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An Overview of Transistor: Its Types

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Abstract

Transistor-based artificial synapses have been paid much attention in recent years because of their good stability, clear operation mechanism, possibility of multiterminal operation, and can be constructed from a variety of materials. In addition, they can perform concurrent learning to perform synaptic weight updates without interrupting the signal transmission process. Through proper material selection and structural design, transistors can convert external stimulus (light, pressure, temperature, etc.) into the electrical signal, which provides the possibility of implementing sensory synapses with sensorimotor functions as well as achieving synergistic control of one device by two or more signals. However, the development of transistor-based artificial synapses is still in its very early stages. Herein, this article presents a review of recent advances in transistor-based artificial synapses in order to give a guideline for future implementation of synaptic functions with transistors.

Introduction

A transistor is a type of semiconductor device that can be used to conduct and insulate electric current or voltage. A transistor basically acts as a switch and an amplifier. In simple words, we can say that a transistor is a miniature device that is used to control or regulate the flow of electronic signals.

Transistors are one of the key components in most of the electronic devices that are present today. Developed in the year 1947 by three American physicists, John Bardeen, Walter Brattain and William Shockley, the transistor is considered one of the most important inventions in the history of science

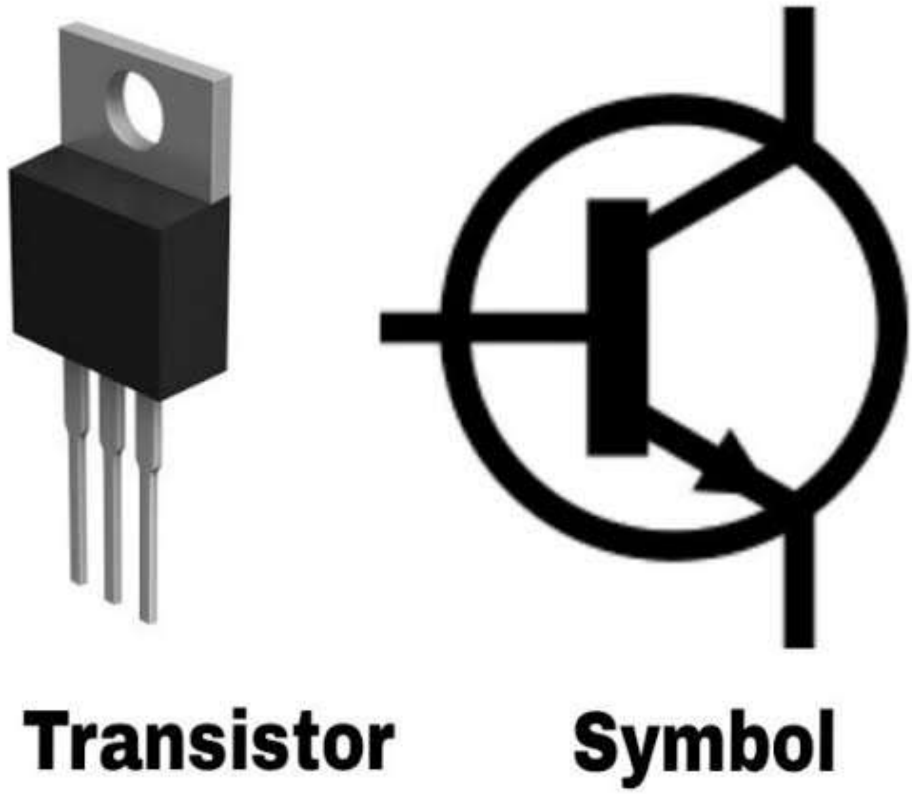
Parts of transistor

A typical transistor is composed of three layers of semiconductor materials or, more specifically, terminals which help to make a connection to an external circuit and carry the current. A voltage or current that is applied to any one pair of the terminals of a transistor controls the current through the other pair of terminals. There are three terminals for a transistor. They are listed below:

Base: This is used to activate the transistor.

Collector: It is the positive lead of the transistor

Emitter: It is the negative lead of the transistor.



Well, the very basic working principle of a transistor is based on controlling the flow of current through one channel by varying the intensity of a smaller current that is flowing through a second channel.

Types of transistor

There are mainly two types of transistors, based on how they are used in a circuit.

