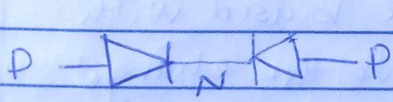
INTRODUCTION TO BIPOLAR JUNCTION TRANSISTORS. (BJTs)

A transistor is a solid state electronic device ~~where~~ that can use a small amount of current to drive a larger current to power LEDs or to amplify a-c signals. There are two types of transistors: PNP and NPN transistors.

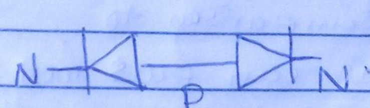
A PNP transistor is formed when a layer of N materials is sandwitched between two layers of 'P' materials while NPN transistor is formed when a layer of 'P' material is sandwitched between two layers of N material. These transistors are known as bipolar junction transistors (BJTs).

BJTs have two junctions; the emitter and collector of a PNP transistor are made up of a 'P' type material while the base is made up of an 'N' type Semi-conductor. On the other hand, in NPN transistors, the emitter and collector are made up of an 'N' type Semi-conductor while the base is made up of a 'P' type material.

PNP transistor is centrally two diodes connected to each other in the way shown below



Also, NPN transistor is centrally two diodes connected to each other as shown below



Symbolically, NPN and PNP are differentiated from each other by the direction of the arrow of the emitter.

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In PNP, the arrow points towards the base while in NPN, it points out of the base.

TRANSISTOR TERMINALS

It has been mentioned that transistor is a single crystal in which there are two P-N junctions. The reason is to have one section supply the charges (either electrons or holes) which will be collected by the third section through the middle section. The section supplying the charges is the emitter while the section collecting the charges is the collector and the section in between the emitter and the collector is called the base.

1 EMITTER: this is the section of the transistor whose main function is to supply majority charge carriers (electron in the case of NPN and holes in case of PNP) to the base. Emitter is always forward biased with respect to the base so that it can supply the majority charge carriers to the base. The emitter is heavily doped so that it can inject a large number of charge carriers

2. Collector: this is the right hand section of the transistor. It's main function is to collect majority carriers. Collector is always reverse biased with respect to base so it can remove the charge carriers away from it's junction with base. It is moderately doped.

3. BASE: this is the middle section of the transistor, it is very thin and lightly doped in comparison to either emitter or collector so that it can pass most of the injected charge carriers to the collector. Base forms two junctions ie emitter junction and the collector junction, each having it's own barrier voltage.

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The forward biased emitter base junction offers low resistance to the emitter current where as the collector base junction ~~offer~~ which is reverse biase offers high resistance to the collector current. As the resistance of the emitter-base junction is small as compared to that of the collector-base junction, the forward biase applied to the emitter-base ~~is small~~ junction is small where as the reverse biase on the collector base junction is large. As regards to the symbol, arrow-head is always on the emitter. The direction indicates the conventional direction of current flow. (from emitter to base in case of PNP and from base to emitter in case of NPN)

TRANSISTOR BIASING

For a transistor to work properly, it is essential to apply voltages of correct polarity across its two junctions.

To biase a transistor properly, we should put the following points into consideration

1) The emitter-base junction is alway forward biased.
2) The collector-base junction is always reverse-biased

See the diagram below.

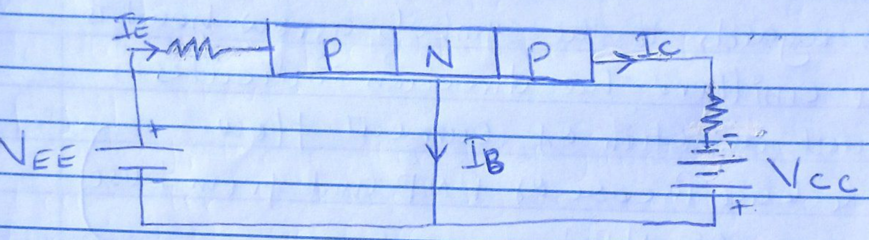

fig 3- Biasing of PNP transistor

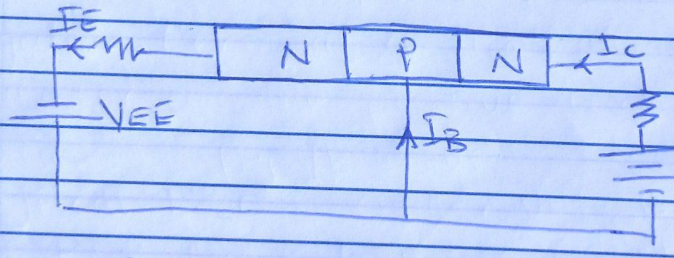

fig 4 Biasing of NPN transistor

Now, to make these diagrams again and again, we symbolize it. Below is the symbol

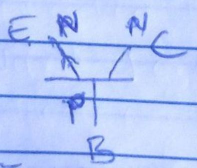

fig 5

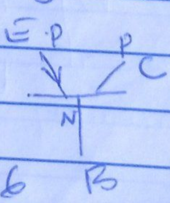

fig 6

We can identify whether PNP or NPN through the arrow on the emitter Terminal. The arrow shows the flow of electric current and we all know that current flows from positive to negative.

