Transistor

- A simple diodes are made up from two pieces of semiconductor material, either silicon or germanium to form a simple PN-junction.
- If we now join together two individual signal diodes back-to-back, this will give us two PN-junctions connected together in series that share a common P or N terminal. The fusion of these two diodes produces a three layers, two junction, three terminal device forming the basis of a **Bipolar Transistor**, or **BJT** for short.
- Transistors are three terminal active devices made from different semiconductor materials that can act as either an insulator or a conductor by the application of a small signal voltage. The transistor's ability to change between these two states enables it to have two basic functions: "switching" (digital electronics) or "amplification" (analogue electronics). Then bipolar transistors have the ability to operate within three different regions:

1. Active Region - the transistor operates as an amplifier and $I_c = \beta . I_b$

2. Saturation - the transistor is "fully-ON" operating as a switch and $I_c = I(saturation)$

3. Cut-off - the transistor is "fully-OFF" operating as a switch and $I_c = 0$

Figure (1)
Typical bipolar transistor

- There are two basic types of bipolar transistor construction, NPN and PNP, which basically describes the physical arrangement of the P-type and N-type semiconductor materials from which they are made.
- The **Bipolar Transistor** basic construction consists of two PN-junctions producing three connecting terminals with each terminal being given a name to identify it from the other two. These three terminals are known and labelled as the Emitter (E), the Base (B) and the Collector (C) respectively.
- Bipolar Transistors are current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing voltage applied to their base terminal acting like a current-controlled switch. The principle of operation of the two transistor types NPN and PNP, is exactly the same the only difference being in their biasing and the polarity of the power supply for each type.

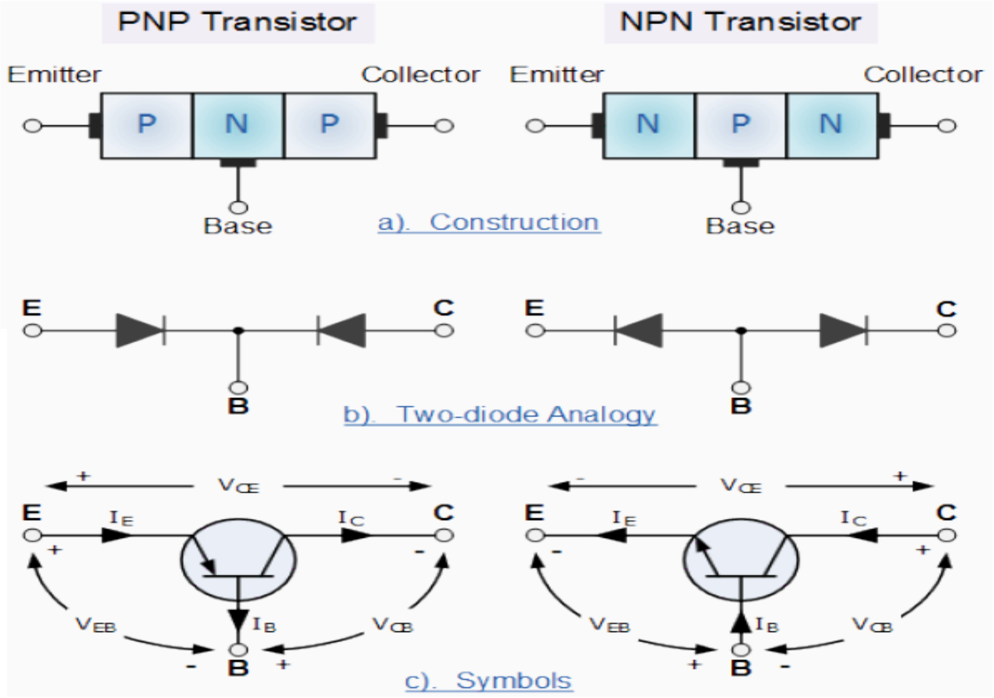
PNP Transistor
NPN Transistor
Emitter
Collector
Emitter
Collector
P
N
P
N
P
N
Base
a). Construction
Base
E
C
E
C
B
b). Two-diode Analogy
B
VCE
E
IE
IC
C
VEB
IB
VCB
B
VCE
E
IE
IC
C
VEB
IB
VCB
B
c). Symbols

