TRANSISTORS

Transistor is a three teminal semiconductor device that acts as switch and amplifier.

Transistor is derived from two words ‘transfer’ and ‘resistor’ because it transfers the resistance from one end of the device to the other.

BJT

JFET

MOSFET

Transistors types:-

1. Bipolar Junction Transistor (BJT)

BJT is of two types:-

1. NPN
2. PNP

2. Junction Field Effect Transistor (JFET)

JFET is of two types:-

1. N-channel JFET
2. P-channel JFET

3. Metal Oxide Field Effect Transistor (MOSFET)

MOSFET is of two types:-

1. Depletion type (n-channel and p-channel)
2. Enhancement type (n-channel and p-channel)

Biplor Junction Transistor(BJT)

As we discussed BJT transistors is of two types:-

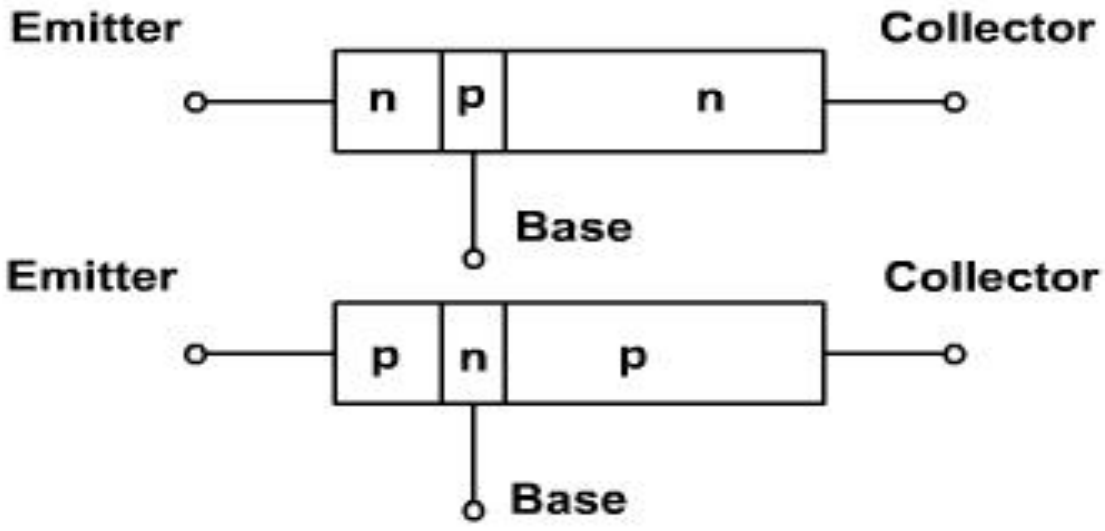
1.NPN

2.PNP

As the name suggest Biplor Junction Transistor,Bipolar means it has two charge carriers i.e, electrons(-ve) and holes(+ve).It has two junctions for example NPN transistor it has one NP junction and one PN junction.

BJT transistors are made up of two PN junction diode.

As discussed earlier in the PN junction ,the majority of charge carriers in N-type body are electrons and minority are the holes where as in P-type body the majority of charge carriers are holes and minority are electrons.



In the above figure you can see the width of the collector ,base and emitter in BJT transistor NPN and PNP.

According to the construction of the transistor the width of the Collector is greater than the Base and Emitter.The width of the Emitter is less than the Collector but greater than the Base.Base is the thin part of the transistor which is less than the Width of Collector and Emitter.

Collector width > Emitter width >Base width.

Pure semiconductor acts as an insulator so doping is used to increase the electric conductivity .

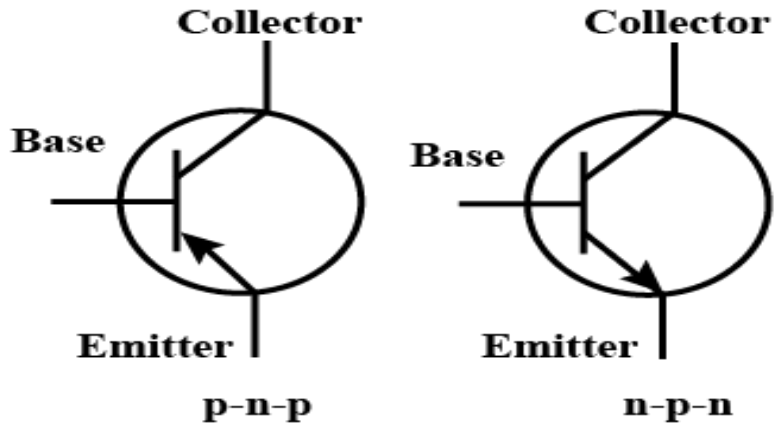
Concentration of charge carriers in a transistor

Emitter's work is to emit electrons at a large number.So it is heavily doped.It has maximum no of free charge carrires in a moderate width.

Base is made very thin and very lightly doped.Base is the control lead of the transistor.

Collector is lightly doped and its region is large it mainly collects the charge carriers emitted from the emitter.

Electrical symbol of NPN and PNP transistor

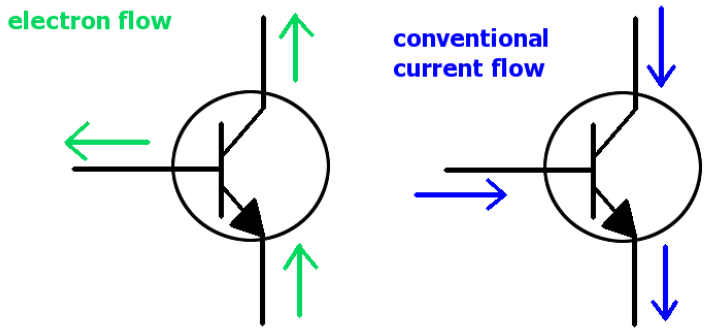


Working of NPN transistor

When a small positive voltage (>=0.7) is applied at its base ,allows the flow of large current from collector to emitter.

Base current in microamps and collector current in milliamps.

Transistor is in ON mode.