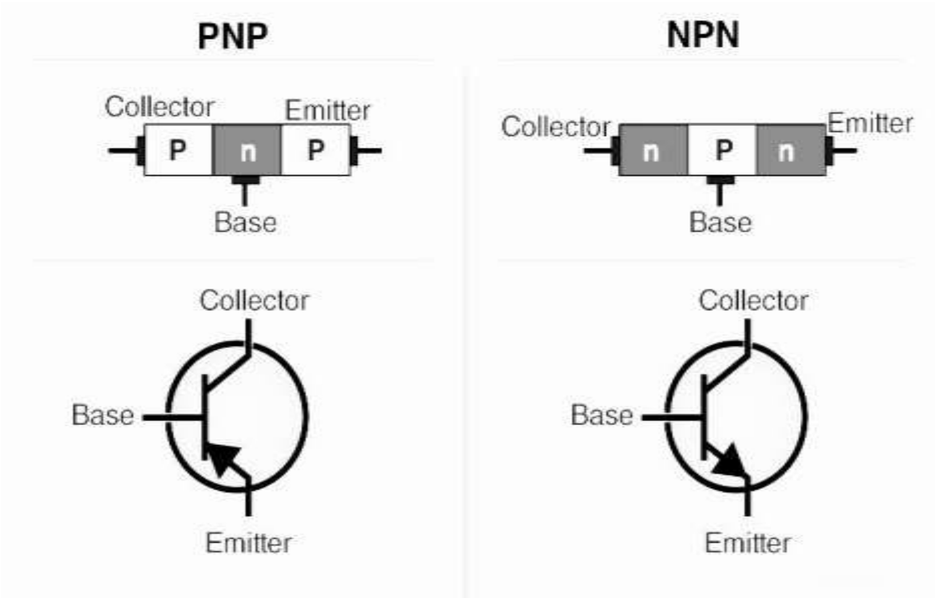
Bipolar Junction Transistor (BJT)

The three terminals of BJT are the base, emitter and collector. A very small current flowing between the base and emitter can control a larger flow of current between the collector and emitter terminal.

Furthermore, there are two types of BJT, and they include:

P_N_P Transistor: It is a type of BJT where one n-type material is introduced or placed between two p-type materials. In such a configuration, the device will control the flow of current. PNP transistor consists of 2 crystal diodes which are connected in series. The right side and left side of the diodes are known as the collector-base diode and emitter-base diode, respective

N_P_N Transistor: In this transistor, we will find one p-type material that is present between two n-type materials. N-P-N transistor is basically used to amplify weak signals to strong signals. In an NPN transistor, the electrons move from the emitter to the collector region, resulting in the formation of current in the transistor. This transistor is widely used in the circuit.



Construction of transistor

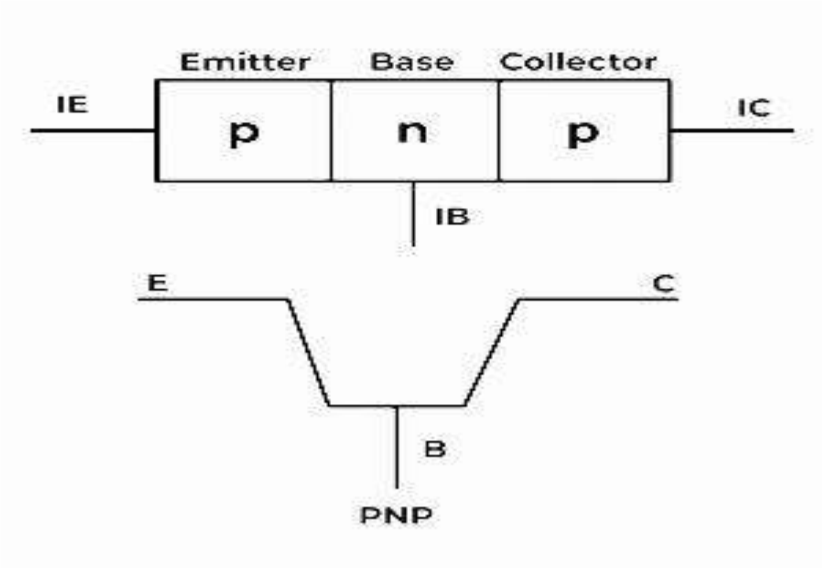
A transistor is an three layer semiconductor device which is sandwiched between two same types of semiconductor. The process of sandwiching is called fabrication of transistor.