Figure (2)

- The construction and circuit symbols for both the NPN and PNP bipolar transistor are given above with the arrow in the circuit symbol always showing the direction of "conventional current flow" between the base terminal and its emitter terminal. The direction of the arrow always points from the positive P-type region to the negative N-type region for both transistor types, exactly the same as for the standard diode symbol.

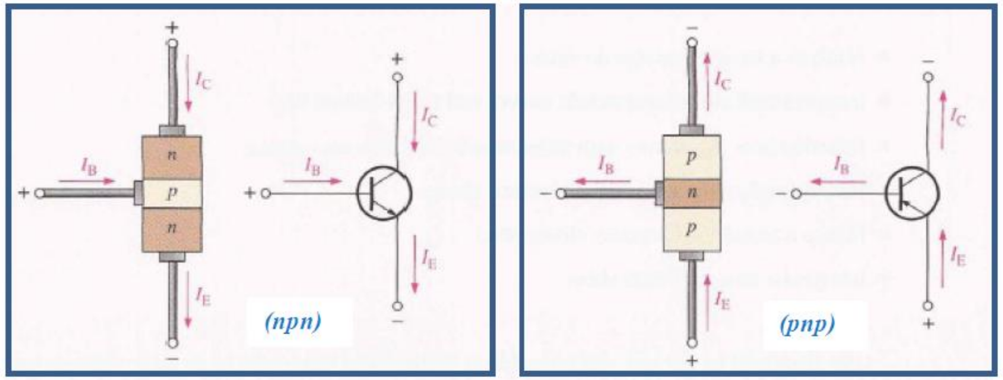

Figure (3)

Transistor Configuration

A-Common base configuration

As its name suggests, in the **Common Base** or grounded base configuration, the BASE connection is common to both the input signal AND the output signal with the input signal being applied between the base and the emitter terminals. The corresponding output signal is taken from between the base and the collector terminals as shown with the base terminal grounded or connected to a fixed reference voltage point. The input current flowing into the emitter is quite large as its the sum of both the base current and collector current respectively therefore, the collector current output is less than the emitter current input resulting in a current gain for this type of circuit of "1" (unity) or less, in other words the common base configuration "attenuates" the input signal.

- Then we can see from the basic common base configuration that the input variables relate to the emitter current I_E and the base-emitter voltage, V_{EB}, while the output variables relate to the collector current I_C and the collector-base voltage, V_{CB}.
- Since the emitter current, I_E is also the input current, any changes to the input current will create a corresponding change in the collector current, I_C. For a common base amplifier configuration, current gain, A_i is given as i_{OUT}/i_{IN} which itself is determined by the formula I_C/I_E. The current gain for a CB configuration is called Alpha, (α).

- In a BJT amplifier the emitter current is always greater than the collector current as $I_E = I_B + I_C$, the current gain (α) of the amplifier must therefore be less than one (unity) as I_C is always less than I_E by the value of I_B. Thus the CB amplifier attenuates the current, with typical values of alpha ranging from between 0.980 to 0.995.
- The electrical relationship between the three transistor currents can be shown to give the expressions for alpha, α and Beta, β as shown.

- Emitter base junction is forward bias condition because the positive voltage supply V_{EB} is connected to p-type material at emitter (E) while base is connected to (B) is connected to negative source V_{BE}. P type contains holes as majority carrier and electrons as minority carrier as shown in figure(5).
- Current from power supply V_{EB}, wilI flow into emitter. The p region nearby the emitter during this forward bias will cause majority carrier (holes)to flow to the base. Therefore, electrons at .N-type material at base will flow to emitter filling up the empty area, left by the holes. This current flow will produce base current, I_B. Remember that the directions of current and electrons are opposite to each other.

