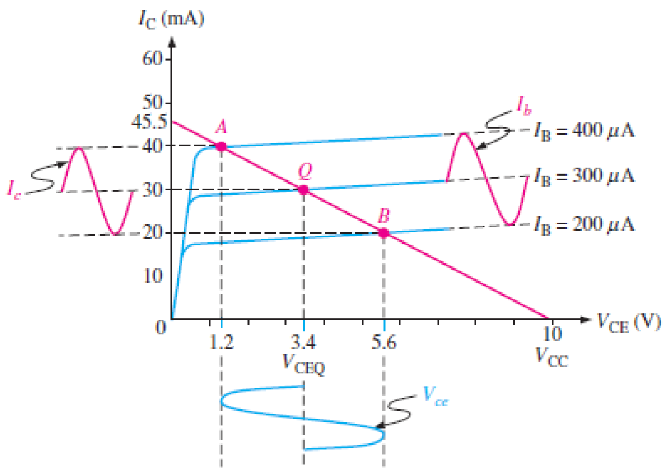
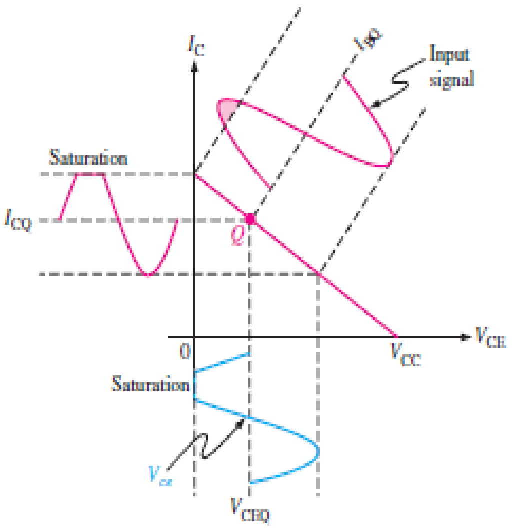
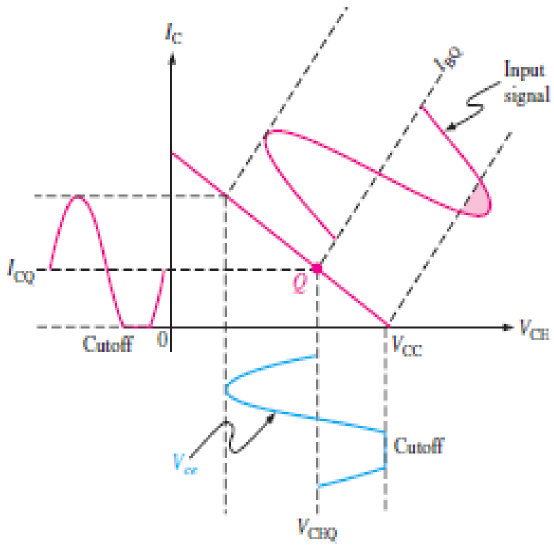


Fig 4.3.3: Graphical load line illustration of a transistor being driven linear region

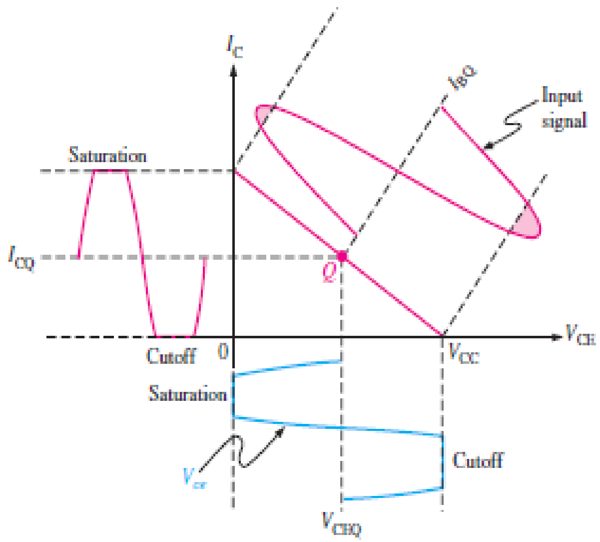
As previously mentioned, under certain input signal conditions the location of the Q-point on the load line can cause one peak of the V_{ce} waveform to be limited or clipped, as shown in parts (a) and (b) of Fig 4.3.4. In each case the input signal is too large for the Q-point location and is driving the transistor into cutoff or saturation during a portion of the input cycle. When both peaks are limited as in Fig 4.3.4 (c), the transistor is being driven into both saturation and cutoff by an excessively large input signal. When only the positive peak is limited, the transistor is being driven into cutoff but not saturation. When only the negative peak is limited, the transistor is being driven into saturation but not cutoff.



