MOSFET & IGBT

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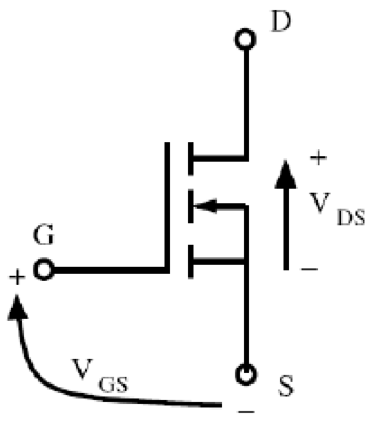
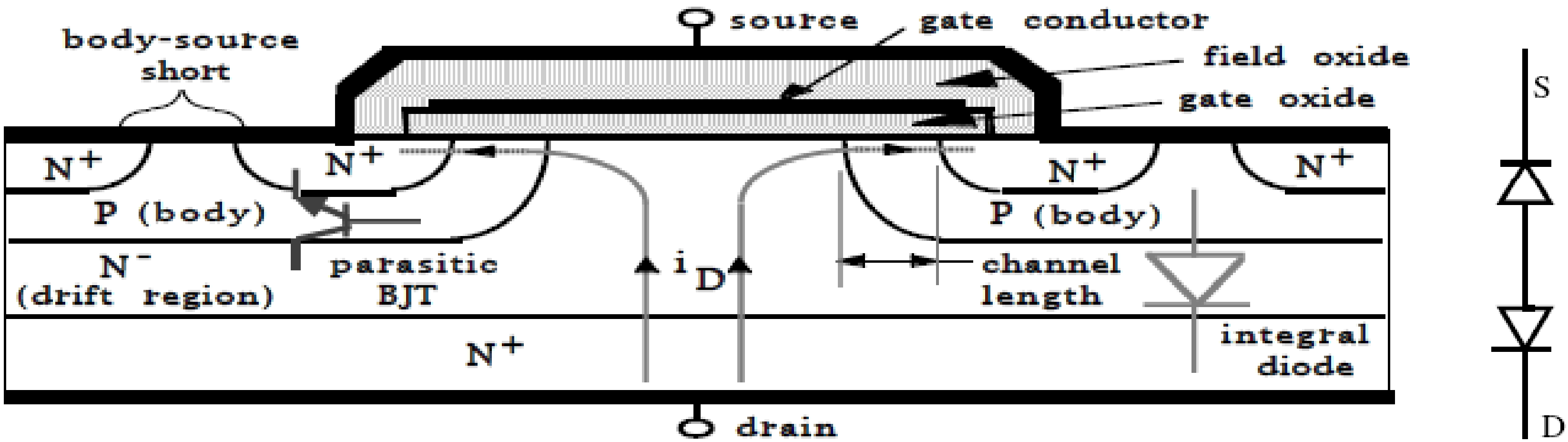
MOSFET

- 1978 : 100V 25 A Power MOSFET
- MOSFET (200V, 500A=> Semikron)
- (60V, 1000A=> Semikron)
- Generally low V and high I device
- Very popular in DC to DC converters
- Metal –Oxide- Semiconductor Field Effect Transistor
- Fast device
- Unipolar device
- Majority carrier device
- Non latching device
- D=> Drain, S=> Source , G= Gate



MOSFET

- Constructional details=> One cell of MOSFET

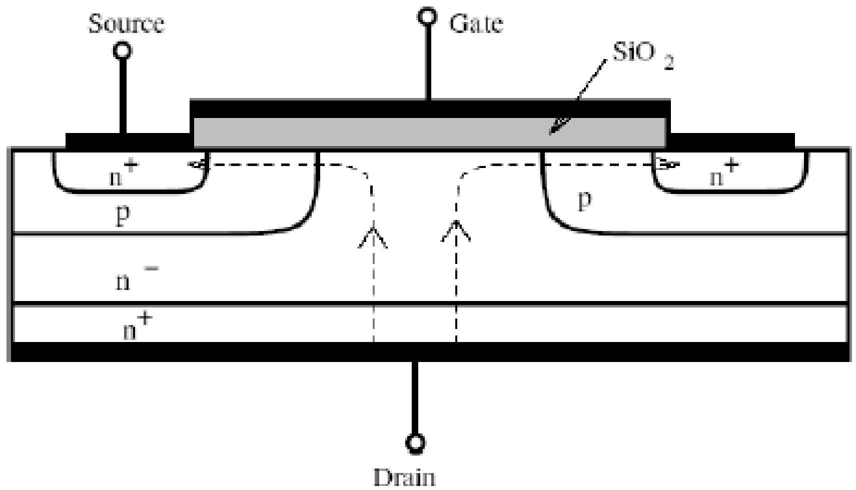


- Gate is insulated from rest of the device
- No steady I => only displacement current
- MOSFET is in cut off when Vgs < threshold value
- When Vgs > threshold value => Convert silicon surface below the gate into N type channel

MOSFET

- N- region => drift region which determines the voltage blocking capability
- Body region is shorted with source=> this used to avoid the turn on of parasitic transistor
- MOSFET turns on by applying VGS= +10 V
- MOSFET turns off by applying VGS=0 V or -5V
- Gate current requirement is in few mA