If we connect fig 5 and fig 6 to [illegible] we will obtain the figure shown below.

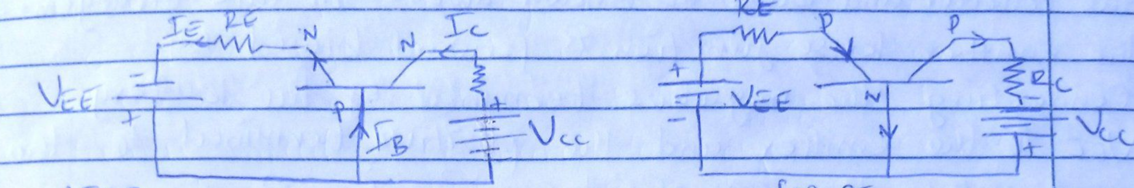

fig 7 fig 8

From the figures above, two batteries respectively provide the d.c emitter supply voltage V_{EE} and collector supply voltage V_{CC} for the proper biasing of the two junctions of the transistor. In fig 5 and fig 8, positive terminal of the V_{EE} is connected to P type emitter in order to repel or push holes into the base. The negative terminal of the V_{CC} is connected to the P-type collector so that it will attract or pull holes through the base. In NPN transistors, similar considerations are applied as shown in fig 6 and fig 7. We should note that transistors will never conduct any current if it's emitter base junction is not forward biased.

DIFFERET TRANSISTOR OPERATING CONDITIONS

As we have mentioned before, a transistor has two junctions (emitter-base and collector-base junctions) and each of these junctions may be forward or reverse biased. For these reason, there are four possible ways of biasing these junctions:

1) Forward-Reverse biasing: As already mentioned, for normal operation of transistors, emitter base-junction is always forward-biased and the collector-base junction is always reverse-biased. This type of biasing is called forward-reverse biasing (FR biasing)

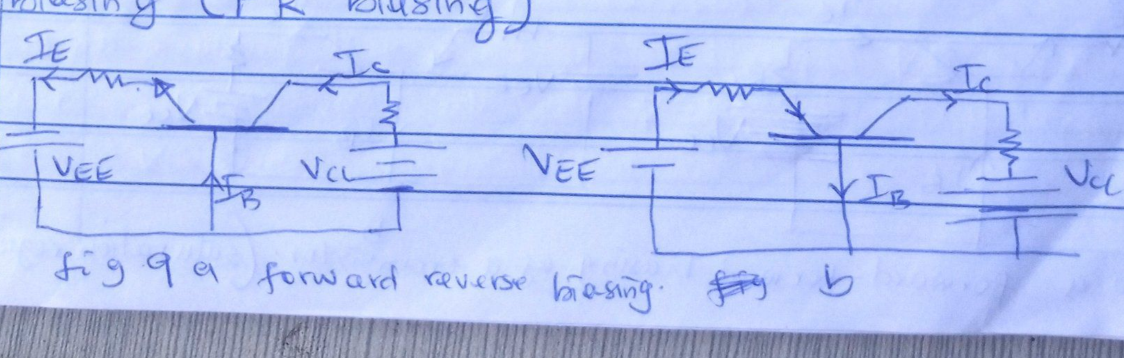

fig 9 a forward reverse biasing. b

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For this reason, a battery V_{EE} is connected between emitter and base while battery V_{CC} is connected between the collector and base as shown above. In this arrangement, the emitter-base junction is forward biased by connecting the negative terminal of the battery V_{EE} to the emitter and the positive terminal to the base while the collector base junction is reverse biased by connecting the positive terminal of the battery to the collector and the negative terminal to the base for NPN transistor as shown in fig 9a above.

Similarly, the emitter-base junction of a PNP transistor is biased by connecting the positive (V_{EE}) terminal of the battery to the emitter and the negative terminal to the base, while the collector-base junction is reverse biased by connecting the negative terminal of the battery (V_{CC}) to the collector and the positive terminal to the base as shown in fig 9b above.