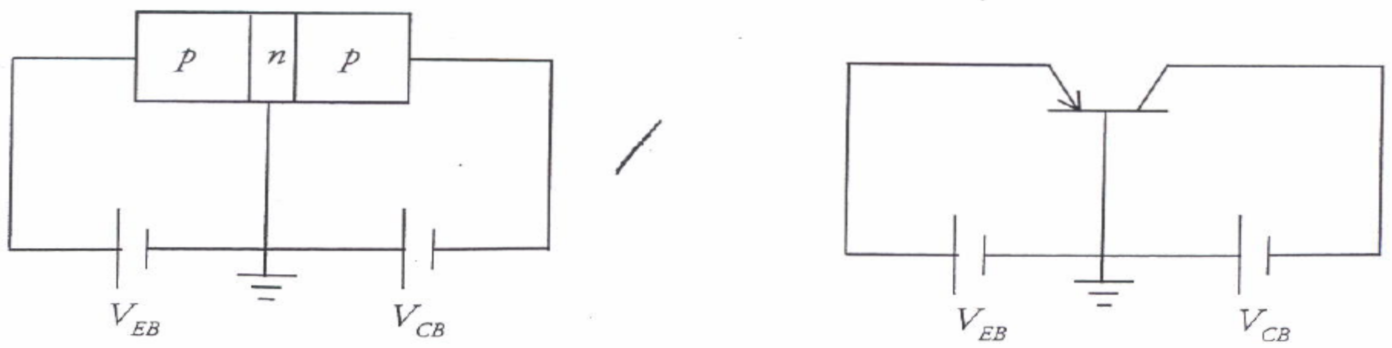

Figure (4) Connection of common base

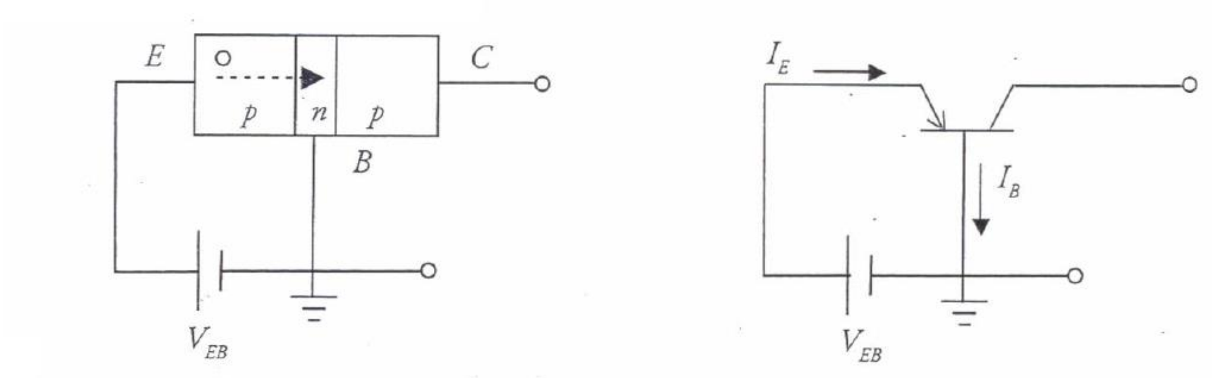

Figure (5) Holes and current flow direction at emitter-base junction is called emitter current

- Figure (6) shows a collector-base junction in reverse bias condition because the negative terminal V_{CB} is connected to P-type material at collector while base is connected to the positive source. This causes the minority carrier at N type material in the base which is holes flow to P-type material at the collector; or electrons flow from the collector to base. Current that produced from this flow is called leakage current I_{CBO}that produced which is collector-base (CB) current when the emitter is opened.
- Referring to Figure (7) the majority current carrier which is holes will diffuse from P-type material at the emitter through N-type. Material at the base and then to the collector. Most of these holes will flow to P-type material region .at the collector because of V_{CB} attraction. Therefore, most of current from the emitter will flow to the collector, producing collector current I_C Only small part of these holes will get trapped in N-type material region that produced base current I_B, Leakage current (I_{CBO})that produced by reversed biased of collector- base junction also flows to collector.