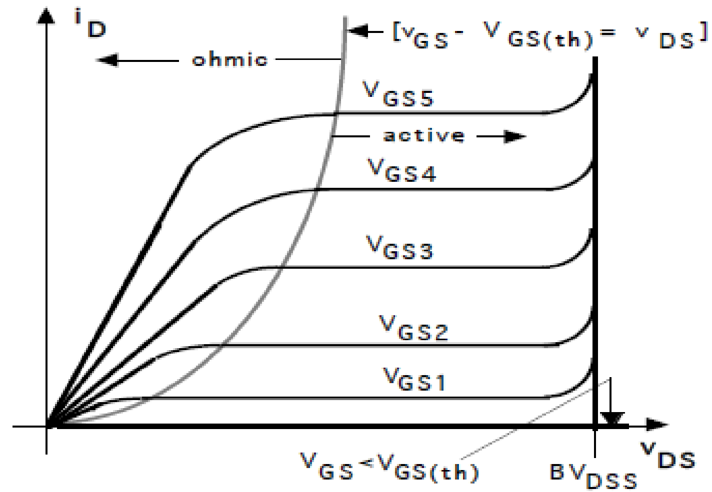
MOSFET

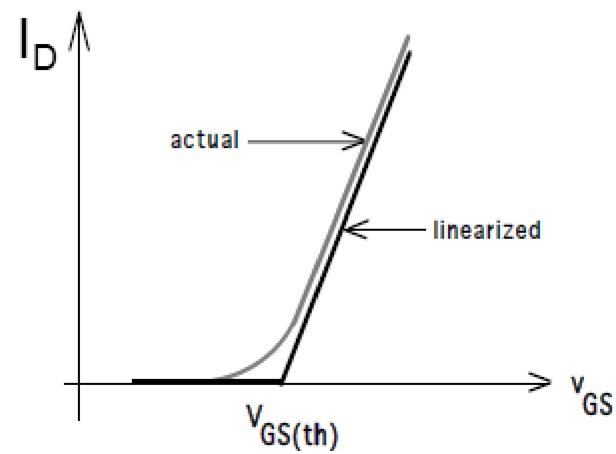


- When Vgs > threshold Voltage
- Connects source to drain
- I starts flowing
- Threshold value depends upon SiO2 thickness
- V_{TH} can be reduced by reducing the thickness of SiO2
- Input impedance is Very High and capacitive in Nature

MOSFET

- O/P characteristics (I_D vs V_{DS})
- When $V_{GS} > V_{TH}$
- Device will in the ohmic region
  power loss is less
- In active region I_D depends
  Only V_{GS}
- Device will be only operated in
  Ohmic region or cut off region
- Transfer Characteristics



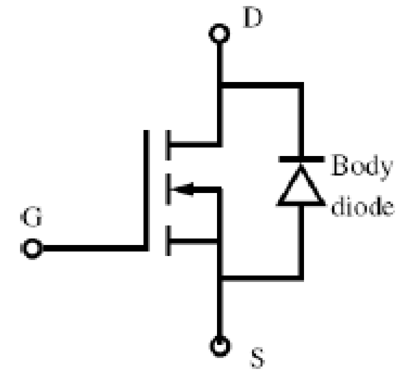


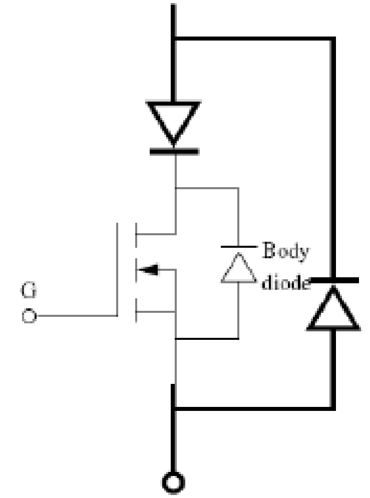
MOSFET

- In on state channel of the device behaves like a resistance $R_{DS(on)}$
- o $$R_{DS(ON)} = \left.\frac{\partial V_{DS}}{\partial i_D}\right|_{V_{GS\ (constant)}}$$
- Conduction loss = $I_D^2\ R_{DS(ON)}$
- Conduction loss of MOSFET is higher than power transistor
- Power loss in MOSFET is higher than power transistor

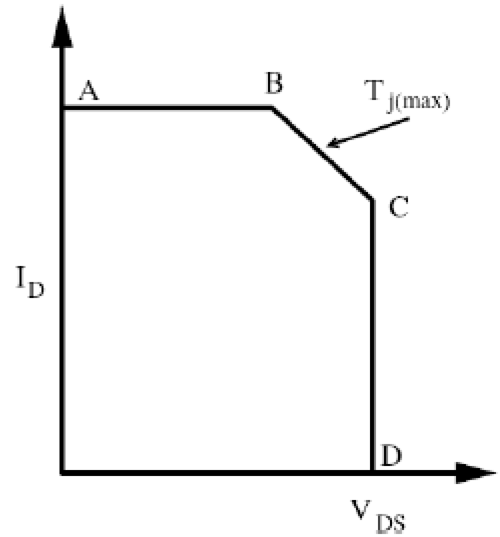
MOSFET

- Internal body diode
- Connected between drain and source
- MOSFET can block only forward voltage
- Current can be bi-directional
- Body diode has adequate current rating
- And switching speed rating
- Some applications require fast diode
- Application=> inverters and choppers