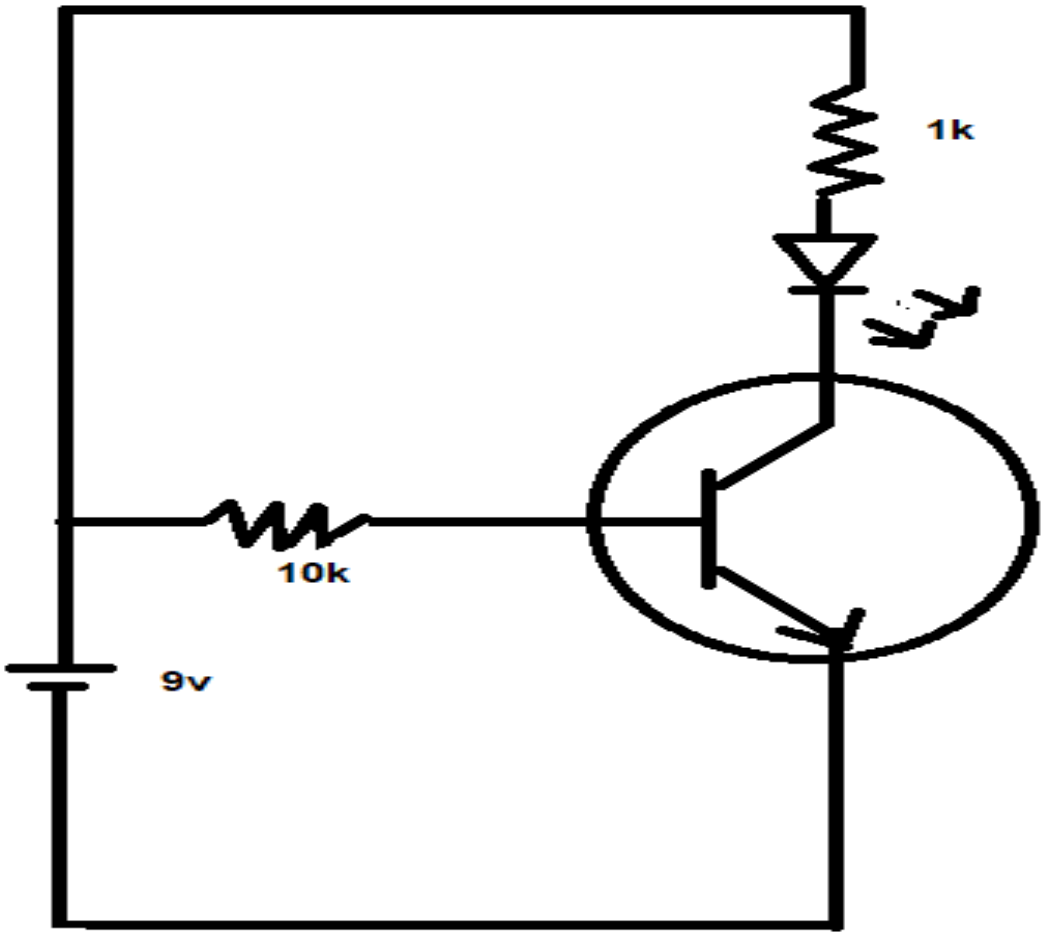


When no voltage is applied at transistor's base, electrons in the emitter are prevented from passing to the collector side because of the pn junction.

If a negative voltage is applied to the base, things get even worse as the pn junction between the base and emitter becomes reversebiased resulting in the formation of a depletion region that prevents current flow.

Transistor is in OFF mode.

Circuit for the working of NPN transistor



Working of PNP transistor

When a negative voltage or 0V is applied at its base ,allows the flow of large current from emitter to collector.

PNP transistor is in ON mode.

When a positive voltage is applied at its base the electrons accumulated at the positive terminal of the base ,there is no flow of electrons thus restricts the flow of current from emitter to the collector.

The PNP Transistor is in OFF mode.

Application of BJT transistors:-

Electronic switches,Amplifiers,filter,oscillators etc.

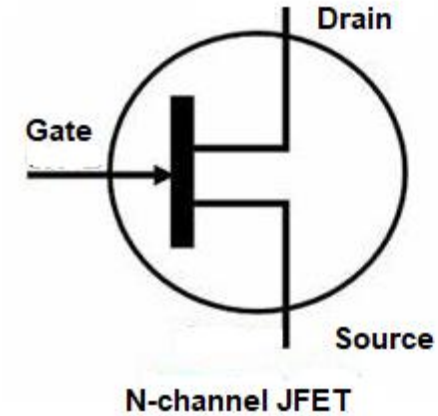
JFET Transistor

Junction Field Effect Transistor is a three terminal semiconductor device commonly used as switch and amplifiers. It consists of three terminals source, drain, and gate.It is a unipolar current controlled device .unipolar means flow of either electrons or holes.

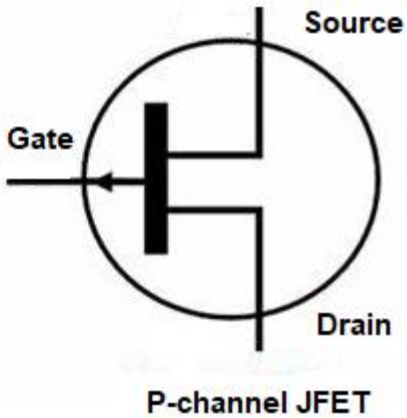
JFET is of two types:-

1. N-channel JFET
2. P-channel JFET

Electrical Symbol



N-channel JFET



P-channel JFET

N-channel JFET

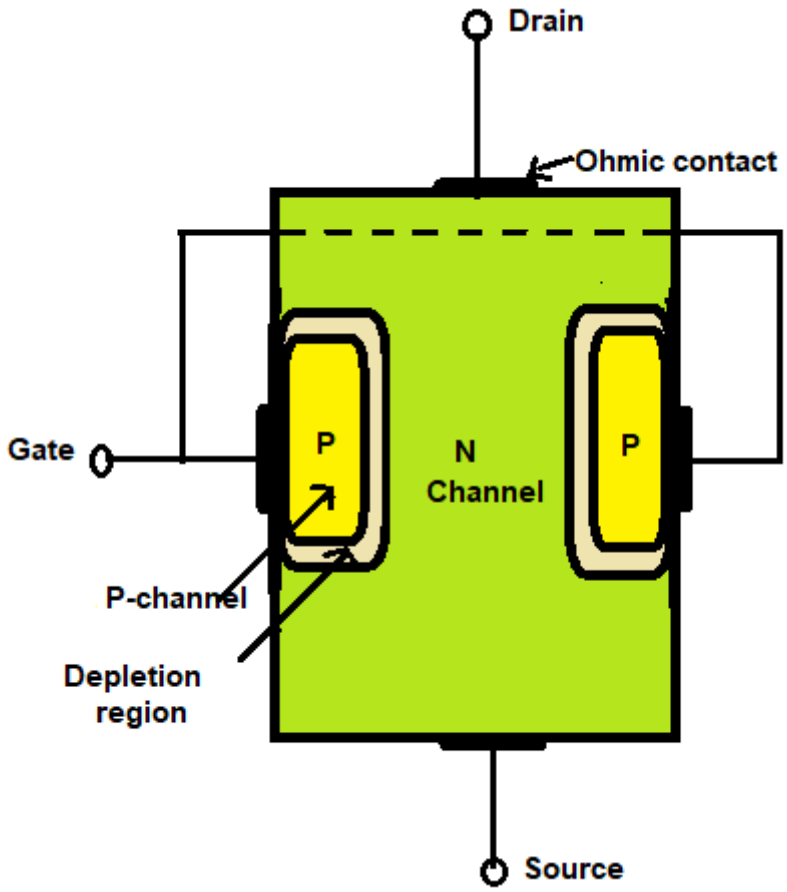
The major part of the N-channel JFET structure is n-type material and it is forming a channel between two p-type material.

It consists of two pn junction.

It has two depletion region (no free charge carrier in the region).

Drain and Source connected to the N-type by ohmic contact and Gate is connected to P-channel.Ohmic contact is also called as metallic contact.

The construction of N-channel JFET given below.



When the source and drain is connected to the potential difference(V),the electrons is drifted from source to drain and the current flows from drain to source(Id).**V**GS control the output current Id. So the device is called Voltage Control Device.