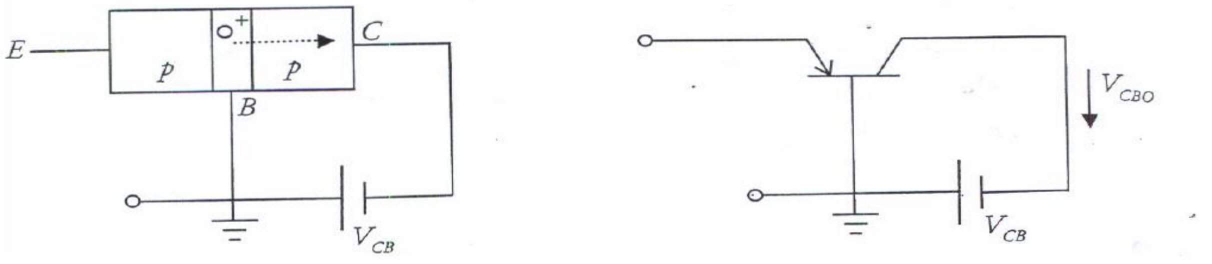

Figure (6) N type material minority charge carrier produce I_{CBO} at collector-base junction that reverse biased

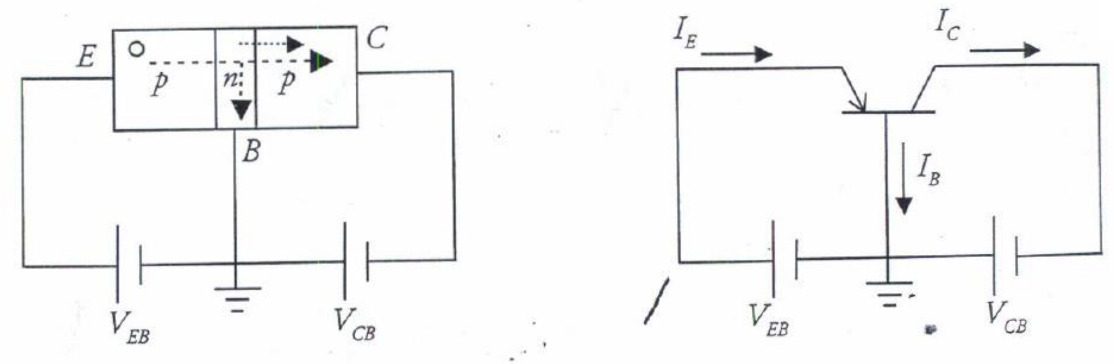

Figure (7) PNP transistor and current flow direction

- Base current I_B, is smaller if compared to collector current , Base current is normally in MA range while emitter current I_E and collector current I_c usually in mA. The relationship of these currents can be shown using Kirchhoffs current law :-
- $I_E = I_C + I_B$
- Actually, a collector current consists of two parts. First, result from majority current that is most of current that flows from an emitter. Second is from minority carrier which is leakage current I_{CBO}.Majority current which is most of current from an emitter that can reach a-collector is known as $\alpha_{DC} i_E$ or αI_E The value is higher than leakage current. The leakage current can be ignored because its value is within 10^{-6} A range.
- $I_c = I_{c\ (majority)} + I_{c\ (minority)}$
- $I_c = \alpha I_E + I_{CBO}$
- $I_C = \alpha I_E$

If I_{CBO} is ignored (its very small), hence:-

$$\alpha = \frac{I_C}{I_E}$$

where α is common base current gain factor. It shows the transistor competency by calculating the current percentage from an emitter that can reach a collector. This equation also can be used for other transistor configurations. Typical value for a is 0.900 - 0.998.