Depending on the way of construction it is of two types as mentioned below: PNP and NPN

1. Construction of PNP Transistor

In this type of transistor N types transistor is sandwiched between two P types semiconductor layer as shown in the diagram. In PNP-type transistors, conduction happens through holes that carry a positive charge in other words it can conduct in the absence of electrons.

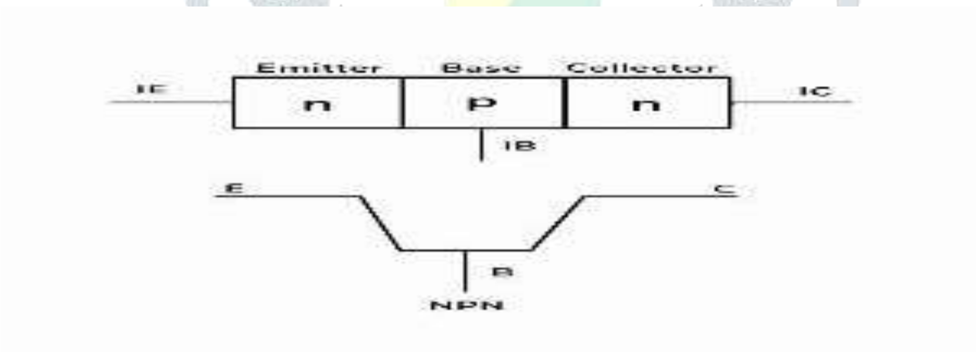
Note that current carrying collector part is less than the emitter part and base part is the one which will control the control flow between two other parts.



2. Construction of NPN Transistor

In this particular type of transistor, P type transistor is sandwiched between two N types semiconductor layers. In NPN-type transistors, conduction happens through electrons and not by holes. Note that electrons having a negative charge pass from the emitter to the base and are collected by the collector.

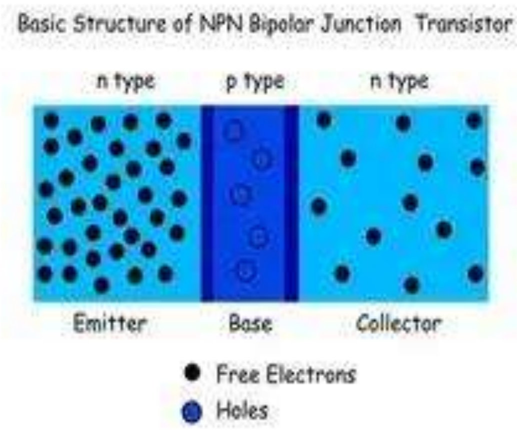
Also, the base controls the number of electrons from the emitter.



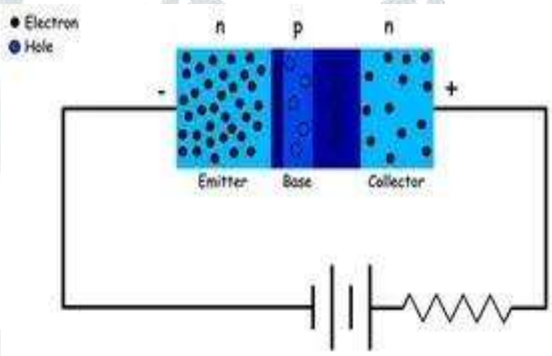
Working and principle of Transistor

There are different types of transistor available in the market, but for sake of understanding, we will consider a common emitter mode of NPN transistor. For this let us recall the basic structural features of npn bipolar junction transistor. Its emitter region is heavily doped and wider hence the number of free electrons (majority carriers) is large here.

The collector region is also wider but it is moderately doped hence the number of free electrons is not as much as the emitter region. The base region is diffused in between the wider emitter and collector region but the base region is quite thin compared to the outer emitter and collector region and also it is very lightly doped so the number of holes (majority carriers) is quite small here