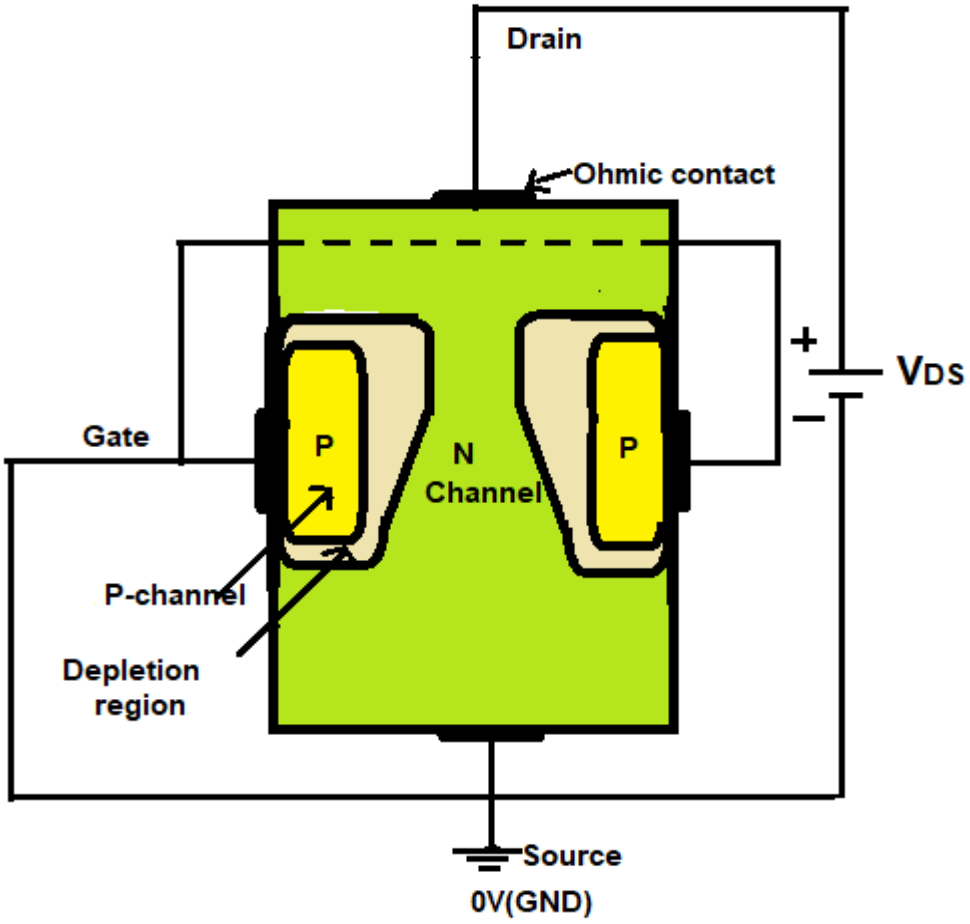
In JFET the flow of current is controlled by the applied voltage between the gate and source .

Working of N-channel JFET($V_{GS=0V}$ & $V_{DS>0V}$) (ON condition)

The N-channel JFET Transistor is ON condition,when 0V applied to the gate terminal i.e,the voltage across gate to source (**V**GS=0V) and potential difference is applied across the Drain to source (**V**DS). The Source terminal is connected to the negative(-) terminal of the DC

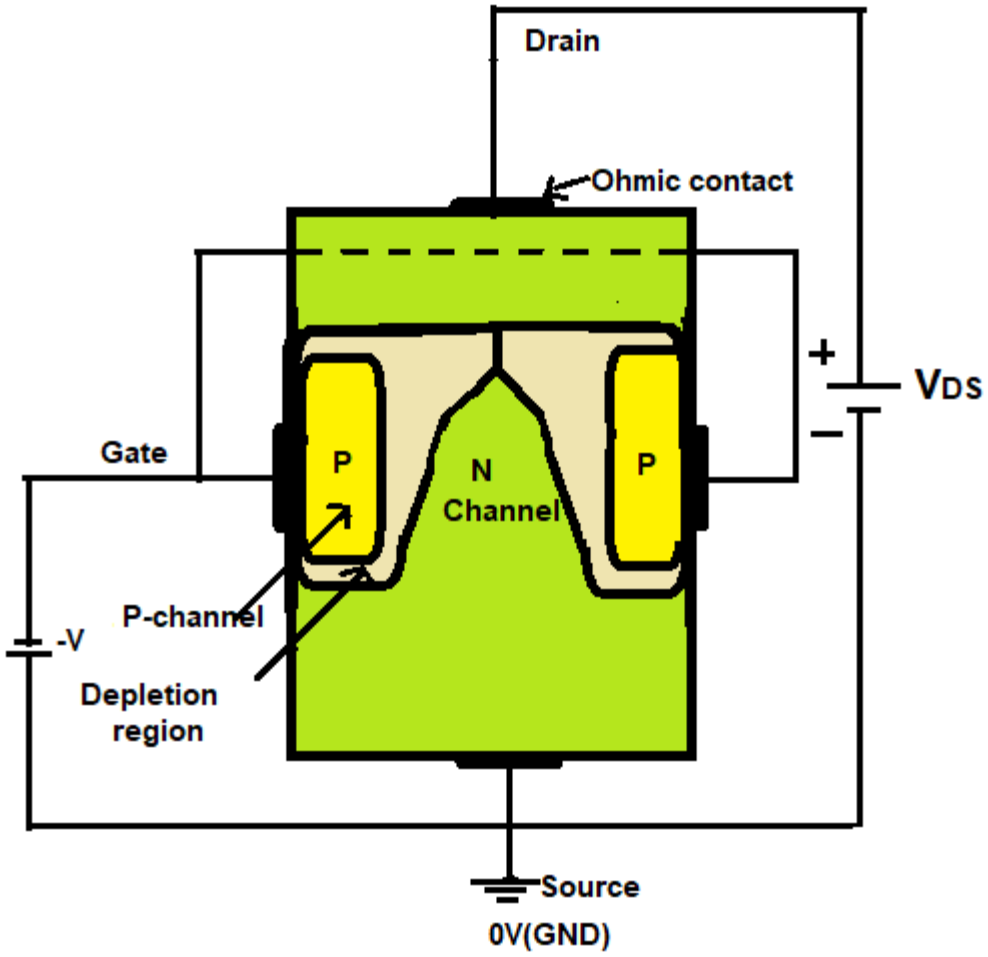
voltage and Drain is connected to the positive terminal(+).The electrons flow from Source to Drain and in the opposite direction the drain current(Id) flows from drain to source.

When the potential difference or voltage increases across the drain to source terminal ,the drain current also increases.Current conduction when electric field is applied so JFET is called Voltage Controlled Device.The width of the depletion regions near the Drain terminal(+ve) increases as most of the negative chage carriers electrons accumulates near the Drain terminal which is connected to the positive terminal of DC voltage.The N-channel decreases when width of the depletion layer near the drain increases and current remains constant.



N-channel JFET($V_{GS=-ve\ V}$ & $V_{DS>0V}$)

When negative(-ve) voltage applied to the gate terminal the drain current is reduced.As the gate voltage V_g becomes more negative the depletion layer near to the drain widens and at certain negative voltage both the depletion region meet.Thus does not allow the current to flow from drain to source.So in this condition the transistor is in OFF mode.