Typical base to emitter voltage for both NPN and PNP transistors are 0.7V for Si and 0.3V for Ge.

In FR biasing, the transistor is said to be in active or linear region and the collector current (I_C) depend upon the emitter current (I_E). Generally, transistors are operated in this region for amplification.

2) **Forward-Forward biasing:** In this method of biasing, both collector and emitter are forward biased as shown in fig 10 below

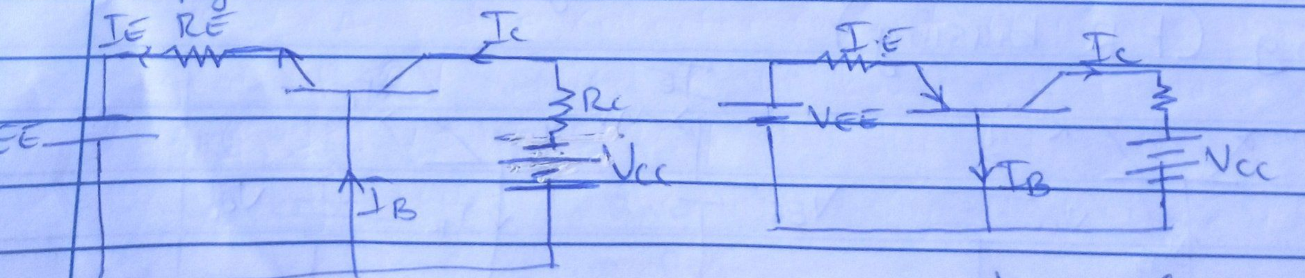


fig 10 a forward-forward biasing of a transistor. b (saturation region)

In this type of arrangement, the transistor is said to operate in a saturation region. In this arrangement, the Collector Current I_c is independent of the emitter current I_E. Thus the transistor acts like a closed switch.

3) **Reverse-Reverse biase**:- In this type of biasing, both the junctions are reverse biased. In this arrangement, the transistor has practically zero current because the emitter does not emit charge carriers into the base and no charge carrier is collected by the collector except the few thermally generated minority carriers. Thus the transistor acts like an open switch and said to operate in cut off region.

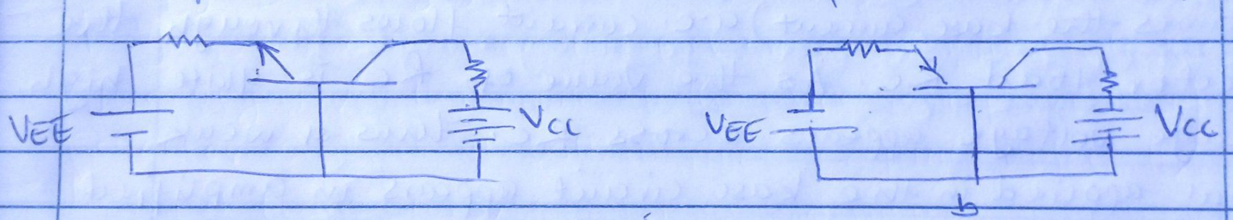


fig 11 a cut off region

4) **Reverse-Forward biasing**: In this biasing arrangement, the emitter junction is reverse biased while collector junction is forward biased. As the collector is not doped like the emitter, it cannot inject majority carriers into the base. So, in this region, the action of the transistor is poor. This type of biasing is of little or no importance.
The transistor is used in active mode if it is to be used as an **Amplifier** while switching operation makes use of cut-off mode and saturation mode.

Transistor as an amplifier.

What is amplification: Amplification is the process in which low level intensity sound is converted into high level intensity of the sound. The circuitry that is doing this job of amplification is called amplifier.

How Transistor Amplifies

Fig 12 below shows a single stage transistor amplifier. When a weak a.c signal is given to the base of transistor, a small base current (which is a.c) starts flowing. Due to transistor action, a much larger (B times the base current) a.c. current flows through the collector load Rc. As the value of Rc is quite high, a large voltage appears across Rc. Thus a weak signal applied in the base circuit appears in amplified form in the collector circuit. This is what makes a transistor act as amplifier.

