Basics of Electronics Engineering (EC142)

Metal Oxide Semiconductor FET (MOSFET)

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- Introduction to MOSFET
- Depletion Type MOSFET
- Circuit Symbol of DE MOSFET
- Working of DE MOSFET
- Enhancement Type MOSFET
- Circuit Symbol of EN MOSFET
- Working of EN MOSFET
- Characteristics of DE MOSFET and EN MOSFET
- Comparison of JFET,MOSFET and BJT

Introduction to MOSFET

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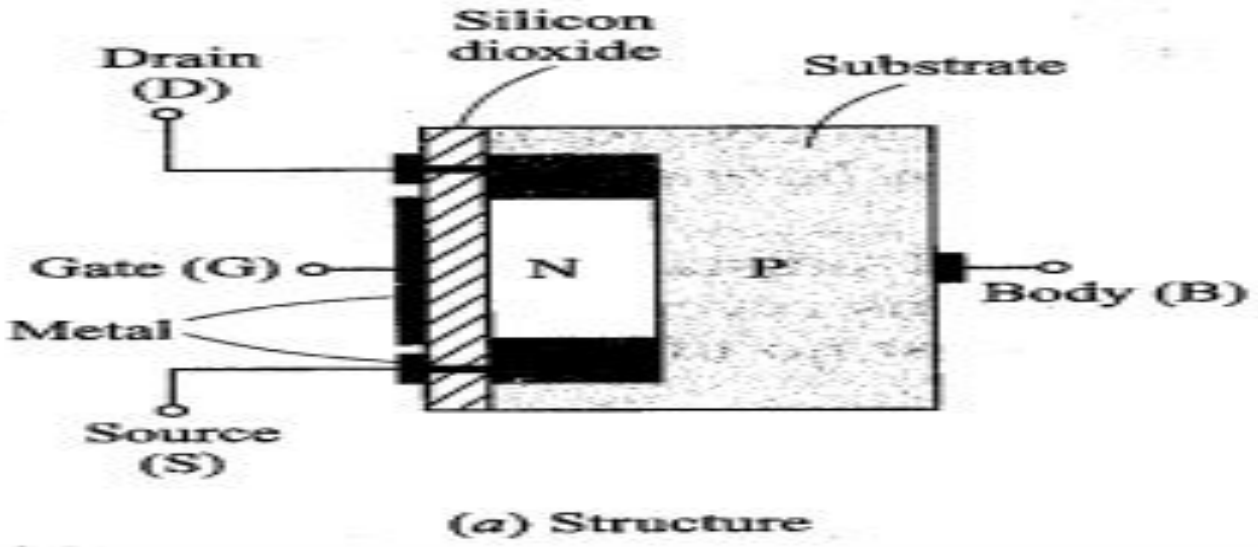
- MOSFET(***Metal Oxide Semiconductor Field Effect Transistor***)
- Has Drain(D), Source(S), and Gate(G). and body.
- Conductivity of MOSFET controlled by Gate to Source Voltage, V_{GS}.
- MOSFET differs from JFET that its terminal is electrically insulated from its channel region,is also called ***Insulated Gate Field Effect Transistor(IGFET).***
- Two types of MOSFETs

  (a) Depletion type (DE MOSFET)
  (b) Enhancement type (EN MOSFET)