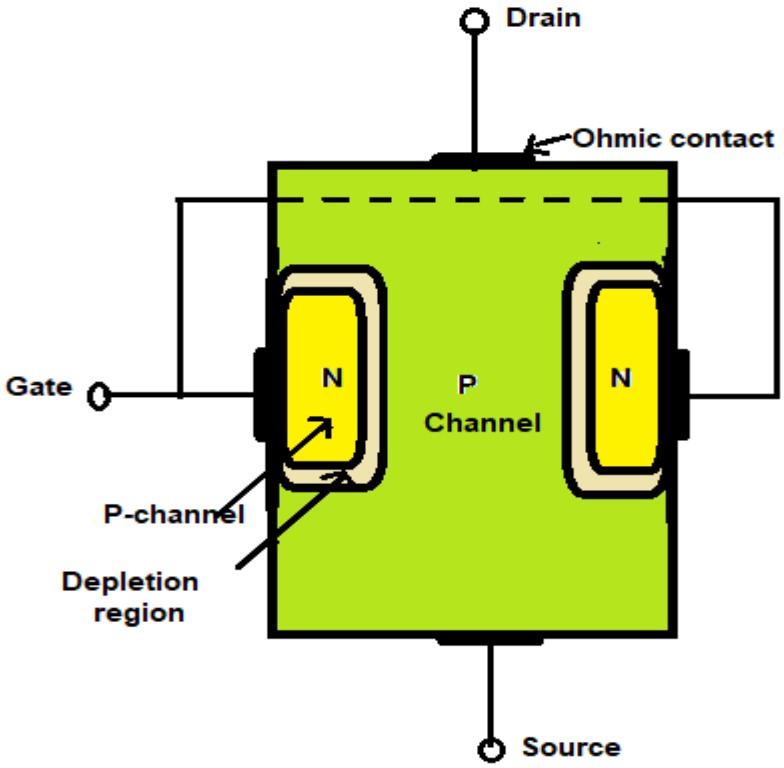


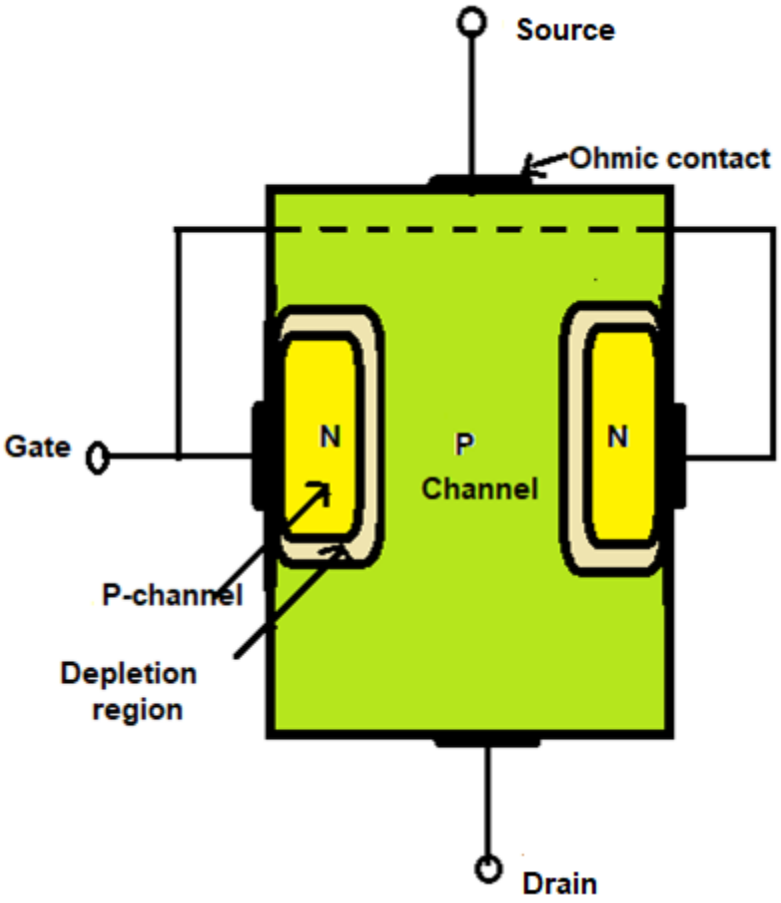
P-channel JFET

The major part of the P-channel JFET structure is p-type material and it is forming a channel between two n-type material.

It consists of two pn junction.

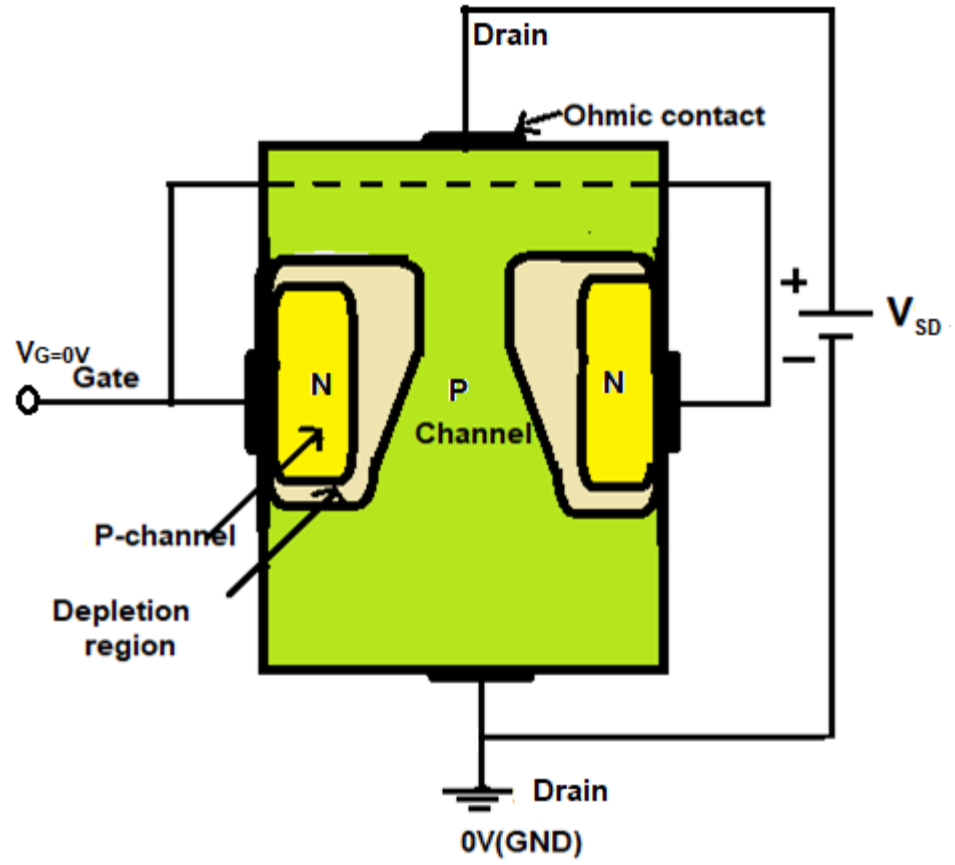
It has two depletion region (no free charge carrier in the region).The current flow from source to drain due to the movement of holes.Here current conduction is due to the holes.