MOSFET

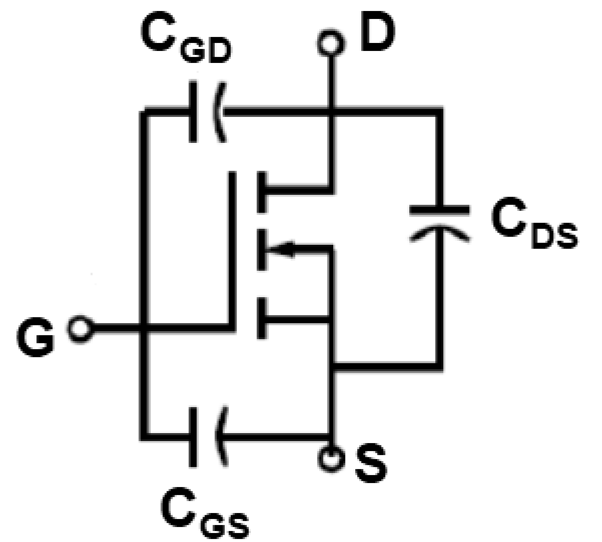


- Safe operating area (SOA)
- No secondary breakdown
- SOA is limited by
- AB => maximum drain current
  at steady state
- CD => Maximum VDS device can sustain
- BC => Maximum power dissipation allowed
  Imposed by RDS(on)
- Has + ve resistance coefficient
- Paralleling is easy

MOSFET

- Internal capacitance
- Parasitic capacitance

  Limits the switching speed
- C_{GS} => dielectric is oxide layer and independent of V_{DS}



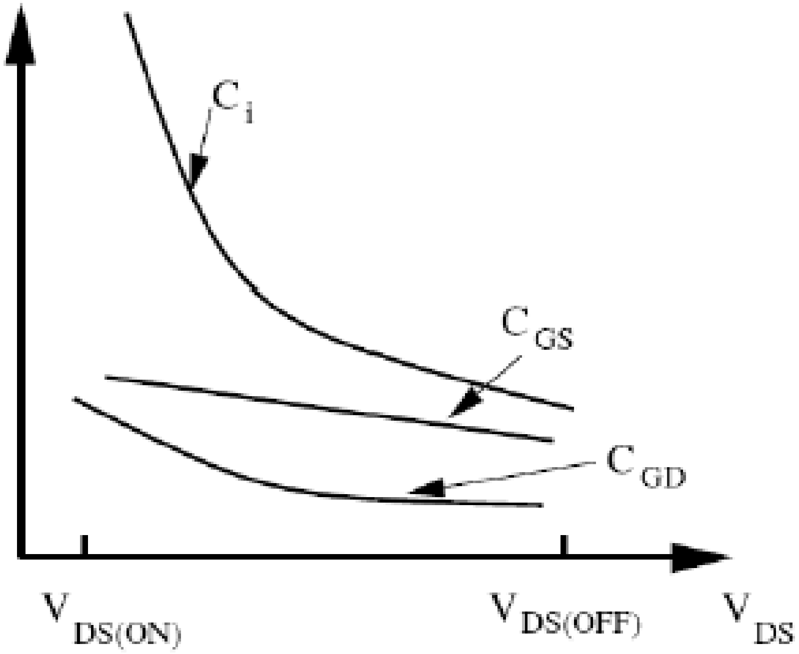
- Gate-Drain capacitance C_{GD}

  Varies considerably with V_{DS}

  Negligible when V_{DS} is high

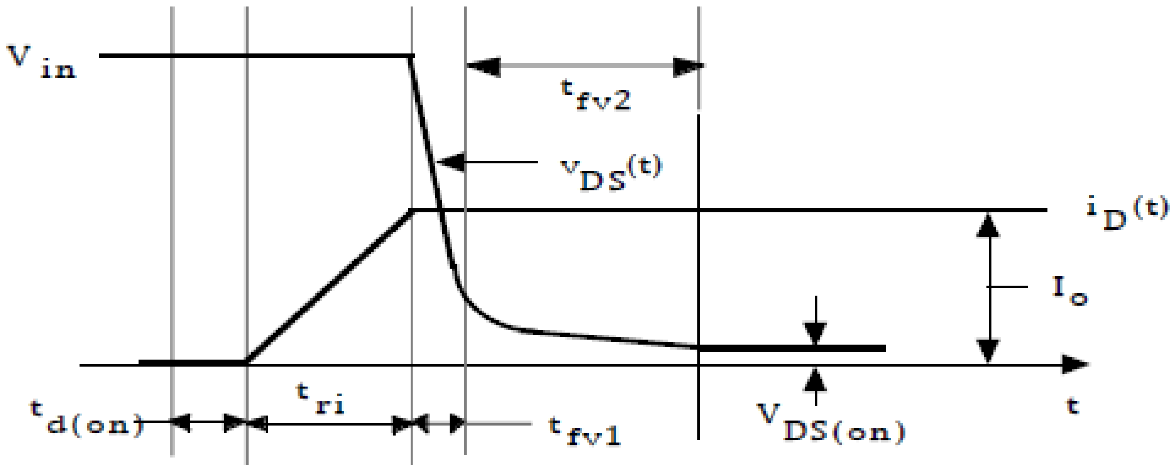
MOSFET

- C_{DS} less important
- C_i = input capacitance
- $C_i = C_{GD}+C_{GS}$
- C_i => Input capacitance in pico -farad
- During turn on C_{GD} &C_{GS} must be charged through gate