Depletion Type MOSFET

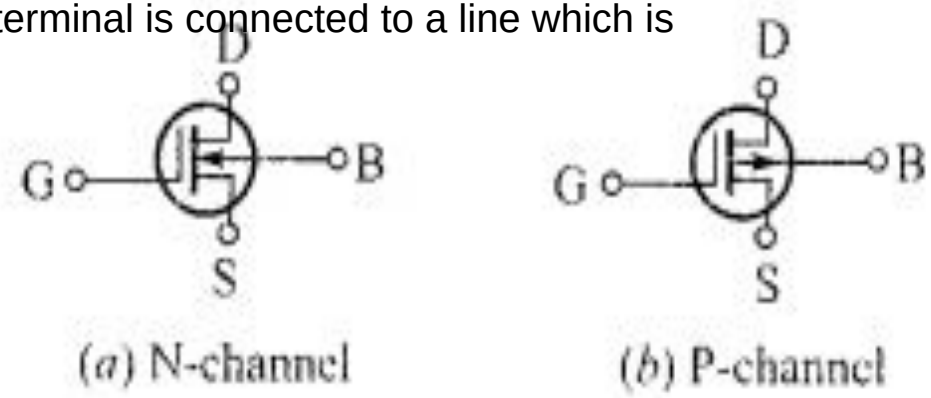
- Silicon oxide layer insulates the gate from the channel.
- P channel DE MOSFET is made from a lightly doped N substrate.
- Drain and Source are heavily doped P^+ (two heavily doped P type wells) in between these well, there is a lightly doped P region which makes the channel.
- N-Channel Depletion type MOSFET



(a) Structure

Circuit Symbol of DE MOSFET

- Thick Vertical line representthe channel.
- Arrow drawn on the body terminal and points from P to N.
- For N channel arrow is inward, for P channel arrow is outward.
- Gate terminal is connected to a line which is seperated from solid th



(a) N-channel (b) P-channel

Working of DE MOSFET

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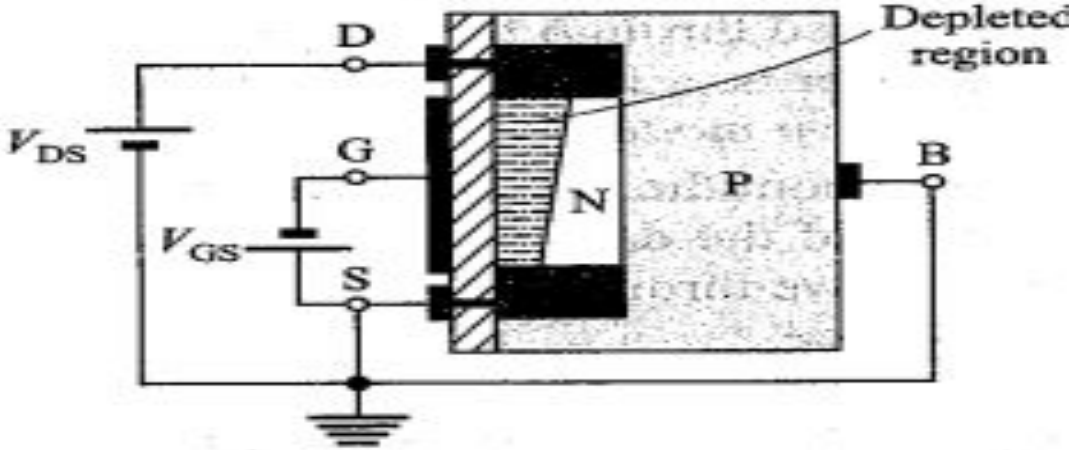
- V_{DS} is connected b/w Drain (D) and Source (S). Body (B) connected to the source (S).
- Gate is negative w.r.t source by connecting V_{GS}.
- E/F is created in channel and field repels e^- away from portion of the channel and width is reduced.
- Narrower the channel,greater it resistance ,smaller is the current from drain to source.
- By varying V_{GS} the drain current can be controlled.
- This is similar to N channel JFET difference is that in MOSFET the channel width is controlled by action of E/F, in JFET width is controlled by size of depletion region of the reversed biased PN junction

Working of DE MOSFET

- when V_{GS} is made positive field attracts more electrons into channel from N^+ region which increases the conductivity of the channel as result drain current increases.
- In DE MOSFET the gate voltage can be vary through both negative and positive values to control the drain current .
- DE MOSFET is capable of working in both depletion and the enhancement mode.



