

# Classification and Different Types of Transistors | BJT, FET, NPN, PNP

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The Transistor became an essential component in modern electronics and we cannot imagine the World without Transistors. In this tutorial, we will learn about the classification and different Types of Transistors. We will learn about BJT (NPN and PNP), JFET (N-Channel and P-Channel), MOSFET (Enhancement and Depletion) and also Transistors based on their applications (Small Signal, Fast Switching, Power, etc.).

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## Introduction

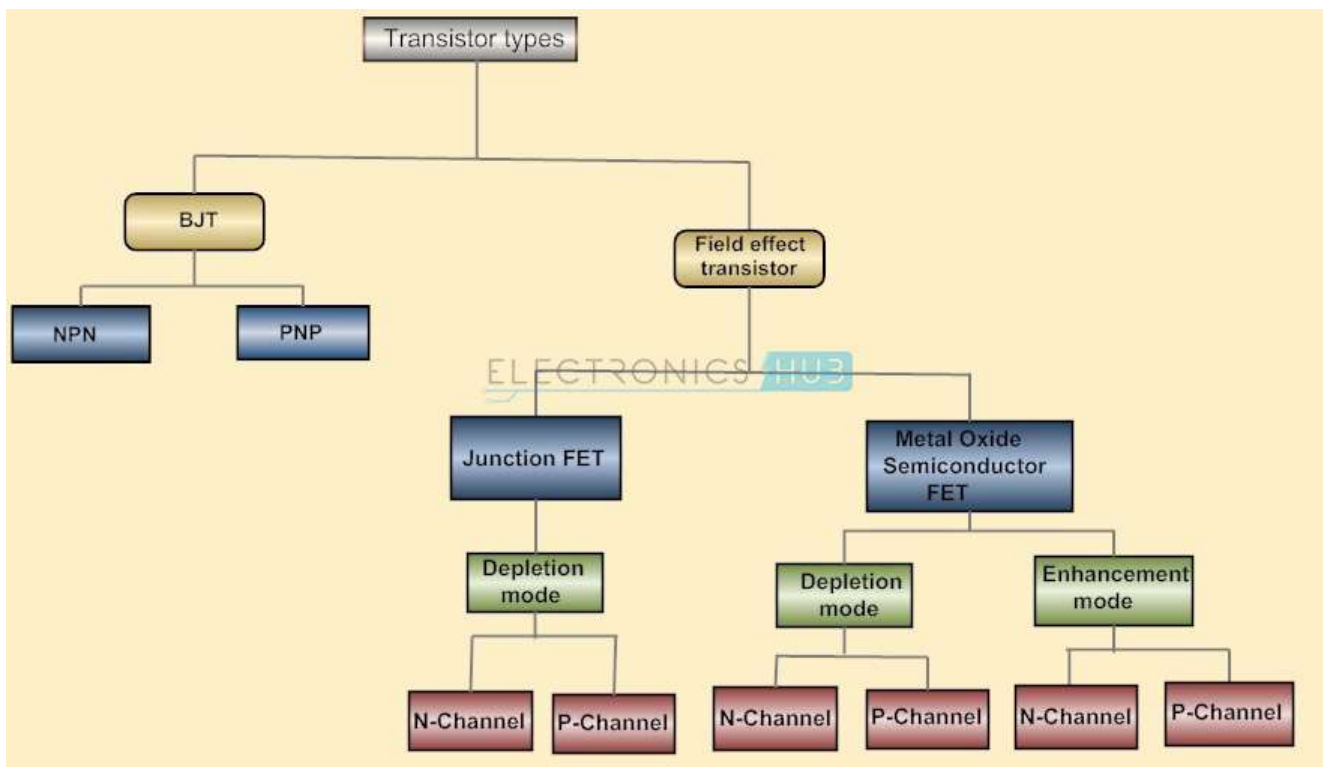
Transistor is a semiconductor device which is used to either amplify the signals or to act as an electrically controlled switch. A Transistor is a three terminal device and a small current / voltage at one terminal (or lead) will control a large flow of current between the other two terminals (leads).