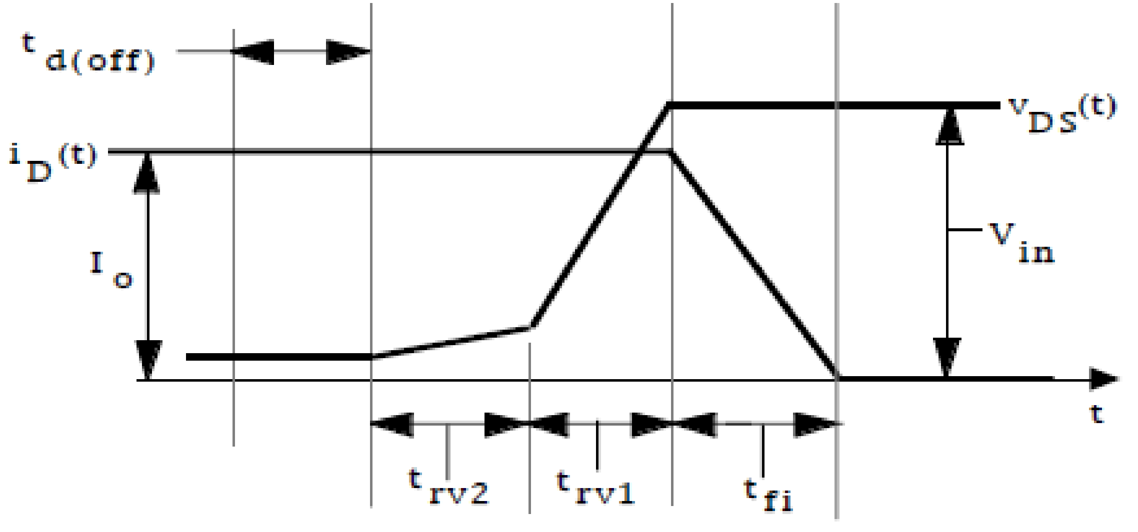
MOSFET

- Turn on characteristics +



- $t_{on} = t_{d(on)} + t_{ri} + t_{fv1} + t_{fv2}$
- Turn on time is in nano-seconds
- Total turn on time => 100 nanoseconds

MOSFET

- Turn off characteristics
- 

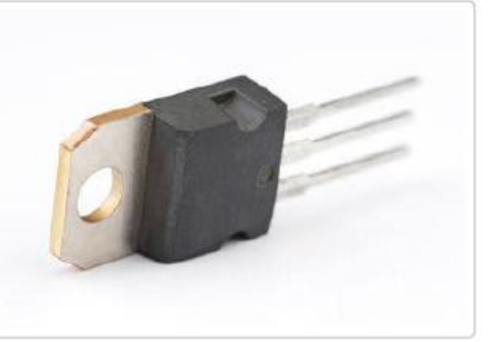
- $t_{off} = t_{d(off)} + t_{rv2} + t_{rv1} + T_{fi}$
- Total turn off time = 160 Nano seconds
- Switching frequency in MHz

MOSFET

Difference between BJT & MOSFET

BJT	MOSFET
1) Current controlled device	1) Voltage controlled device
2) Minority carrier device ∴ has -ve resistance co-efficient.	2) Majority carrier device has +ve resistance co-efficient.
3) Has secondary breakdown	3) No secondary breakdown
4) Paralleling device is difficult	4) Easy
5) On state power loss $(V_{CS(sat)} I_c)$ is low	5) $I_D^2 \, R_{DS(ON)}$ is higher than on state losses of BJT
6) Turn-off time is higher	6) Very fast device

MOSFET Data sheet



IRFP460PBF

Trans MOSFET N-CH 500V 20A 3-Pin(3+Tab) TO-247AC

Description	Value
Channel Mode	Enhancement
Channel Type	N
Maximum Continuous Drain Current	20 A
Maximum Drain Source Voltage	500 V
Maximum Gate Source Voltage	±20 V
Mounting	Through Hole
Operating Temperature	-55 to 150 °C

MOSFET Data sheet

	Description	Value
☐	Product Dimensions	15.87 x 5.31 x 20.7 mm
☐	RDS-on	270@10V mOhm
☐	Supplier Package	TO-247AC
☐	Typical Fall Time	58 ns
☐	Typical Rise Time	59 ns
☐	Typical Turn-Off Delay Time	110 ns
☐	Typical Turn-On Delay Time	18 ns
☐	Voltage	600

Power Transistor

- Advantages
- Power transistor has low on state voltage drop => conduction loss is less.
- Disadvantage
- Power transistor is current controlled device
- +Ve base current to turn on and -Ve base current to turn off
- Turn off gain is low in the range of 5 to 6
- Large -Ve base current for turn off of the device

MOSFET

- Disadvantage
- On state voltage drop and power loss is high
- Conduction loss = $I_D^2 \, R_{DS(ON)}$
- Advantages
- Voltage controlled device
- Gate current is few mA
- Gate drive circuit is simple
- High switching frequency

Insulated Gate bipolar Transistor : IGBT

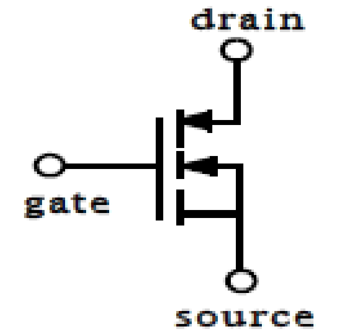
- IGBT has the advantages of both power transistor and MOSFET.
- IGBT has low on state voltage drop => conduction loss is less.
- Voltage controlled device
- Gate current is few mA
- Gate drive circuit is simple
- High switching frequency