(b) Working principle

Circuit Symbol of EN MOSFET

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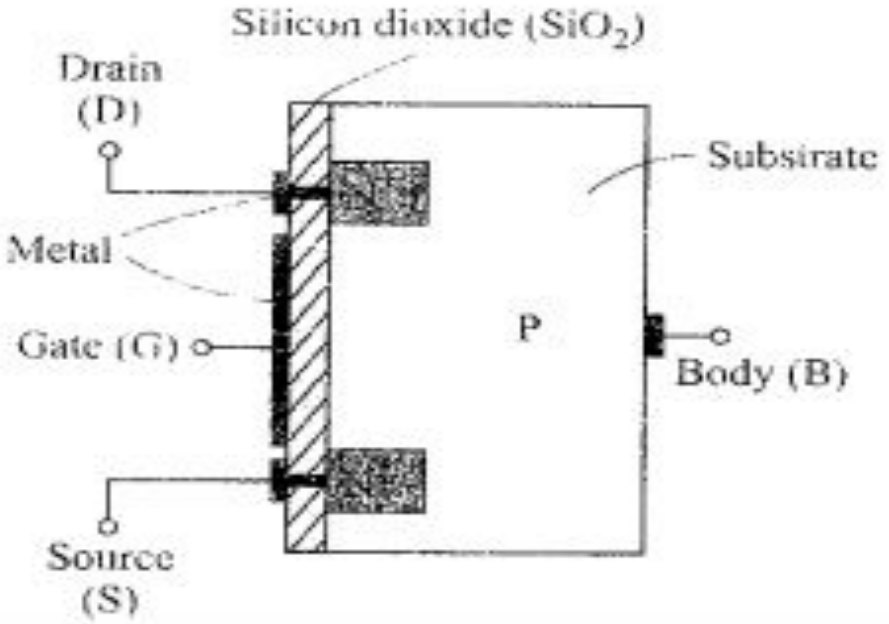
- The vertical solid line denotes the gate electrode.
- The vertical broken thick line denotes channel.
- Spacing between gate and channel represent insulating Sio_2 layer.
- The arrow head on line represnting substratepoints from P to N.

(a) N-channel (b) P-channel

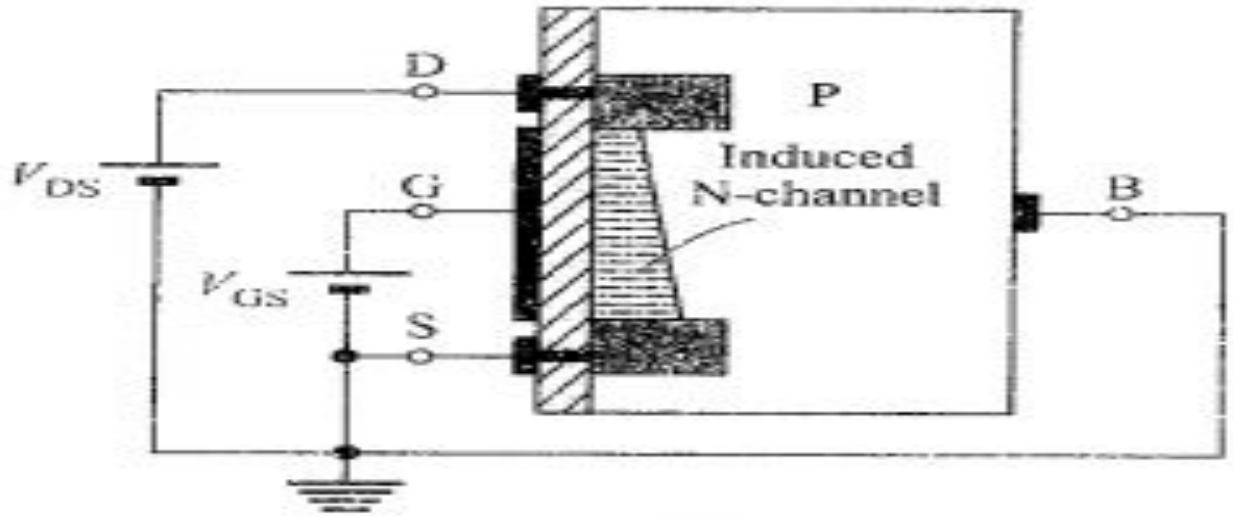
Enhancement Type MOSFET

- There is no N type material between the Drain and Source.
- P type substrate extends all the way to the Sio_2 layes adjacent to the gate.
- V_{GS} is connected ,gate repels holes from the region ,this leaves behind a depletion region containing negative immobile ions.