Drain
Ohmic contact
Gate
N
P
Channel
N
P-channel
Depletion
region
Source



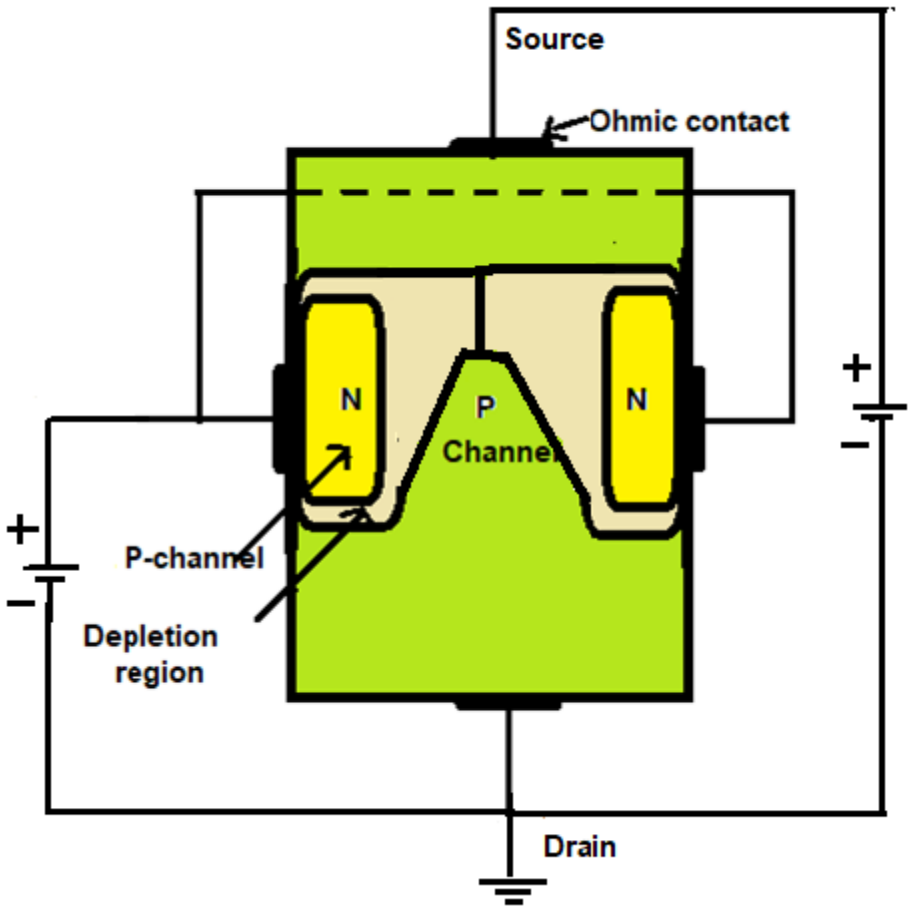
P-channel JFET($V_{G=0V}$ & $V_{SD>0V}$) (ON condition)

When no voltage is given to the gate terminal of P-channel JFET and potential difference applied across the Souce to Drain where the Source is connected to the positive terminal and Drain is connected to the negative terminal so the holes flows freely in the channel from Source to Drain.The direction of current flow is same as the holes flow.



P-channel JFET($V_{G=+ve}$ & $V_{SD>0V}$) (OFF condition)

When a positive voltage is applied to the gate,the source-drain current is reduced as we increase the positive voltage across the gate terminal the width of the depletion regions increases and at certain positive voltage across the gate terminal ,both the depletions regions widens meets near the source terminal .Thus no current flows from source to drain.



Applications of JFET transistors:-

Electronic switches,amplifers,chopper,oscillator,filters ,current limiter circuits etc.

MOSFET

Metal Oxide Semiconductor Field Effect Transistor is a four terminal semiconductor device used for switching and amplification of signal. The four terminals are Source, Gate, Drain and Substrate/body. The body of the MOSFET is connected with the Source terminal forming a three terminal device.

It has insulated gate terminal. The gate insulated with Silicon dioxide(SiO_2) with the body of the MOSFET.

MOSFET transistors are of two types:-

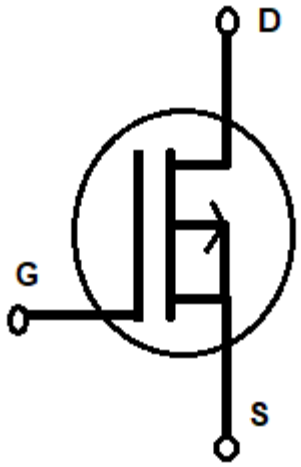
Enhancement Type

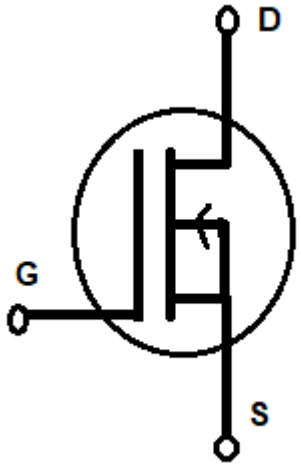
i. N-channel ii. P-channel

Depletion Type

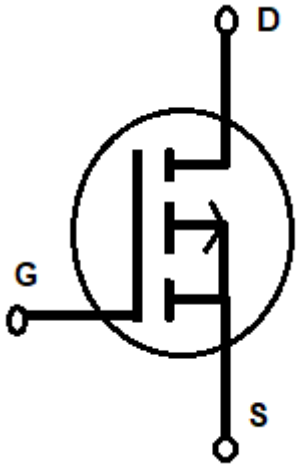
i. N-channel ii. P-channel

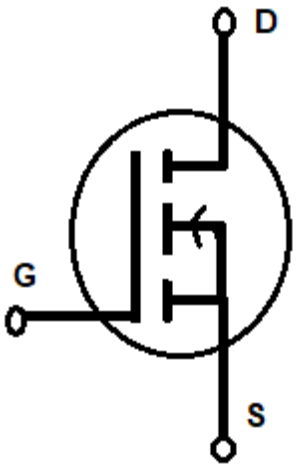
Electrical symbol of MOSFETs:-





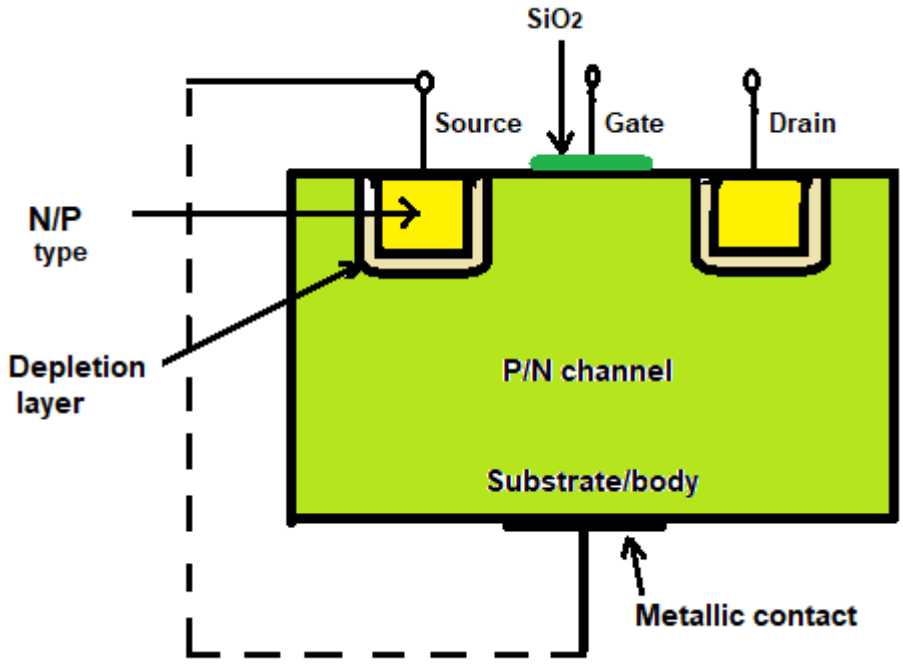
P-channel Enhancement MOSFET N-channel Enhancement MOSFET





P-channel Depletion MOSFET N-channel Depletion MOSFET

Construction of MOSFET(Enhancement type)



N-channel Enhancement MOSFET

In N-channel Enhancement type MOSFET there is no channel between the Drain and Source. If the voltage is applied across the Drain to