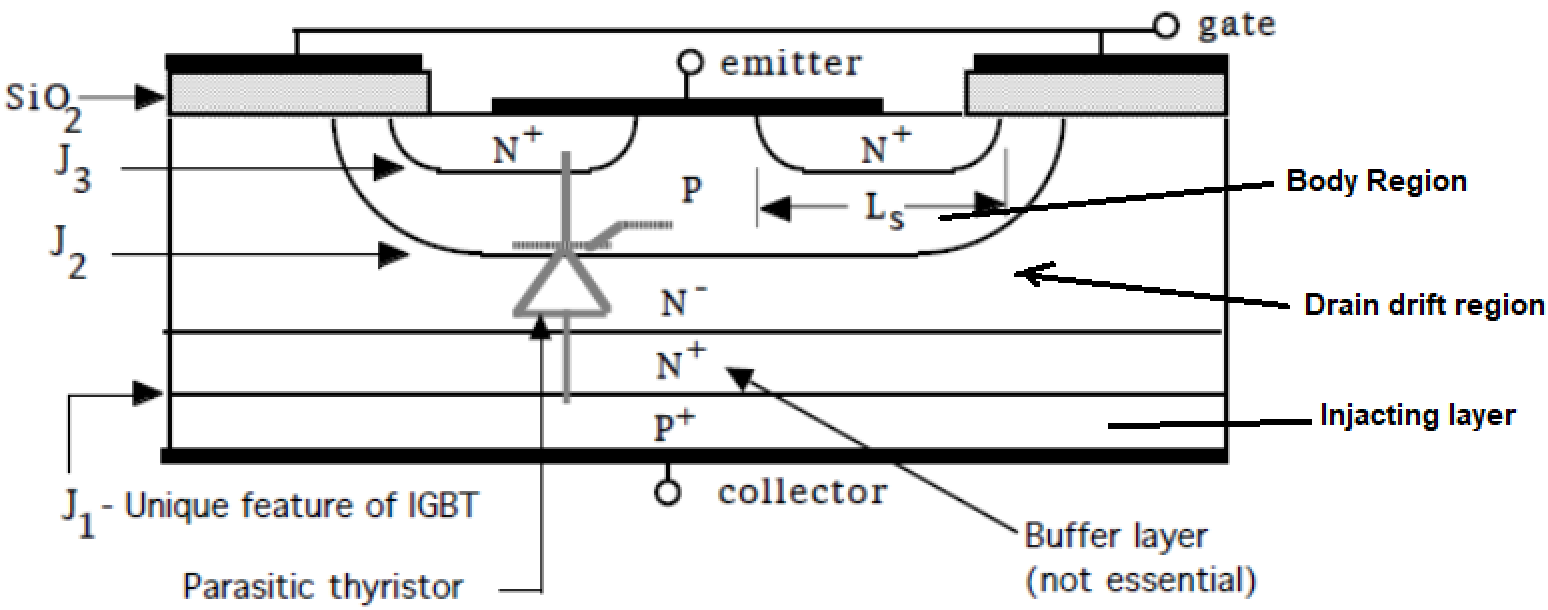
IGBT

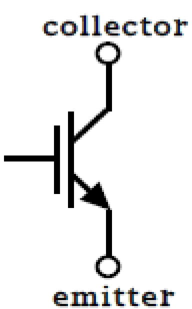
- Power transistor and MOSFET have the characteristics that are complement to each other.
- IGBT=> Combination of good characteristics of MOSFET and IGBT
- IGBT => Insulated gate => similar to MOSFET
- Power transistor => output stage

IGBT : Structure

- Structure

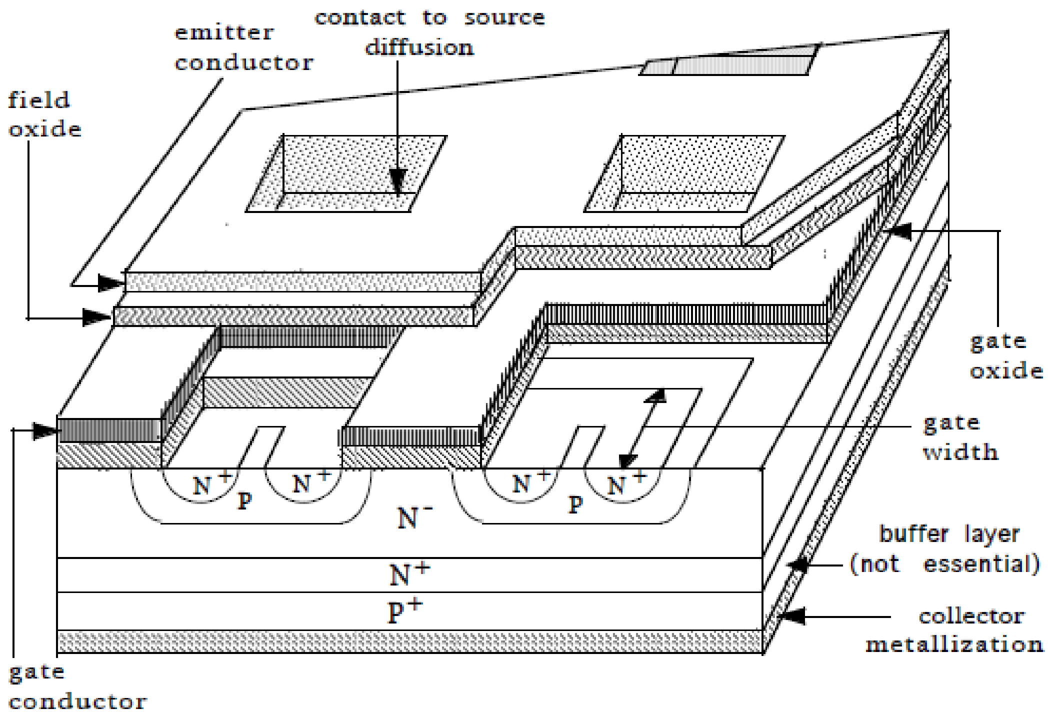






IGBT: Perspective View

- IGBT = insulated gate bipolar transistor.