Enhancement Type MOSFET

- if V_{DS} is applied a current flows from drain to source through N region and induced N region acts as channel for the current flow and MOSFET called ***N channel MOSFET*** or ***NMOS Transistor.***
- NMOS Transistor is formed in P type substrate, the channel created by inverting the substrate from P Type to N type, induced channel is called ***Inversion Layer.***



(b)

Enhancement Type MOSFET

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- The minimum voltage V_{GS} at which suffcient no. of electrons acumulates in the channel is called ***threshold voltage*** $\boldsymbol{V_T}$.
- Once channel formed, on applying v_{DS} causes free electrons to travel from S To D, a small current i_D.
- At $\boldsymbol{v_{DS}=V_T}$, the channel is just induced.
- As v_{DS} is increases beyond V_T, the conductivity of channel increases and results current i_D also increases.
- As continue to increases v_{DS} the channel starts becoming narrower at the drain end, field at drain end reduced to almost zero,the channel is ***pinched off.***
- if we increases v_{DS} beyond the point ,the channel shape remains almost same and current remains constant and MOSFET enters ***saturation or active region***.

Output Characteristics of N channel DE MOSFET

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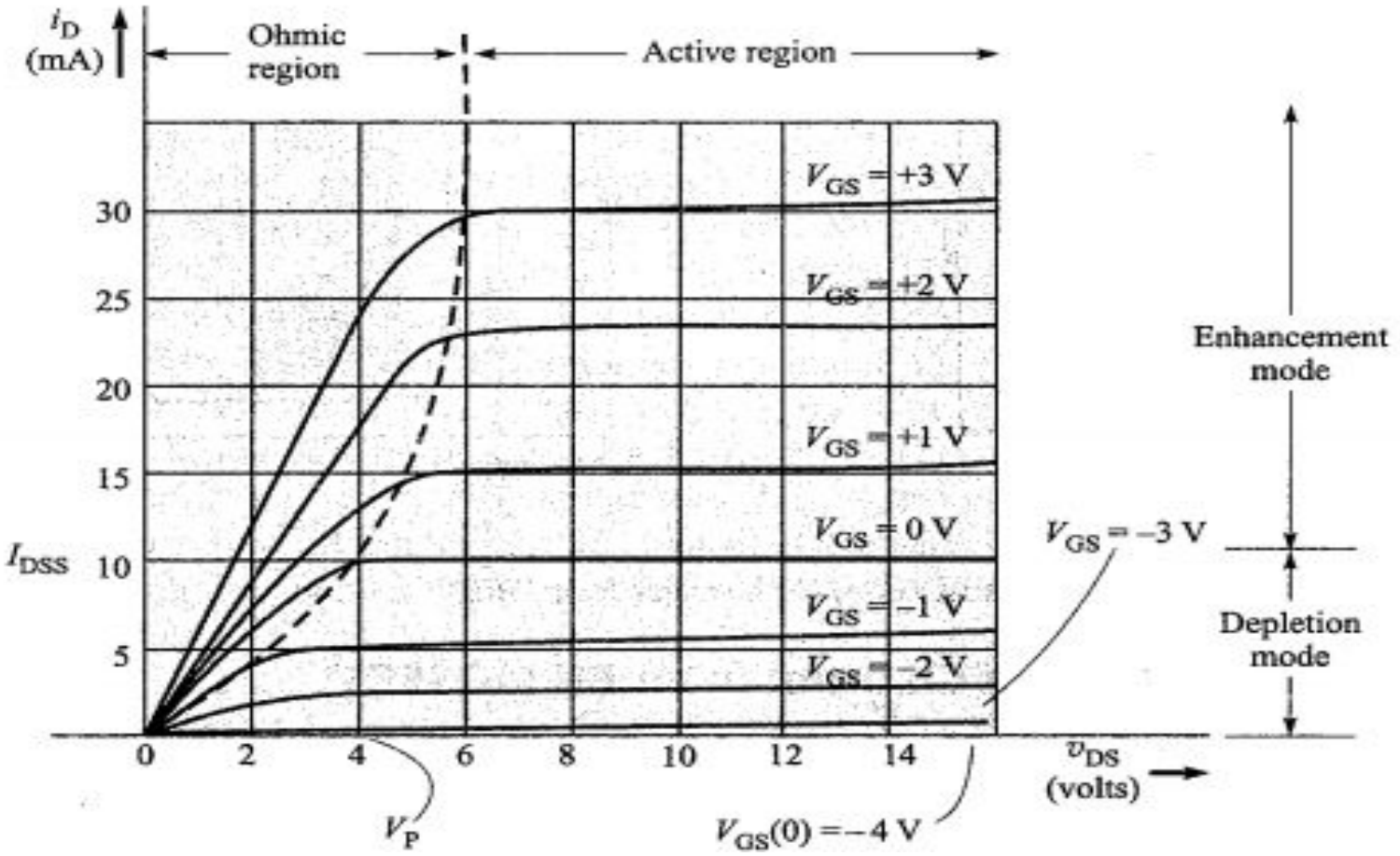