(a) Transistor is driven into saturation because the Q-point is too close to saturation for the given input signal.



(b) Transistor is driven into cutoff because the Q-point is too close to cutoff for the given input signal.

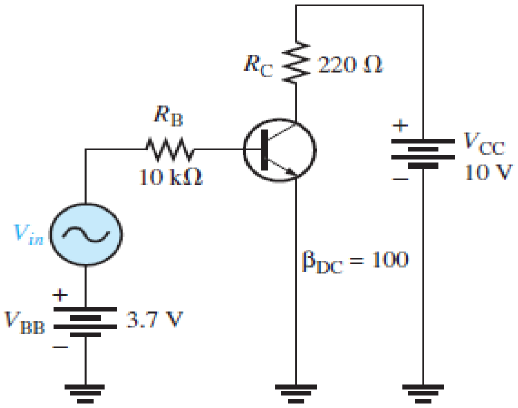


(c) Transistor is driven into both saturation and cutoff because the input signal is too large.

Fig 4.3.4: Graphical load line illustration of a transistor being driven into saturation and / or cutoff

Solved Problems 02

7) Find the DC Q-point values for the transistor shown below.



Solution:

$$I_{BQ} = \frac{V_{BB} - V_{BE}}{R_B} = \frac{3.7 - 0.7}{10k} = 300\ \mu A$$

$$I_{CQ} = \beta I_{BQ} = 100 \times 300\mu = 30\ mA$$

$$V_{CEQ} = V_{CC} - I_{CQ}R_C = 10 - (300\ m \times 220) = 3.4\ V$$

Self-Test 02

20) The coordinates of Q-point are ____.

a) (I_{CQ}, V_{CEQ})

b) (V_{CEQ}, I_{CQ})

c) (V_{CEQ}, I_{BQ})

d) (I_{CQ}, I_{BQ})

21) Ideally, a dc load line is a straight line drawn on the collector characteristic curves between _____.

a) the Q-point and cutoff

b) the Q-point and saturation

c) $V_{CE(cutoff)}$ and $I_{C(sat)}$

d) $I_B = 0$ and $I_B = I_C/\beta$

Short Answer Questions 02

18) Explain the effect of location of Q-point on DC load line on the output of transistor.

19) Determine the Q-point for a biased transistor for which $I_B = 150\ \mu A$, $\beta = 75$, $V_{CC} = 18$ V and $R_C = 1$ kΩ.

Summary

- A transistor can be operated as an electronic switch in cutoff and saturation.
- In cutoff, both PN junctions are reverse-biased and there is essentially no collector current. The transistor ideally behaves like an open switch between collector and emitter.
- In saturation, both PN junctions are forward-biased and the collector current is maximum. The transistor ideally behaves like a closed switch between collector and emitter.
- The purpose of biasing a circuit is to establish a proper stable DC operating point (Q-point).
- The Q-point of a circuit is defined by specific values for V_{CE} and I_C. These values are called the coordinates of the Q-point.
- A DC load line passes through the Q-point on a transistor's collector curves intersecting the vertical axis at approximately $I_{C(sat)}$ and the horizontal axis at $V_{CE(off)}$.
- The linear (active) operating region of a transistor lies along the load line below saturation and above cutoff.

Key Words

Switch, Cut-off, Saturation, DC Load Line, Q-point, Linear Region

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- https://en.wikipedia.org/wiki/Load_line_(electronics)#Load_lines_for_common_configurations

OER

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Course Companion Website

Visit Here for Course Companion website for this course:

https://www.circuitbread.com/tutorials/how-to-use-a-bipolar-junction-transistor-bjt-as-a-switch

UNIT 02-05: VOLTAGE DIVIDER BIAS CIRCUIT, SINGLE STAGE CE AMPLIFIER

LEARNING OBJECTIVES

After successful completion of this unit, you will be able to

-

INTRODUCTION

A transistor is like a miniature on-off switch that allows a computer to process information. A computer can't operate without an integrated circuit (chip), and a chip can't operate without a transistor. Transistors have shrunk in size with a factor of 222 since the first Intel 4004 chip was introduced in 1971. The first Intel computer chip had 2,300 transistors, while the latest one has 820 million.