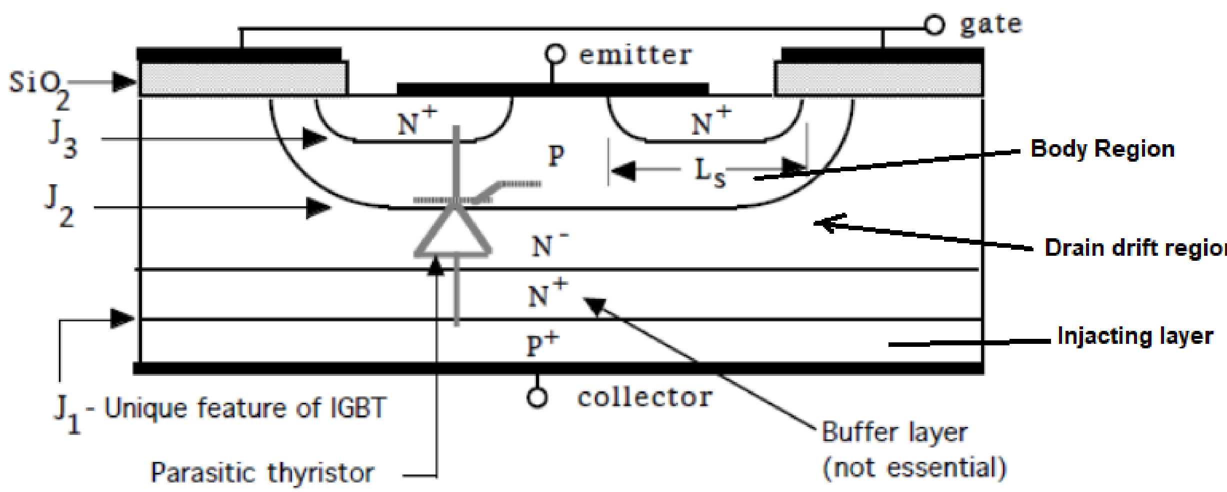


IGBT : Details

- As compared to MOSFET additional P+ layer at drain or collector side => Injecting layer
- Body short structure => parasitic thyristor should not turn on
- Punch through IGBT=> Buffer layer N+ is present => No reverse voltage blocking capability
- Non-Punch through IGBT=> Buffer layer N+ is absent => forward and reverse voltage blocking capability

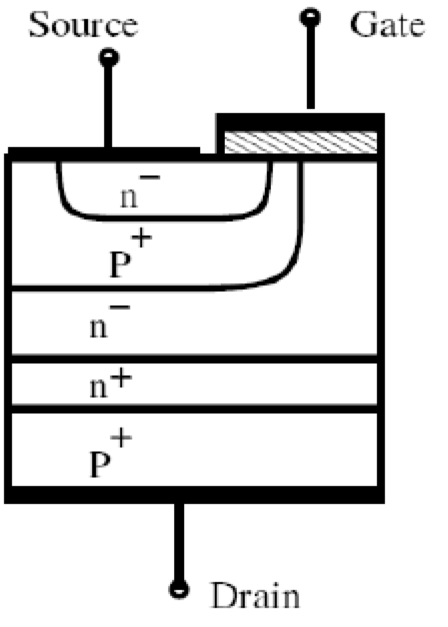
IGBT

- With N+ buffer layer , Junction J1 has small breakdown voltage and very less Reverse voltage blocking capability => punch through IGBT



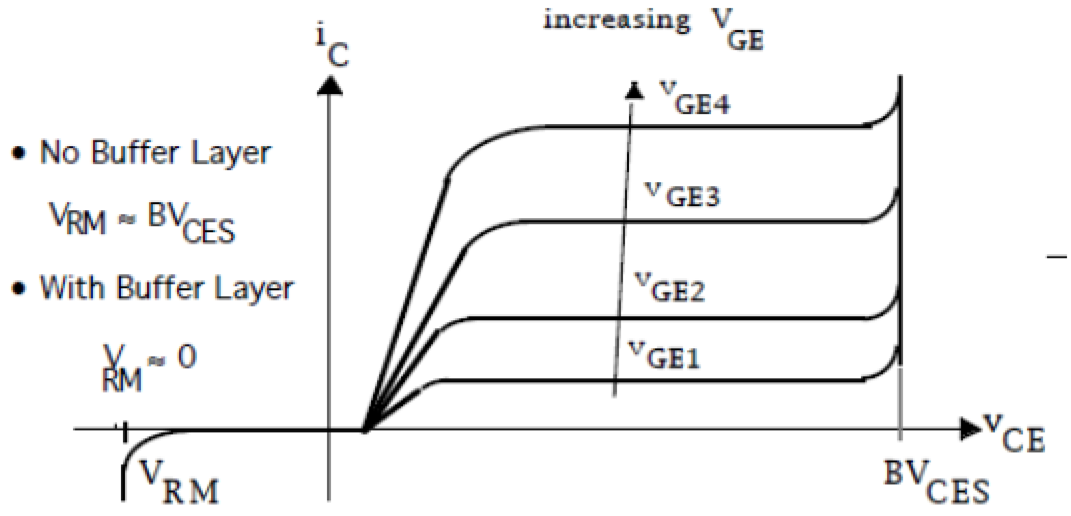
IGBT

- Additional P+ layer compared to MOSFET
- When +ve potential is applied to gate and exceeds threshold voltage n channel is formed similar to MOSFET
- P junction at drain end is unique Feature of IGBT as compared to MOSFET
- IGBT has no Inverse diode as Compared to MOOSFET