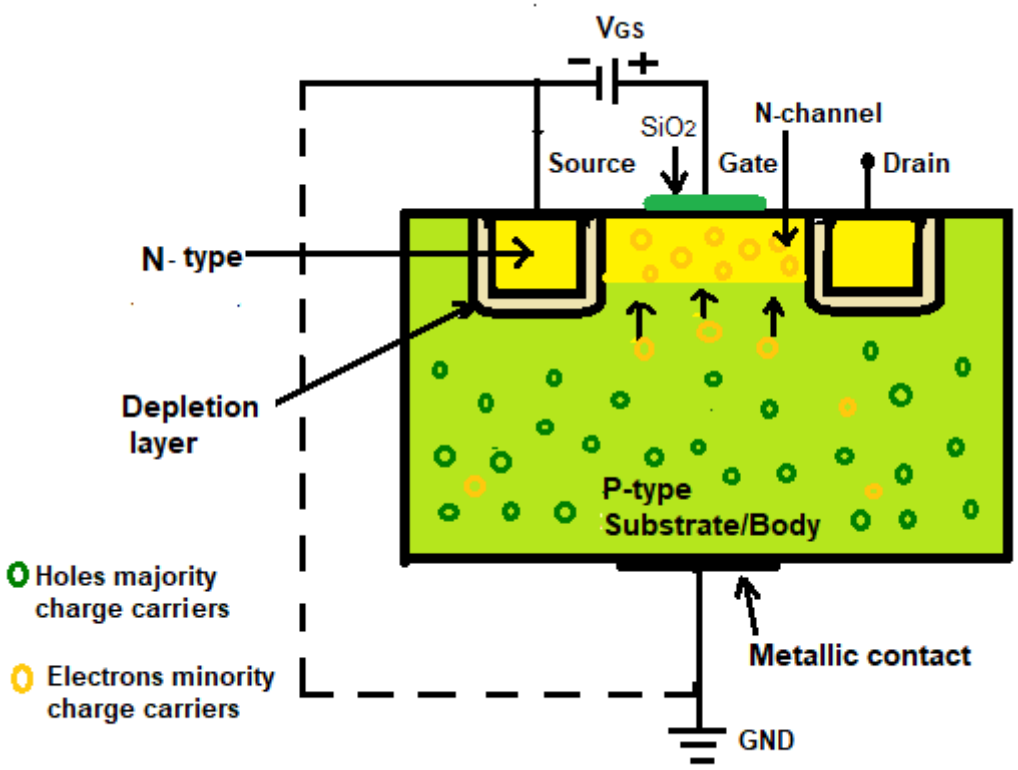
Source terminal(V_{DS}) the current does not flow due to reverse bias between the Drain and the Substrate body. If the Source is at higher potential and Drain at lower potential then also current does not flow.

For the flow of current from Drain to Source we need to create a channel between the Drain and Source and this is possible if we apply voltage in the Gate terminal.

If applying higher potential(+) to Gate terminal and lower potential to Source terminal(-) then the minority charge carrier electrons moves towards the higher potential.So the electrons accumulates near the gate terminal.The more increase in voltage(V_{GS}) the more electrons accumulation near the gate region separated by insulator(SiO_2).The SiO_2 which is an insulator act as dielectric between the Gate and the channel just like a dielectric in a capacitor.

When a voltage is applied due to the electrostatic field or electric field the charge carriers accumulates/attracted near the gate region.

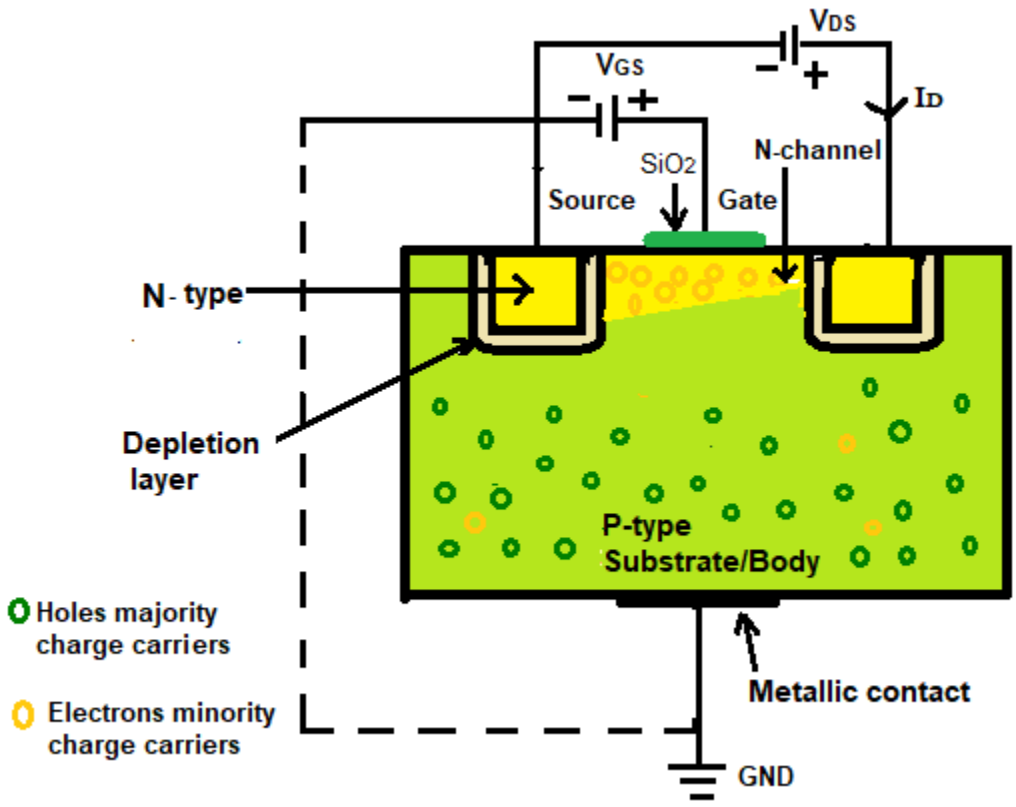
Figure shown below when voltage is applied (V_{GS}) the N-channel is formed between the Drain and Source.



After a certain increase in voltage(V_{GS}) the accumulated electrons form the channel between the Drain and Source and that voltage is called threshold voltage(V_{th}).

If applying voltage across V_{DS}, where V_D at higher potential(+) and V_s at lower potential(-) then the current I_D flows from Drain to Source.If we increase the voltage V_{DS} the current also increases.

If V_{DS} increases the reverse bias between the P-type body/Substrate and N-channel Drain terminal increases that narrows the channel near the Drain side.Depletion region also increases with increase in reverse bias.So narrow the channel the resistivity of the channel increases and that makes the current saturated(constant).