Since a long time, the vacuum tubes are replaced with transistors because the transistors have more benefits over vacuum tubes. Transistors are small in size and it requires low energy for operation and also it has low power dissipation. The Transistor is one of the important active components (a device which can produce an output signal higher power than that in the input signal).

Transistor is an essential component is almost every electronic circuit like: Amplifiers, Switching, Oscillators, Voltage Regulators, Power Supplies and most importantly, the Digital Logic ICs.

From the time of invention of the first transistor to the present day, transistors are classified into different types depending either on their construction or their operation. The following tree diagram explains a Basic Classification of different Transistor types.

## Transistor Tree Diagram



The classification of transistors can be easily understood by observing the above tree diagram. Transistors are basically classified into two types. They are: Bipolar Junction Transistors (BJT) and Field Effect Transistors (FET). The BJTs are again classified into NPN and PNP transistors. The FET transistors are classified into JFET and MOSFET.

Junction FET transistors are further classified into N–Channel JFET and P–Channel JFET depending on their construction. MOSFETs are classified into Depletion Mode and Enhancement Mode. Again, depletion and enhancement mode transistors are further classified into respective N–Channel and P–Channel.

## Types of Transistors

As mentioned earlier, on a broader scale, the major families of Transistors are BJTs and FETs. Irrespective of the family they belong to, all Transistors have proper / specific arrangement of different semiconductor materials. Commonly used semiconductor materials for manufacturing transistor 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 in BJT both majority and minority charge carriers are required to operate, whereas in case FETs, only majority charge carriers are required.

Based on their properties and characteristics, some transistors are primarily used for switching purpose (MOSFETs) and on the other hand, some are transistors are used for amplification purpose (BJTs). Some transistors are designed for both amplification and switching purposes.

## Junction Transistors

Junction Transistors are generally called as Bipolar Junction Transistor (BJT). The term 'Bipolar' means both electrons and holes are required for conducting current and the term 'Junction' means it contain PN Junction (two junctions, in fact).

The BJTs have three terminals named Emitter (E), Base (B) and Collector (C). The BJT transistors are classified in to NPN and PNP transistors depending on the construction.

BJTs are essentially current-controlled devices. If small amount of current flows through the base of a BJT transistor, then it causes a flow of large current from emitter to collector. The Bipolar Junction Transistors have low input impedance and it causes to flow large current through the transistor.

The Bipolar Junction Transistors are only turned ON by the input current, which is given to the base terminal. BJTs can operate in three regions. They are:

- Cut-off Region: Here the transistor is in 'OFF' state i.e., the current flowing through the transistor is zero. It is basically an open switch.
- Active Region: Here the transistor acts as an amplifier.
- Saturation Region: Here the transistor is in fully 'ON' state and also works as a closed switch.

## NPN Transistor

NPN is one of the two types of Bipolar Junction Transistors (BJT). The NPN transistor consists of two n-type semiconductor materials and they are separated by a thin layer of p-type semiconductor. Here, the majority charge carriers are electrons while holes are the minority charge carriers. The flow of electrons from emitter to collector is controlled by the current flow in the base terminal.

A small amount of current at base terminal causes a large amount current to flow from emitter to collector. Nowadays, the more commonly used bipolar transistor is NPN transistor, because the mobility of electrons is greater than mobility of holes. The standard equation for the currents flowing in the transistor is

$$I_E = I_B + I_C$$

The symbols and structure for NPN transistors are given below.

## PNP Transistor

The PNP is another type of Bipolar Junction Transistors (BJT). The PNP transistors contain two p-type semiconductor materials and are separated by a thin layer of n-type semiconductor. The majority charge carriers in the PNP transistors are holes while electrons are minority charge carriers. The arrow in the emitter terminal of transistor indicates the flow of conventional current. In PNP transistor, the current flows from Emitter to Collector.

The PNP transistor is ON when the base terminal is pulled LOW with respect to emitter. The symbol and structure for PNP transistor is shown below.

## FET (Field Effect Transistor)

The Field-Effect-Transistor (FET) is another major type of transistor. Basically, the FET also have three terminals (like BJTs). The three terminals are: Gate (G), Drain (D) and Source (S). Field Effect Transistor are classified into Junction Field Effect transistors (JFET) and Insulated Gate Field Effect Transistors (IG-FET) or Metal Oxide Semiconductor Field Effect Transistors (MOSFET).