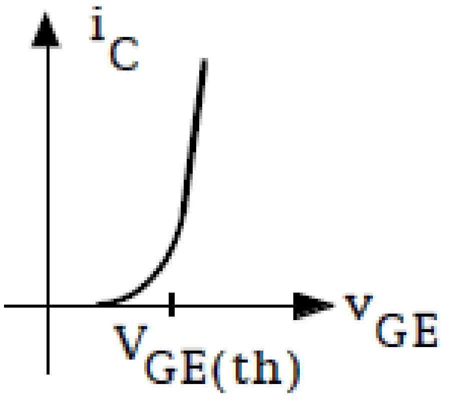


IGBT

- **V-I Characteristics**

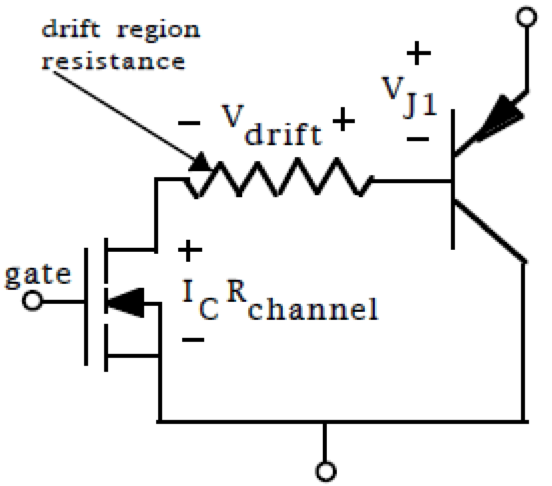


- **Transfer characteristics**



IGBT : Equivalent circuit

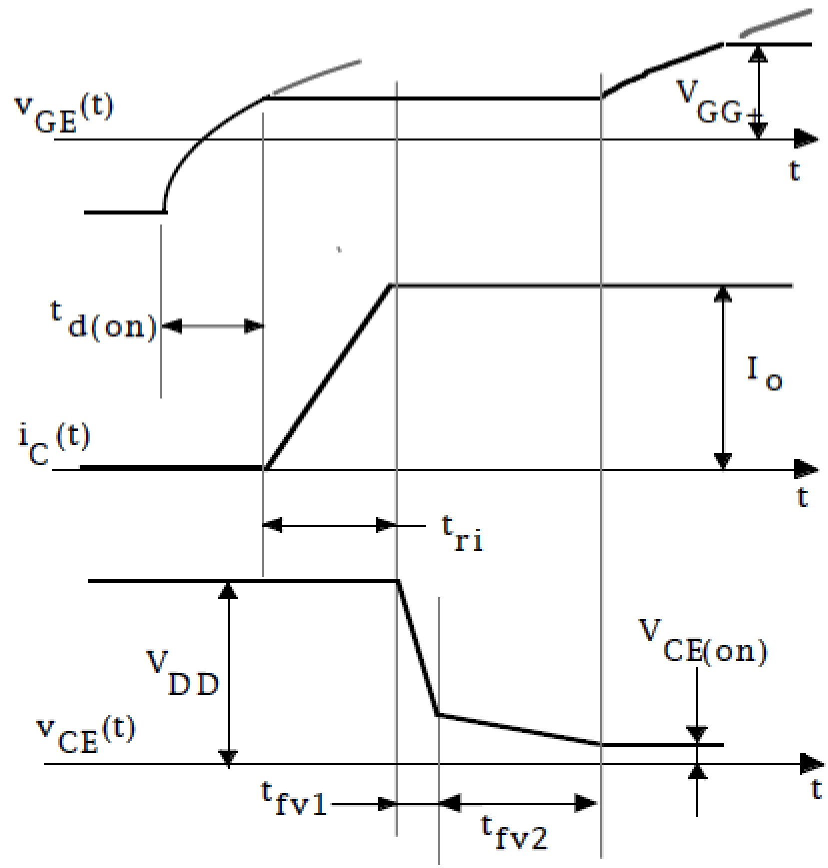
- Approximate Equivalent Circuit
- o/p side PNP transistor
- Input side n channel
- MOSFET
- Design modifications are
- Done to avoid the turn on
- of parasitic Thyristor