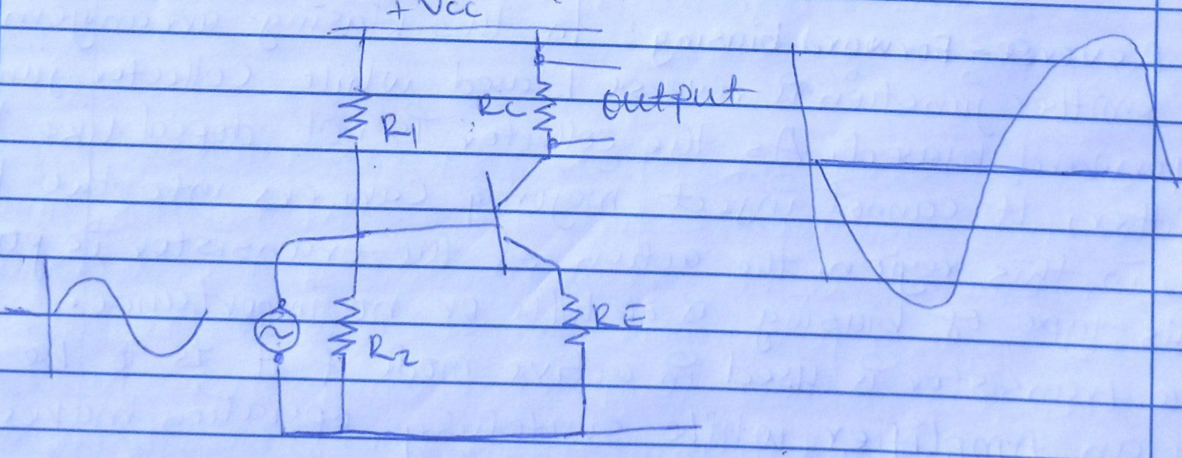
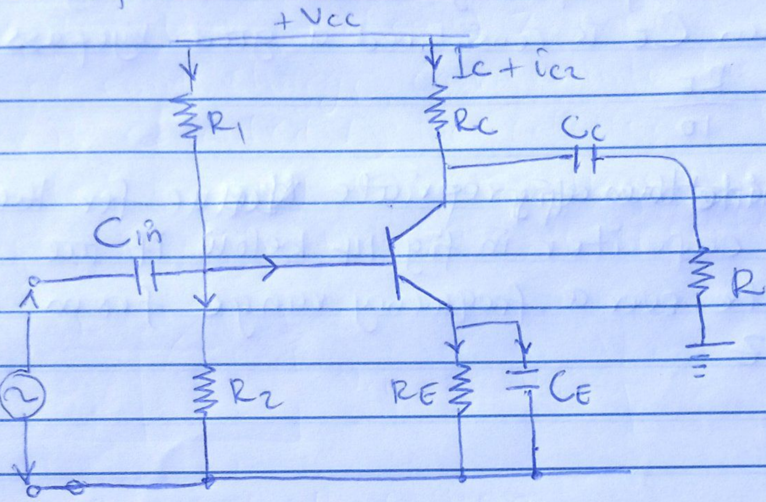


Fig 12

The action of a transistor can be explained further by referring to fig 12. Suppose a change of 2V results to a 5mA in the collector current, it means that signal of 2V applied to the base will produce an output of ~~5mA×5kΩ~~ (V = IR) = 25V. Thus the transistor to raise the voltage level of the input signal from 2V to 25V

Practical circuit of transistor amplifier

It is important to note that, for a transistor to perform a proper amplification function, a proper associated circuitry must be used with it. fig. 13 below shows a single stage transistor amplifier circuit. the various circuit elements and their functions are also described.



1. **Biasing circuit**: the resistances R1, R2 and RE form the biasing ~~circuit~~ and stabilization circuit. The biasing circuit should establish a proper operating point ~~else~~ if not, a part of the half negative cycle ~~of~~ the signal may be cut off in the output.

2. **Input capacitor Cin**: An electrolytic capacitor Cin ($\simeq 10\mu F$) is used to couple the signal to the base of the transistor. It's work is to block dc and allow only a-c signal to pass

3. **Emitter bypass capacitor C_E**: An emitter bypass capacitor C_E ($\simeq 100\mu F$) is used in parallel with RE to provid a low reactance path to the amplified a-c signal. If it is not used, the the amplified a-c signal flowing through RE will cause a voltage drop across it, thereby reducing the output voltage.

4: **Coupling capacitor Cc**: the coupling capacitor ($\simeq 10\mu F$) Couples one stage of amplification to the next stage. If it is not used, the bias condition of the next stage of amplification will be seriously affected.

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Note: Since amplifier usually handles more than one frequency, the value of C_E is selected so that it provides adequate byepass for the lowest of all the frequencies. Then it will also be a good byepass for all the higher frequencies ($X_c \propto 1/f$)

Suppose the minimum frequency to be handled by C_E is f_{min}, then C_E is considered a good byepass if at f_{min}. $X_c = \frac{R_E}{10}$

problem: Determine the appropriate value for the emitter bypass capacitor in fig 14 below if the amplifier operate over a frequency range from 2kHz to 10kHz