For the connections in the circuit, we also consider a fourth terminal called Base or Substrate. The FETs have control on the size and shape of a channel between Source and Drain, which is created by voltage applied at Gate.

The Field Effect Transistors are uni-polar devices, as they require only the majority charge carriers to operate (unlike BJT, which are bipolar transistors).

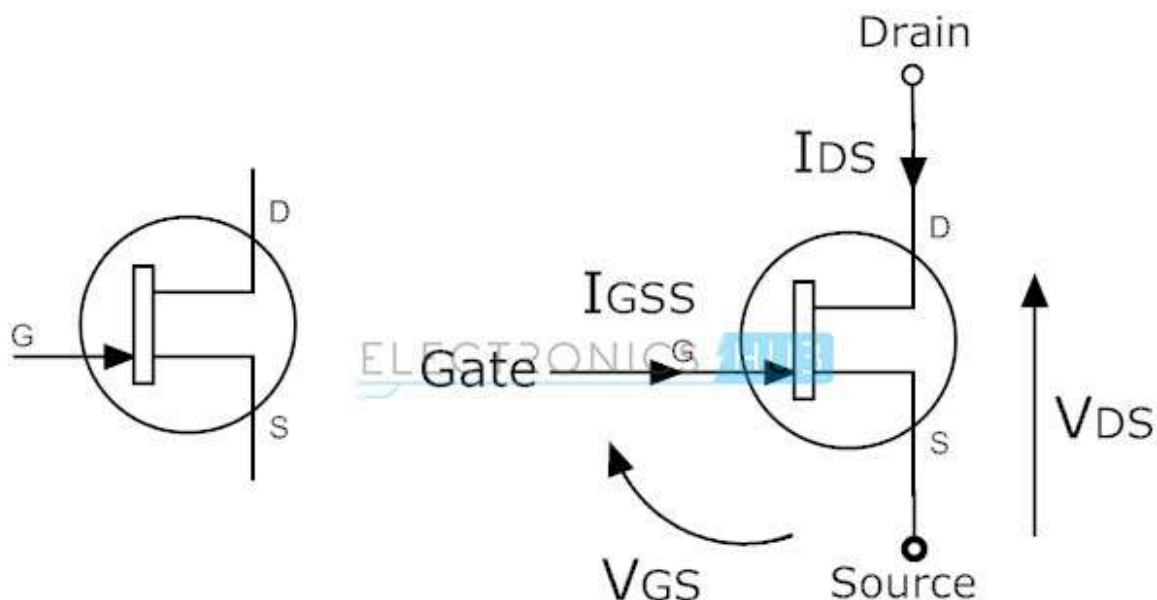
## JFET (Junction-Field Effect Transistor)

The Junction-Field-Effect transistor (JFET) is an earliest and simple type of Field Effect Transistor. The JFETs are used as switches, amplifiers and resistors. This transistor is a voltage-controlled device. It doesn't need any biasing current.

The voltage applied between gate and source controls the flow of electric current between source and drain of the transistor. The JFET transistors are available in both N-Channel and P-Channel types.