Common base NPN

In general, the operation of an NPN transistor is same as operation of PNP transistor. For a transistor to operate correctly, an emitter-base junction should be forward biased while a collector-base junction has to be reverse bias. Figure (9) that shows a NPN transistor that connected to common base transistor. N type materials contains electrons as a majority carrier and it’s minority carrier is a holes.

Common base configuration NPN

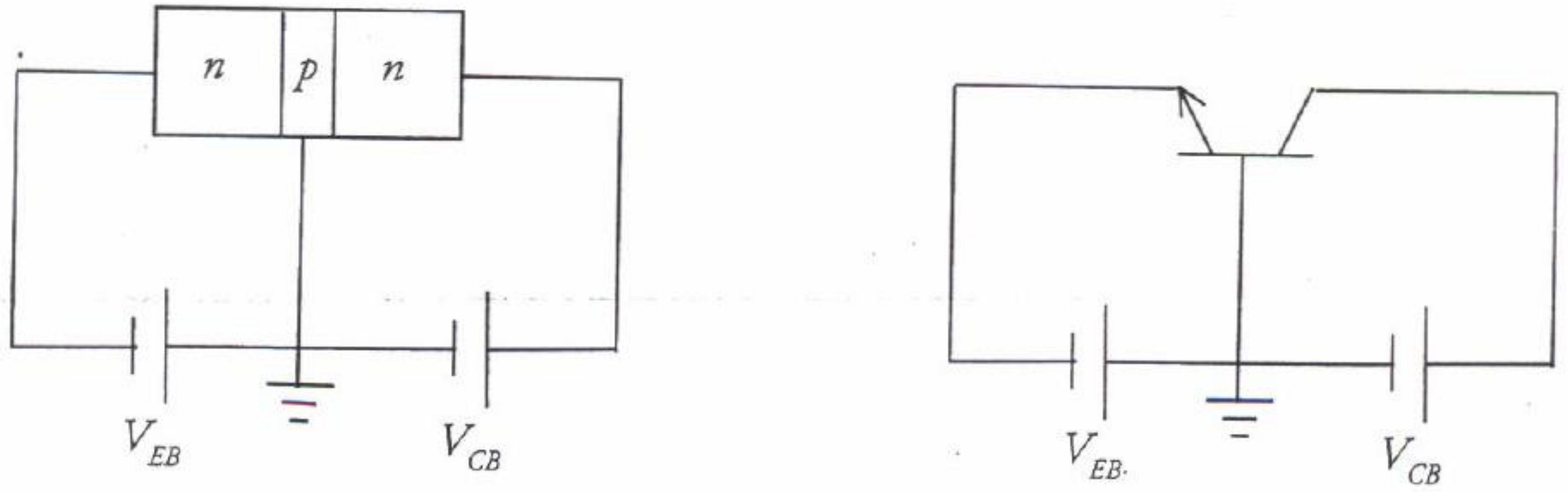

Figure (9) Connection of common base

- Based on Figure (10) the collector-base junction is in reverse bias condition because the positive source supply V_{EB} is connected to an N-type material collector . Therefore, there is no current produced from its majority carrier. Only the minority current carrier produces current which is known as leakage current I_{CBO}.
- In figure (11) the emitter-base junction is in a forward bias condition because its negative source V_{EB} is connected to N-material at the emitter. Hence electron injected will flow into the emitter through NP junction and enter the base region.