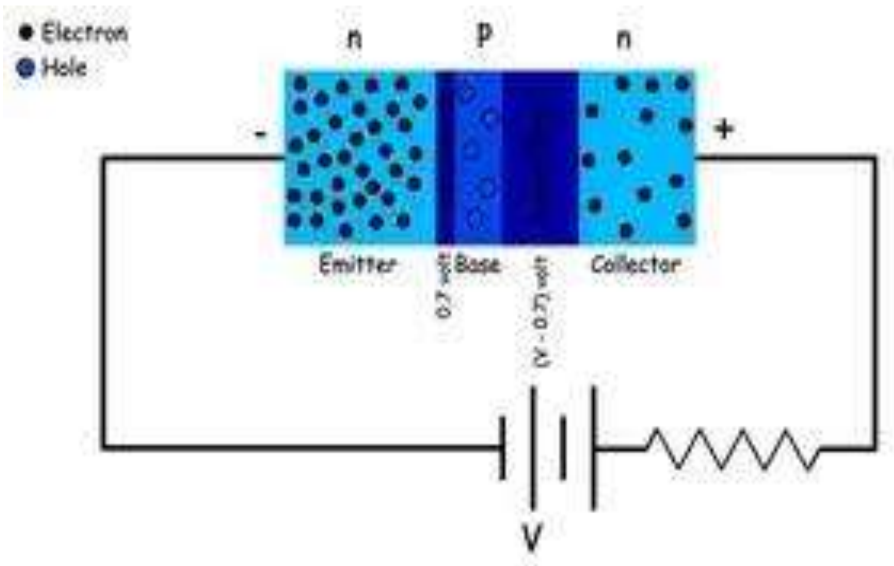


Now, we connect one battery in between emitter and collector. The emitter terminal of the transistor is connected to the negative terminal of the battery. Hence the emitter-base junction becomes forward biased, and base-collector junction becomes reverse biased.



In this condition, no current will flow through the device. Before going to the actual operation of the device let us recall the constructional and doping details of an NPN transistor. Here the emitter region is wider and very heavily doped. Hence the concentration of majority carriers (free electrons) in this region of the transistor is very high.

The base region, on the other hand, is very thin it is in the range of few micrometers whereas emitter and collector region are in the range of millimeter. The doping of the middle p-type layer is very low, and as a result, there is a very tiny number of holes present in this region. The collector region is wider as we already told and doping here is a moderate and hence moderate



number of free electrons present in this region

The entire voltage applied between emitter and collector is dropped at two places. One is at the forward barrier potential across the emitter-base junction and this is about 0.7 volt in case of silicon made transistors. The rest portion of the applied voltage is dropped as a reverse barrier across the base-collector junction.

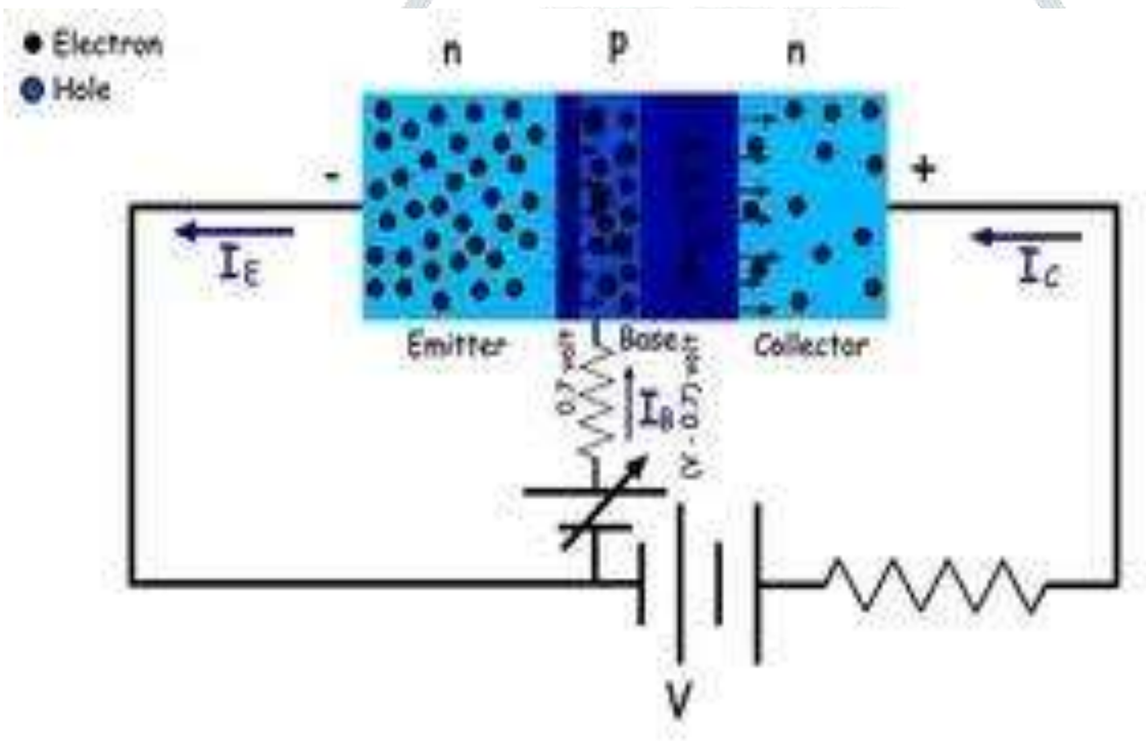
Whatever may be the voltage across the device the forward barrier potential across emitter-base junction always remains 0.7 volts and the rest of the source voltage is dropped across the base-collector junction as reverse barrier potential.