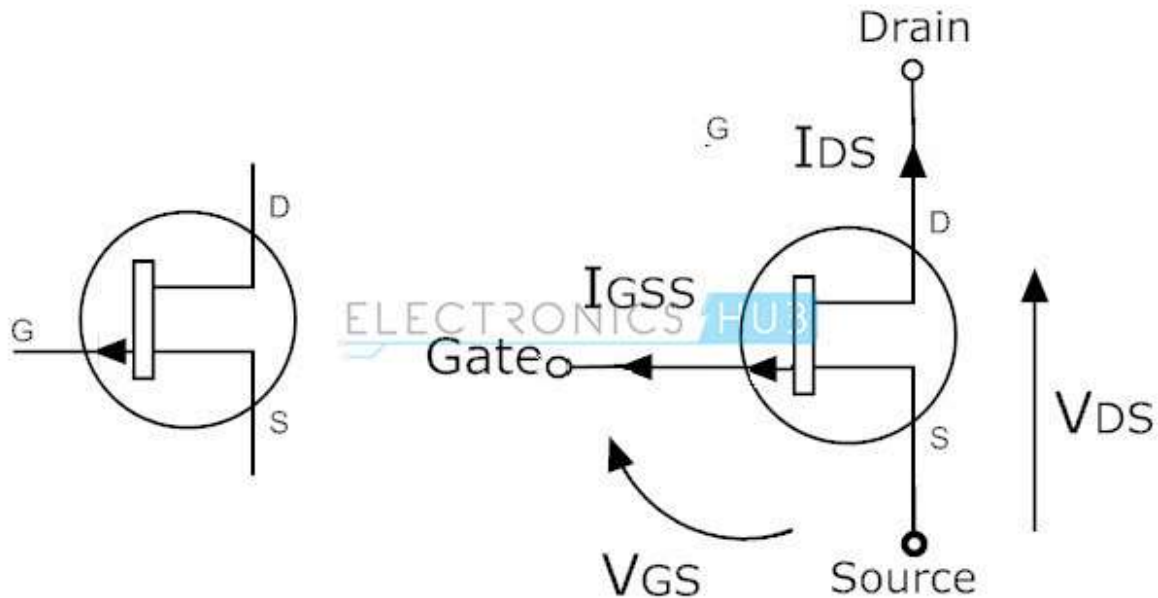
### N-Channel JFET

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. Nowadays, N-Channel JFETs are preferable type than P-Channel JFET. The symbols for N-channel JFET transistor are given below.



## P-Channel JFET

In this type of JFET, the current flow is because of holes. The channel between source and drain is called P-Channel. The symbols for P-Channel JFETs are given below. Here, the arrow marks indicate the direction of current flow.



## MOSFET

Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is most commonly used and most popular type of among all transistors. The name 'Metal Oxide' indicates that the Gate region and the channel are separated by a thin layer of metal oxide (usually,  $\text{SiO}_2$ ).

Hence, MOSFET is also known as Insulated Gate FET as the Gate region is completely insulated from the Source – Drain region. There is an extra terminal known as Substrate or Body, which is the main Semiconductor (Silicon) in which the FET is fabricated. So, the MOSFET has four terminals drain, source, gate and body or substrate.

MOSFET has many advantages over BJT and JFET, mainly it offers high input impedance and low output impedance. It is used in switching and power circuits and it is a main component on Integrated Circuit designing technologies.