05-01: VOLTAGE DIVIDER BIAS CIRCUIT

The purpose of biasing a circuit is to establish a proper stable DC operating point (Q-point). Up to this point a separate DC source, V_{BB} was used to bias the Base-Emitter junction because it could be varied independently of V_{CC} and it helped to illustrate transistor operation. But in practice different biasing methods are used like Emitter-bias, Base-bias, Emitter-feedback bias, Collector-feedback bias, Voltage divider bias, etc. As the voltage divider bias method has some advantages over other methods, it is explained here.

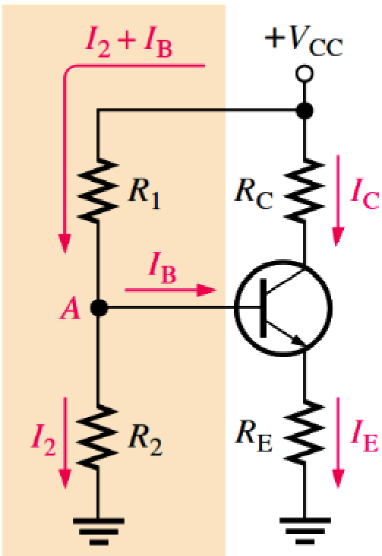


Fig 5.1.1: Voltage divider bias

Voltage divider bias is a method of biasing a transistor for linear operation using a single source resistive voltage divider. It has the single bias source V_{CC} as shown in Fig 5.1.1. To simplify the schematic, the battery symbol is omitted and replaced by a line termination circle with a voltage indicator (V_{CC}) as shown. A DC bias voltage at the Base of the transistor can be developed by a resistive voltage divider that consists of R_1 and R_2, as shown in Fig 5.1.1. V_{CC} is the DC Collector supply voltage. Two current paths are between point A and ground - one through R_2 and the other through the Base-Emitter junction of the transistor and R_E. Generally, voltage-divider bias circuits are designed so that the Base current is much smaller than the current (I_2) through R_2 in Fig 5.1.1. In this case, the voltage divider circuit is very straightforward to analyze because the loading effect of the Base current can be ignored. A voltage divider in which the Base current is small compared to the current in R_2 is said to be a **stiff voltage divider** because the Base voltage is relatively independent of different transistors and temperature effects.

To analyze a voltage divider circuit in which I_B is small compared to I_2, first calculate the voltage on the Base using the unloaded voltage divider rule.

$$V_B \cong \left(\frac{R_2}{R_1+R_2}\right) V_{CC} \qquad \text{..... (5.1.1)}$$

Once you know the Base voltage, you can find the voltages and currents in the circuit, as follows:

$$V_E = V_B - V_{BE} \qquad \text{..... (5.1.2)}$$

and

$$I_C \cong I_E = \frac{V_E}{R_E} \qquad \text{..... (5.1.3)}$$

then

$$V_C = V_{CC} - I_C R_C \qquad \text{..... (5.1.4)}$$

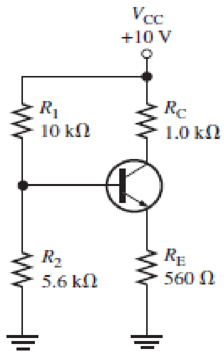
and

$$V_{CE} = V_C - V_E \qquad \text{..... (5.1.5)}$$

Voltage divider bias provides good Q-point stability with a single-polarity supply voltage. It is the most common bias circuit.

SOLVED PROBLEMS 01

8) Determine V_{CE} and I_C in the stiff voltage divider biased transistor circuit shown below if β = 100.