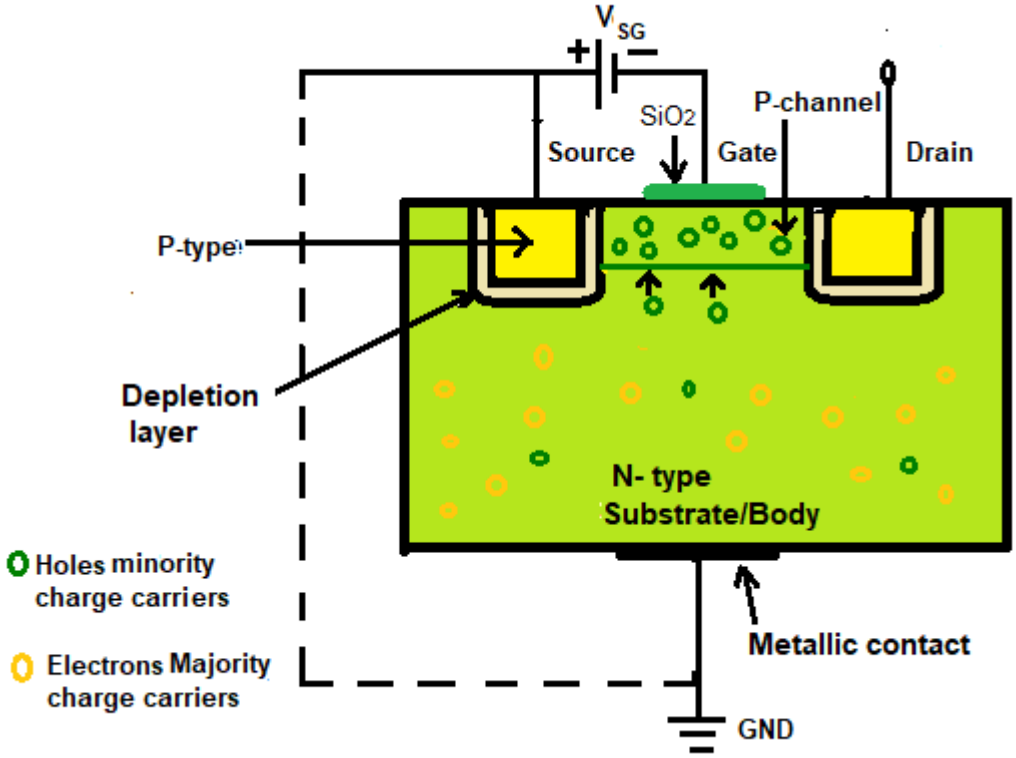


To turn off the current flow in this transistor if the positive voltage across the gate is removed(OFF condition).

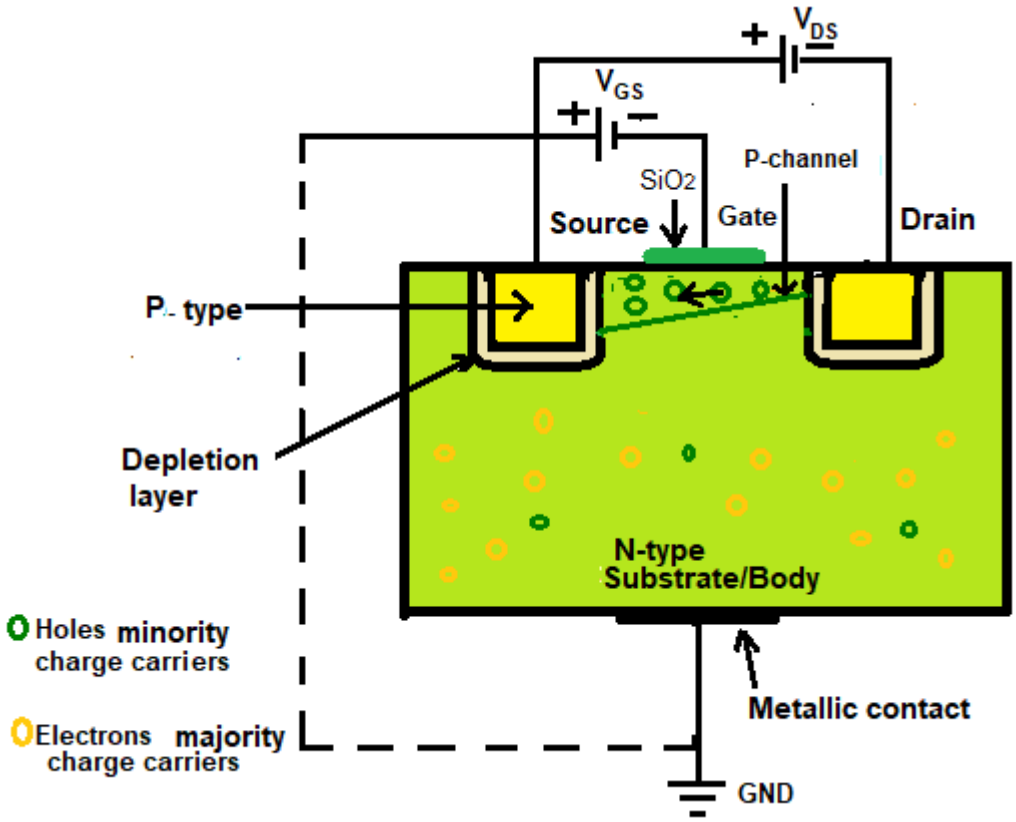
P-channel Enhancement MOSFET

The working mechanism of P-channel Enhancement MOSFET is similar to N-channel enhancement MOSFET,the only difference is in the polarities of applied voltages.In P-channel enhance type MOSFET a positive voltage V_s is applied to the Source and negative voltage is given at the Gate terminal.Then the Minority charge carriers holes in the N-type body moves towards the gate terminal.With increase in negative voltage the holes starts accumulating near the Gate region.

After a certain increase negative voltage the holes forms the channel between the Drain and Source and that voltage is called threshold voltage(V_{th}).



Applying voltage(V_{DS}) to the Source at higher potential(+) and Drain at lower potential(-) then the current flows from the Source to Drain.



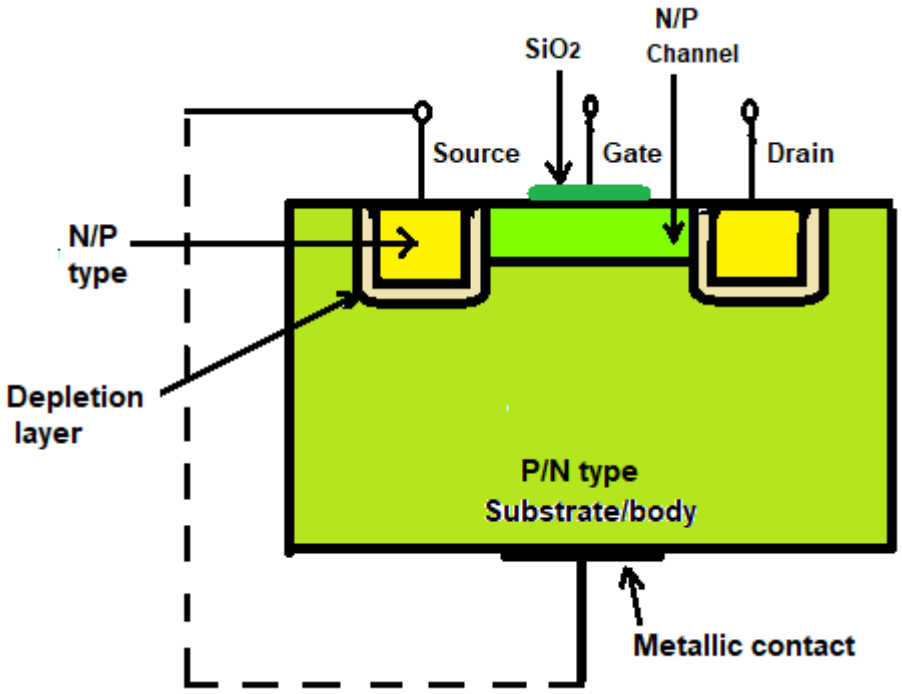
If we remove the negative voltage V_G at the Gate terminal the current stops flowing from Source to Drain (OFF condition)

Depletion type MOSFET

In Depletion type MOSFET there is a channel present between the Drain and Source terminal. The construction of the Depletion type MOSFET shown below in the figure.

In N-channel Depletion MOSFET, the N-channel is present between the Drain and Souce.In P-channel Depletion MOSFET,the P-channel is present between the Drain and Source.Here the channel connects the Drain and Source.Unlike in Enhancement type MOSFET which requires

Gate voltage for the formation of channel between the Drain and Source.