Output Characteristics of EN MOSFET

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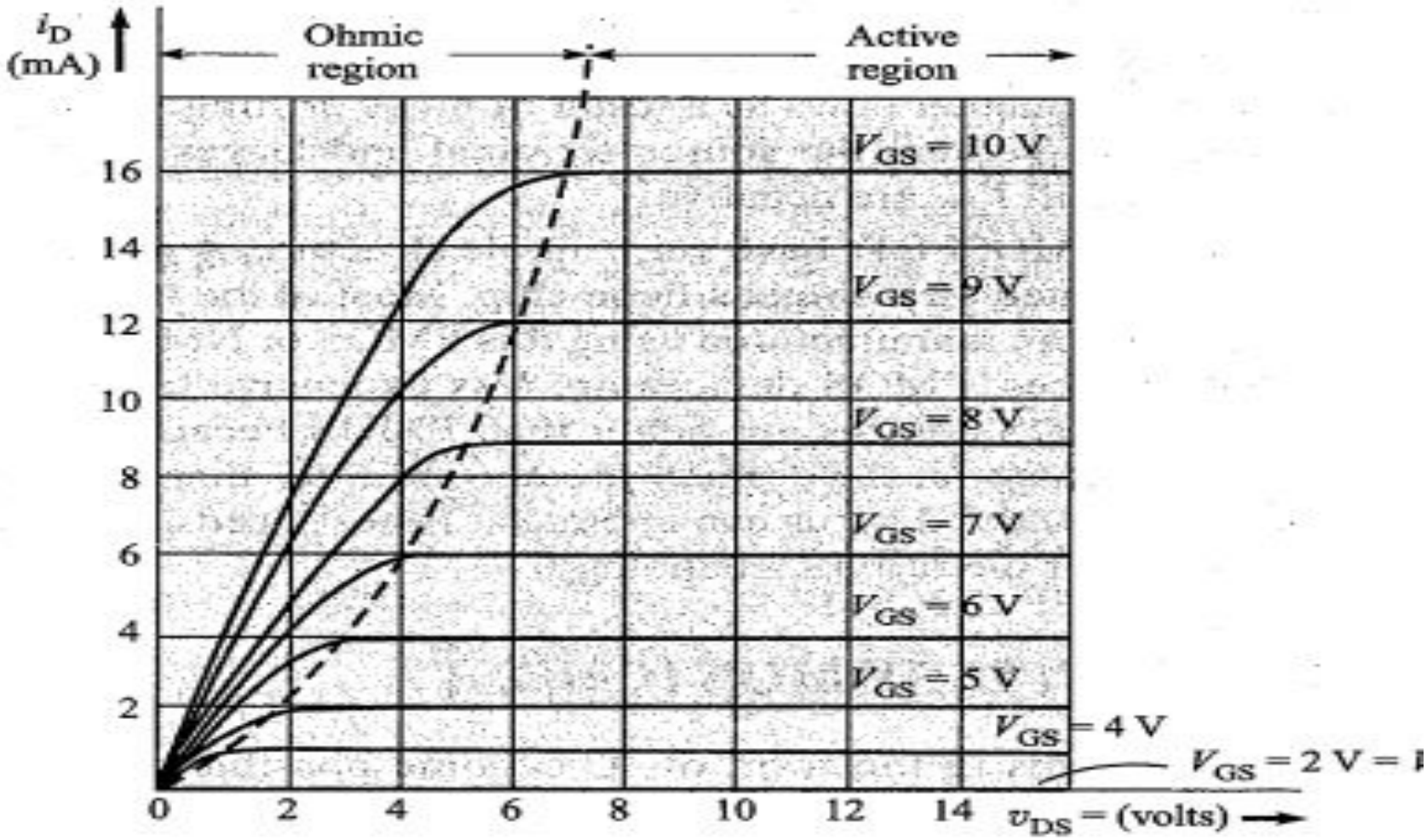