That means none of the collector voltage can overcome the forward barrier potential. Hence ideally none of the free electrons in the emitter region can cross the forward barrier potential and can come to the base region. As a result of the transistor will behave as an off switch.

– As at this condition the transistor does not conduct any current ideally, there will be no voltage drop at the external resistance hence entire source voltage (V) will drop across the junctions as shown in the figure above.

Now let us see what happens if we apply a positive voltage at the base terminal of the device. In this situation, the base-emitter junction gets forward voltage individually and certainly, it can overcome the forward potential barrier and hence the majority carriers, i.e., free electrons in the emitter region will cross the junction and come in the base region where they get very few numbers of holes to recombine.

But due to the electric field across the junction, the free electrons migrating from emitter region get kinetic energy. The base region is so thin that the free electrons coming from emitter do not get sufficient time to recombine and hence cross the reverse biased depletion region and ultimately come to the collector zone. As there is a reverse barrier present across the base-collector junction, it will not obstruct the flow of free electrons from the base to the collector as the free electrons in the base region are minority carriers



In this way, electrons flow from emitter to collector and hence collector to emitter current starts flowing. As there are few holes present in the base region some of the electrons coming from emitter region will recombine with these holes and contribute base current. This base current is quite smaller than collector to emitter current.

As some of the entire electrons migrating from emitter region contribute base current, rest major portion of them contribute current through the collector region. The current through emitter is called emitter current, the current through the collector is called collector current and the tiny current flowing through the base terminal is called base current. Hence here emitter current is the sum of base current and collector current.

Now let us increase the applied base voltage. In this situation due to the increased forward voltage across emitter-base junction proportionately more free electrons will come from the emitter region to the base region with more kinetic energy. This causes a proportionate increase of collector current. In this way, by controlling a small base signal, we can control quite a large collector signal. This is the basic working principle of a transistor.

Applications of Transistor

1. The core use of transistors includes switching applications or both amplification and switching.

2. There is a kind of transistors that produce current flow depending on the amount of light shined upon them; those are known as phototransistors.

3. Bipolar Junction Transistors(BJT) can cause a greater current flow from the emitter to the collector when a small amount of current is passed through the base.

4. Field-Effect Transistors act as voltage controlled devices. Field-Effect Transistors (FETs) have very high input impedance and it helps to run very little current through them. This is helpful for not causing the power source to load down as they are not disturbing the original circuit power elements to which they are connected. FETs are cheaper and easier to manufacture and cause less loading.

5. Heterojunction Bipolar Transistors (HBT) can provide faster switching speeds and are used in analog and digital microwave applications. They are priceless to fabricate and can provide better lithographic yield. They are used in mobile and laser drivers as power amplifiers.

6. Darlington Transistors have a much higher ability to gain current. Because of its sensitivity, it can pick currents from human skin, which is why it is used to create a touch-sensitive button.

7. Schottky Transistors divert high input currents and prevent the transistors from saturating.

Multiple Emitter Transistors are used in Transistor-Transistor Logic (TTL) and NAND logic gates.

8. Dual Gate MOSFETs are used in RF mixers/multipliers and RF amplifiers where two controlled gates are required in a series.

9. Avalanche Transistors can switch high currents in less than nanosecond transition times.

Conclusion

In this particular article we have seen in detail about the transistor, its types, working principle and its application. Transistors play a vital role in this digitalized world as it helps to improve the efficiency of operational electronic signals and make more compact electronic devices and so on.

So a transistor is used as a switch in the circuit , as the base voltage goes high then current flow from collector to emitter and then transistor gets switch on and as the current stops flowing then the transistor gets off.

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