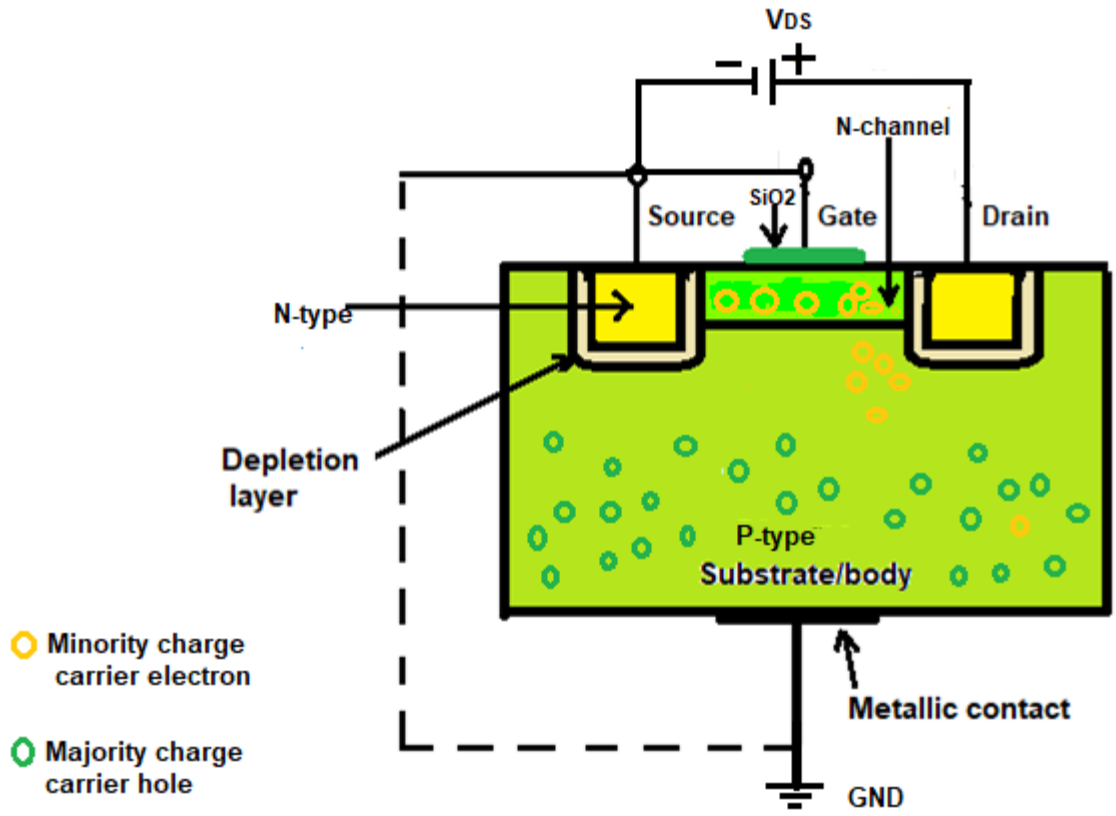
Depletion type MOSFET construction

N-channel Depletion MOSFET

When the voltage is applied between the Drain(+) and Source(-),the current flows from Drain to Source.Here there is no requirement of Gate voltage for the flow of current.The Gate terminal is grounded.As we increase the voltage V_{DS} the current I_D also increases.The minority charge carriers electrons accumulated near the positive drain terminal.On further increasing V_{DS} the current is saturated(constant).

When voltage is applied across Gate to Source terminal i.e, V_{GS}>0V.The minority electrons from the P-type will get attracted towards the Gate terminal ,thereby increasing the concentration of electrons in the N-channel,so here maximum current will flow from the Drain to Source.

Figure below when V_{DS} >0V and V_G=0V,The current I_D flows

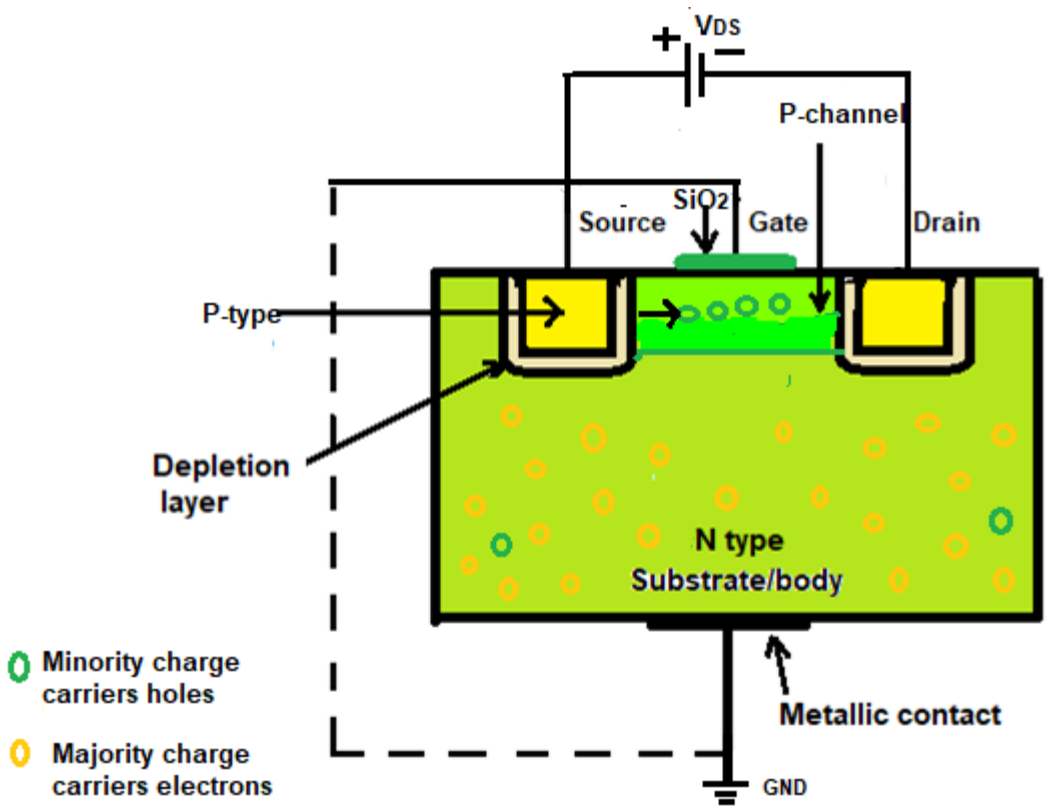


The transistor will be OFF condition if negative voltage is applied to the Gate terminal**(V_{GS}).**The negative terminal Gate will attract the holes from the body/Substrate there by forming the electron-hole pairs in the N-channel.On increasing negative potential at the Gate more electron – hole combinations will occur decreasing the free electrons in the N-channel as a result current also decreases. After a certain further increase in negative voltage the current will become zero i.e. no current flow.

P-channel Depletion MOSFET

P-channel Depletion type MOSFET consists of P-channel between the Drain and Source.When negative voltage applied(V_{DS}) applied across the Drain to Source terminal and Gate is grounded(V_{GS}=0V) the minority charge carriers holes will move towards the negative Drain terminal and the current flows from Source to Drain.

Further increase in negative voltage the depletion region increases and the channel resistivity increase that restricts increase in current.The current is saturated.



When negative voltage(V_{GS}=0V) is applied at the Gate terminal then the maximum current flows from source to drain.

When positive voltage is applied(V_{GS}>0) is applied at the Gate terminal then the electrons from the substrate moves towards Gate terminal in the P-channel region forming electron-hole pairs .On increasing positive voltage at the Gate more electron-hole combinations will occur decreasing the number of free holes in the P-channel as a result current decreases.After certain increase in positive voltage the current is zero thus the transistor is in OFF condition.

Application of MOSFETs:-

Electronic switches, power circuits, amplifiers, ICs, choppers, converters,digital circuits.