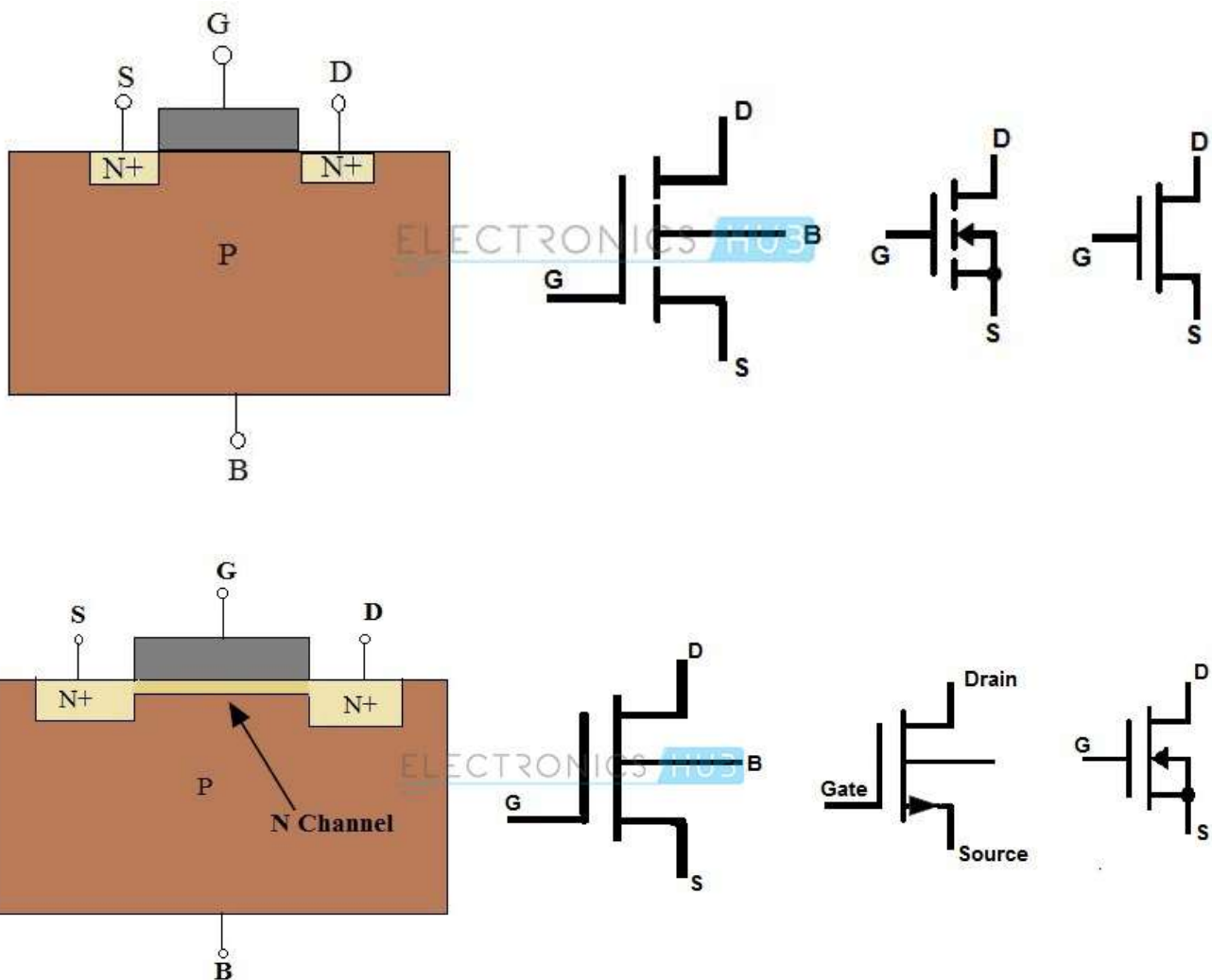
The MOSFET transistors are available in depletion and enhancement types. Further, the depletion and enhancement types are classified into N-Channel and P-Channel types.

## N-Channel MOSFET

The MOSFET having N-channel region between source and drain is called N-channel MOSFET. Here, the source and gate terminals are heavily doped with n-type materials situated in a heavily doped p-type semiconductor material (substrate).

The current flow between source and drain is because of electrons. The gate voltage controls the current flow in the circuit. N-Channel MOSFET is most commonly used than P-Channel MOSFET because the mobility of electrons is high than mobility of holes.

The symbols and structures for N-Channel MOSFET transistors are given below (both Enhancement and Depletion mode).