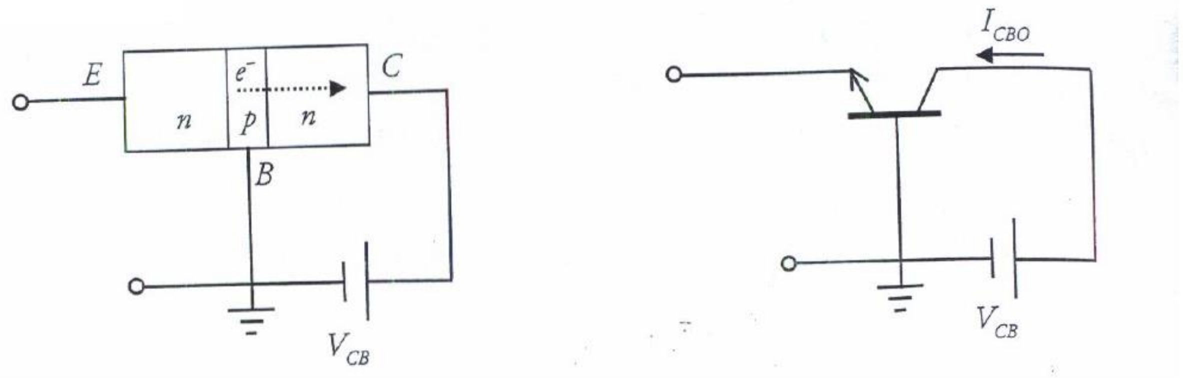

Figure (10) Electron flow produce leakage current at reverse bias of collector-base junction

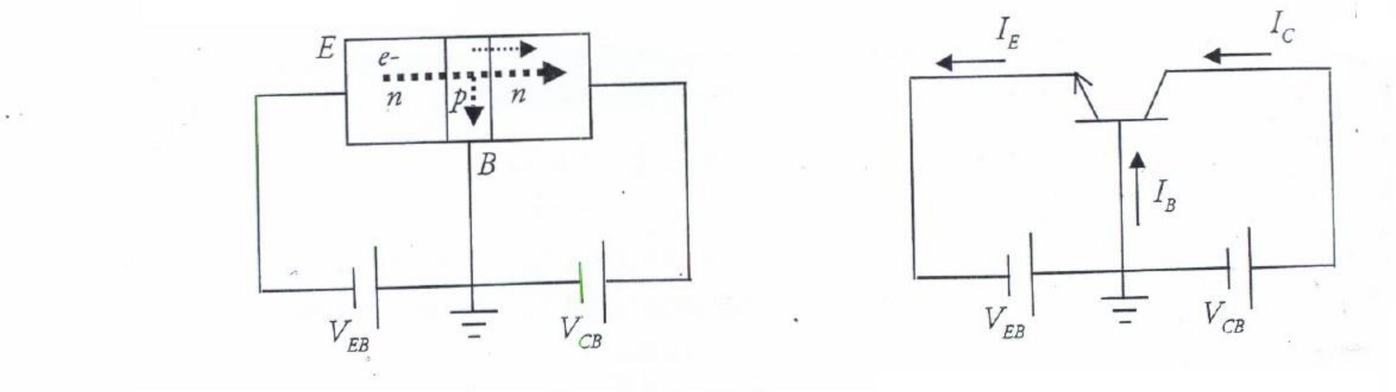

Figure (11) Direction of current and electrons flow through NPN transistor (CB) configuration.

- Base is a P-material , hence the majority carrier is holes. Since the base is dopped lesser than an emitter, thus only a few electrons from the emitter will combine with holes at the base to produce base current I_B, Due to the bias at the collector, V_{CB} , most of the emitter current I_E, will become collector current I_c, where most of electrons from the emitter are collected by C. This is due to the V_{CB} attraction and only small part exists through the base to produce I_B, collector current I_c, same as PNP transistor , consists of two parts:(1) minority current I_{CBO}, and (2) majority current(current that produced from electrons flow from emitter to the collector, αI_E). The equations obtained from a PNP is discussed in previous section. The operations are still the same and can be used for a NPN transistor.