Comparison of BJT, JFET and MOSFET

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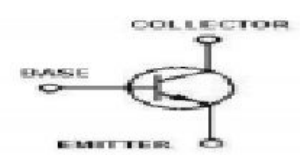
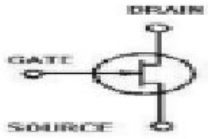
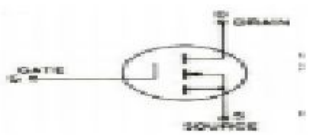
Parameters	Bipolar Junction Transistor (BJT)	Junction Field Effect Transistor (JFET)	Metal Oxide Semiconductor Field Effect Transistor (MOSFET)
Symbol			
Definition	BJT is known as Biploar Junction Device because it uses both electrons and holes for conduction.	JFET is known as unipolar device because current is due to one charge carriers i.e. electrons or holes.	MOSFET is known as unipolar device because current is due to one charge carriers depending on type of MOS.
Input Resistance	BJT offers low input resistance.	JFET offers large input resistance order of $1M\Omega$ to $5M\Omega$.	MOSFET offers very large input resistance.
Biasing used	Fixed bias, Collector base bias, Voltage divider biasing.	Self bias& Voltage divider biasing.	In DMOSFET we use self bias and voltage divider biasing, in EMOSFET we use feedback bias and voltage divider biasing.
Operating Region	Active, Saturation & Cut off region.	Ohmic & Pinch off region	Linear & Saturation region
Thermal Runaway	Thermal runaway occurs at high temperature.	No thermal runaway.	No thermal runaway.
Type of device	Current controlled device.	Voltage controlled device.	Voltage controlled device
Terminals	Base, Emitter & Collector.	Gate, Drain & Source.	Gate, Drain, Source .
Input current	Input current is order of mA (milli ampere).	Gate current is order of nA (nano ampere).	Gate current is order of pA (pico ampere).
Applications	Low Current application.	Low voltage application.	Since power consumption is less used in CMOS circuits

How's MOSFETs are better than JFETs

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- A DE MOSFET can be operated in enhancement mode (by simply applying a positive voltage V_{GS},if the device is N channel)but it is impossible to operate a JFET in enhancement mode.

- If we attempt to apply positive voltage V_{GS}(in case of N channel) the gate channel junction becomes forward biased,as a result gate terminate to control the channel.

- If a JFET is operated with reverse bias the gate current is much larger than that in a comparable MOSFET.

Applications of FETs

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- FETs can be used in circuits of amplifier,oscillator.
- FETs can be used as switches in digital circuits.
- FETs can be used as analogue switches in circuits such as sample and hold, amplitude modulation,ADC or DAC converters.
- CMOS is excellent device for use in an inverter circuits.
- FETs when operated in ohmic region, can be used as voltage variable resisitors(VVR).

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Thank You