Solution:

$$V_B \cong \left(\frac{R_2}{R_1 + R_2}\right) V_{CC} = \left(\frac{5.6\ k}{10\ k + 5.6\ k}\right) 10 = 3.59\ V$$

$$V_E = V_B - V_{BE} = 3.59 - 0.7 = 2.89\ V$$

$$I_C \cong I_E = \frac{V_E}{R_E} = \frac{2.89}{560} = 5.16\ mA$$

$$V_C = V_{CC} - I_C R_C = 10 - (5.16\ m \times 1\ k) = 4.84\ V$$

$$V_{CE} = V_C - V_E = 4.84 - 2.89 = 1.95\ V$$

SELF-TEST 01

22) Voltage-divider bias _____.

a) cannot be independent of β

b) can be essentially independent of β

c) is not widely used

d) requires fewer components than all the other methods

23) In a certain voltage-divider biased npn transistor, V_B is 2.95 V. The DC Emitter voltage is approximately _____.

a) 2.25 V

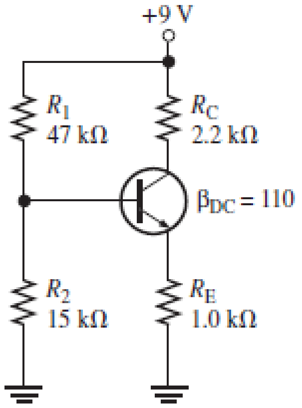
b) 2.95 V

c) 3.65 V

d) 0.7 V

Short Answer Questions 01

20) Determine all transistor terminal voltages with respect to ground shown below.



05-02: Single stage CE amplifier

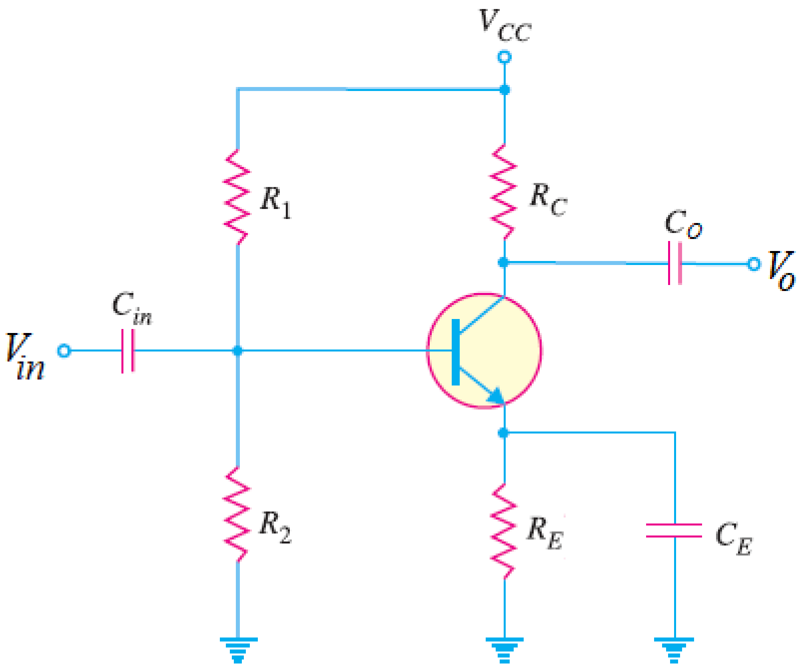


Fig 5.2.1: Single stage CE amplifier

The circuit of single stage CE amplifier is shown in Fig. 5.2.1. The DC operating point (Q-point) is set in linear (active) region using voltage divider bias circuit which has resistors R_1, R_2, R_C and R_E along with single power supply V_{CC}. The input AC signal is applied to Base terminal through input coupling capacitor C_{in} while the output is taken at Collector terminal through output coupling capacitor C_O. The Emitter bypass capacitor, C_E, bypasses the R_E for AC signal.

ANSWERS TO SELF-TESTS AND END OF UNIT EXERCISES

Question No.	Answer	Question No.	Answer
1)	d	2)	a
3)	c	4)	d
5)	b	6)	d
7)	d	8)	c
9)	b	10)	c
11)	a	12)	b
13)	b	14)	c
15)	a	16)	c
17)	b	18)	c
19)	d	20)	b
21)	c	22)	b
23)	a	24)	
25)		26)	
27)		28)	
29)		30)	
31)		32)	
33)		34)	
35)		36)	
37)		38)	
39)		40)	