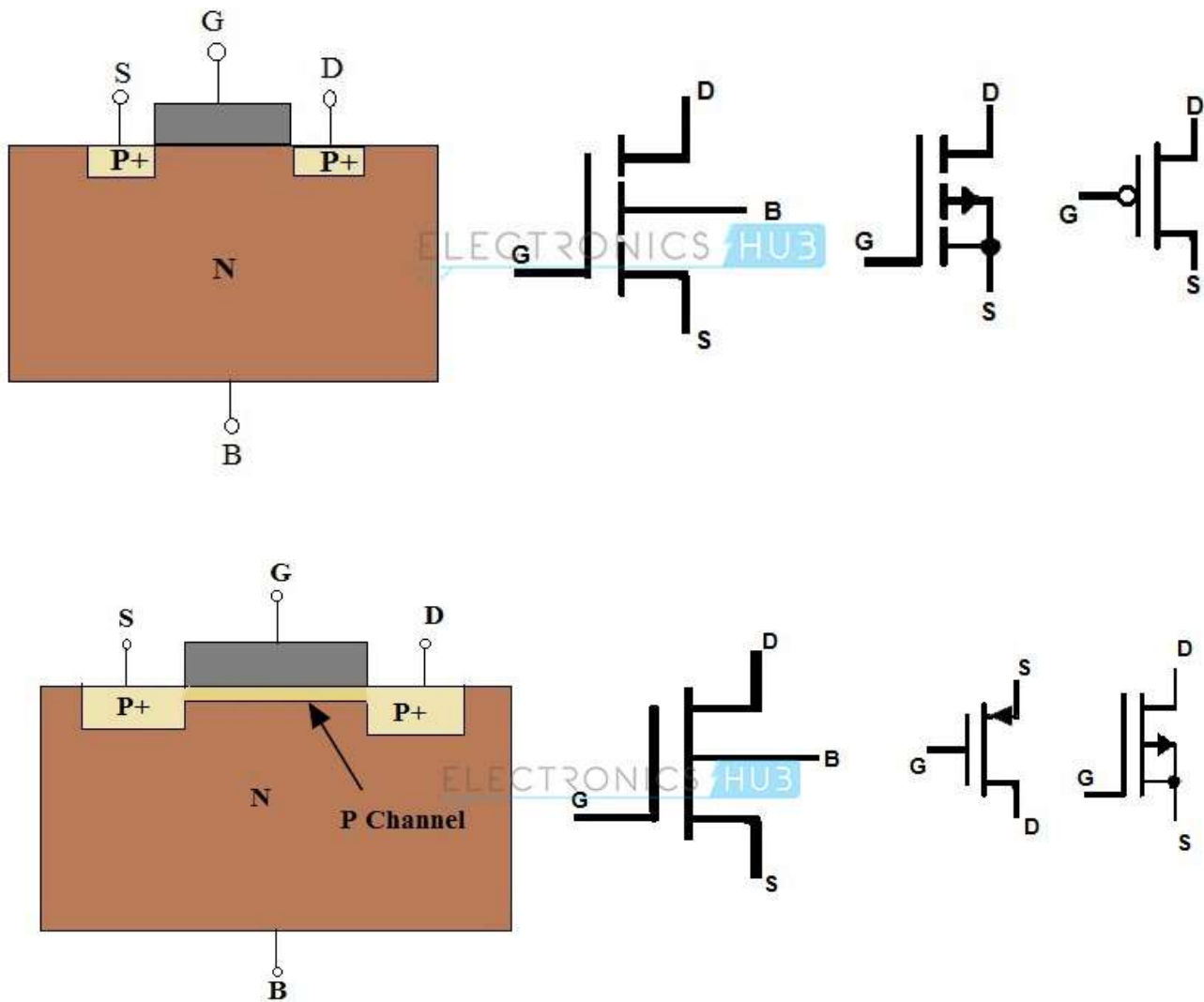


## P-Channel MOSFET



The MOSFET having P-Channel region between source and drain is called as P-Channel MOSFET. Here, the source and drain terminals are heavily doped with P-type material and the substrate is doped with N-type material. The current flow between source and drain is because of holes concentration. The applied voltage at gate will controls the flow of current through channel region.

The symbols and structures for P-Channel MOSFET transistors are given below (both Enhancement and Depletion mode).



## Transistors Based on Function

Transistors are also classified depending on the functions (operations or applications) they perform. Different types of transistors based on their function are explained below.

### Small Signal Transistors

The basic function of small signal transistors is to amplify small signals but sometimes these transistors are also used for switching purpose. Small signal transistors are available in market in the form of NPN and PNP transistors. We can usually see some value printed on the body of small signal transistor, which indicates the hFE of transistor.

Depending on this hFE value, we can understand the capacity of transistor to amplify the signal. The commonly available hFE values are the range of 10 to 500. The collector current value of these transistors is 80 to 600 mA. This type of transistors operates with the frequency range of 1 to 300 MHz. The name of the transistor itself indicates that these transistors amplify small signals, which use small voltages and currents, such as few milli volts and milli amperes of current.



Small signal transistors are used in almost all types of electronic equipment and also these transistors are used in several applications, some of them are ON or OFF switches for general use, LED diode driver, Relay driver, Audio mute function, Timer circuits, Infrared diode amplifier, Bias supply circuits etc.

## Small Switching Transistors

Small switching transistors are those transistors which are primarily used for switching but also sometimes for amplification. Like small signal transistors, small switching transistors are also available in the form of NPN and PNP and these types of transistors also have hFE values.

The  $h_{FE}$  value range for these transistors is from 10 to 200. At  $h_{FE}$  value 200, the transistors are not good amplifiers but they act as better switches. The collector current values range from 10 to 1000 mA. These transistors are used mostly in switching applications.



## Power Transistors

The transistors which are used in the high-power amplifiers and power supplies are called as Power Transistors. The collector terminal of this transistor is connected to the base of a metal device and this structure acts as heat sink which dissipates excess power for the applications.

These types of transistors are available in the form of NPN, PNP and Darlington transistors. Here, the collector current values range from 1 to 100 A. The operating frequency range from 1 to 100 MHz. The power values of these transistors are range from 10 to 300 W. The name of the transistor itself indicates that the power transistors are used in the applications where high power, high voltage and high current are required.



## High Frequency Transistors

High frequency transistors are used for small signals which operate at high frequencies and these are used in high-speed switching applications. High frequency transistors are also called as RF Transistors.

These transistors have maximum frequency values of about 2000 MHz. The collector current ( $I_C$ ) value ranges from 10 to 600 mA. These types of transistors are also available in the form of NPN and PNP. These are mainly used in the applications of high frequency signals and also these transistors must be ON or OFF at high speeds only. These transistors are used in HF, VHF, UHF, CATV and MATV oscillator and amplifier circuits.

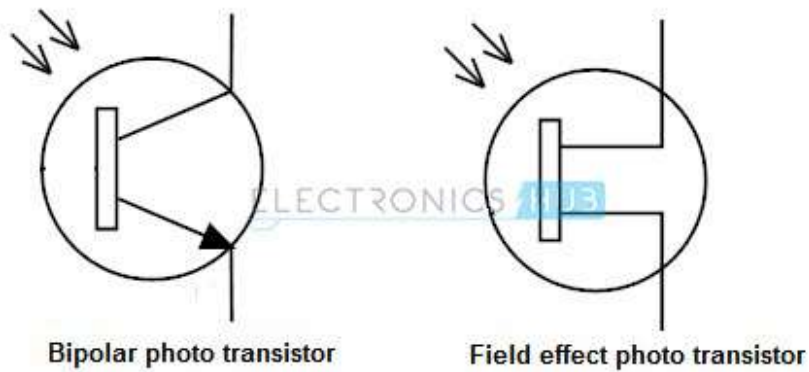


## Photo Transistor

Photo transistors are the transistors which operate depending on the light i.e., these transistors are light sensitive. A simple photo transistor is nothing but a bipolar transistor which contains light sensitive area instead of the base terminal.

The photo transistors have only 2 terminals instead of 3 terminals (in BJTs). When the light sensitive area is dark, then no current flows in transistor i.e., transistor is in OFF state.

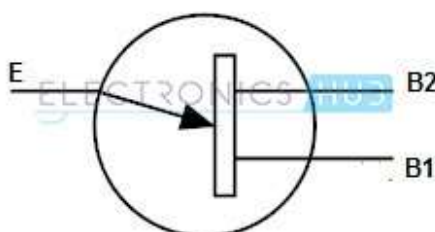




When light sensitive area is exposed to light, then a small amount of current generates at base terminal and it causes a large current to flow from collector to emitter. The photo transistors are available in both BJT and FET transistor types. These are named as photo-BJTs and photo-FETs.

Unlike photo-BJTs, the photo-FETs are generating gate voltage by using light, which controls the current flow between drain and source terminals. Photo-FETs are more sensitive to light than photo-BJTs. The symbols for photo-BJT and photo-FETs are shown above.

## Uni-Junction Transistors (UJT)



Uni-Junction Transistors (UJT) are used only as electrically controlled switches. These transistors do not contain any amplification characteristics because of their design. These are generally three lead transistors, in which, two are called as Base Terminals and the third is called the Emitter.

Now, let us see the operation of uni-junction transistor. If there is no potential difference between emitter and any one of the base terminals (B1 or B2), then a small amount of current flows between B1 and B2.

If sufficient amount of voltage is applied to the emitter terminal, then a high current is generated at emitter terminal and it adds to small current between B1 and B2, which then causes a flow of large current in the transistor.

Here, the emitter current is the primary current source for controlling the total current in the transistor. The current between the terminals B1 and B2 is very small and due to this reason, these transistors are not suitable for amplification purpose.