$$V_{CE(on)} = V_{J1} + V_{drift} + I_C R_{channel}$$

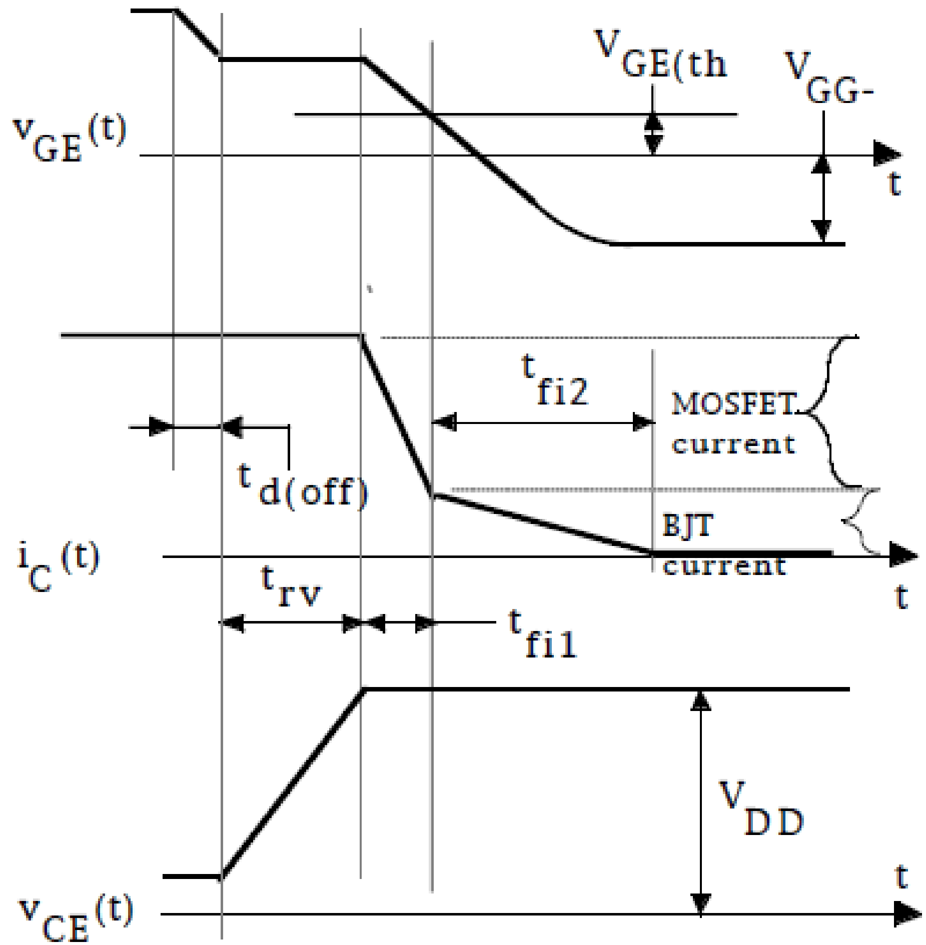
IGBT : Turn on characteristics

- Turn on is similar to MOSFET
- Turn on time consists of
- $t_{on} = t_{d(on)} + t_{ri} + t_{fv1} + t_{fv2}$
- Typical values are
- $t_{d(on)} = 18$ nS
- $T_{ri} = 10$ ns



IGBT

- Turn off cha.



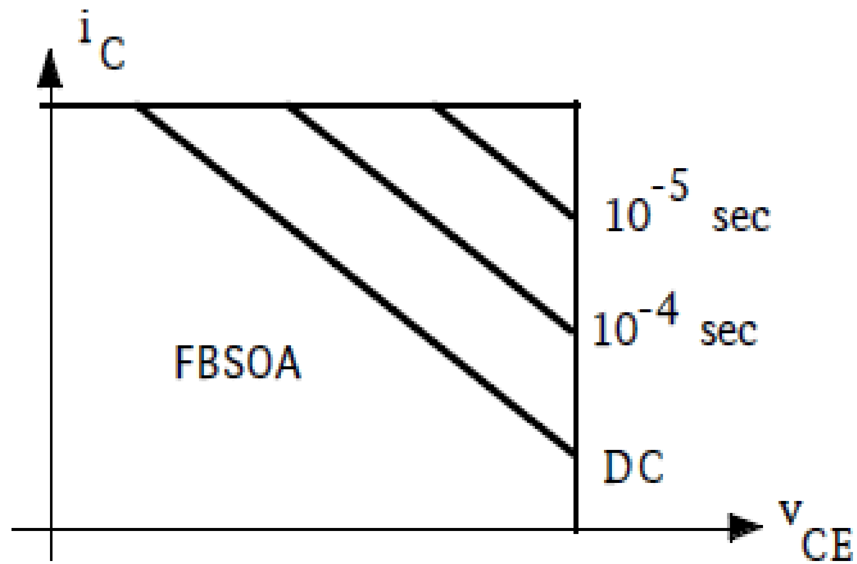
$t_{off} = t_{d(off)} + t_{rv} + t_{fi1} + t_{fi2}$

turn off delay time = 208 nS

fall time = 16 nS

IGBT : safe operating area

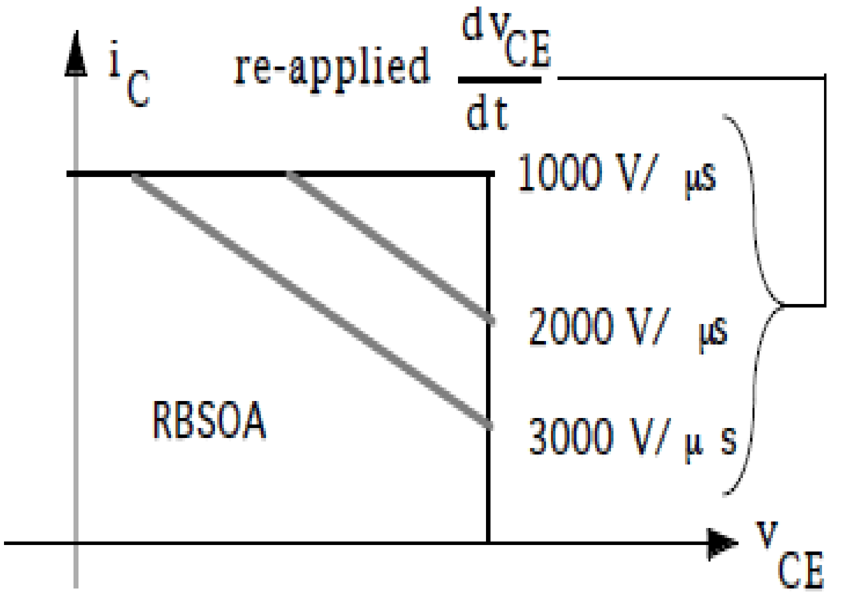
- FBSOA
- Maximum collector emitter voltage set by the breakdown voltage of PNP transistor.



- Maximum collector current set by latch-up consideration
- 100 A device can carry 1000 A for 10μsec and turn off by gate signal

IGBT : safe operating area

- RBSOA

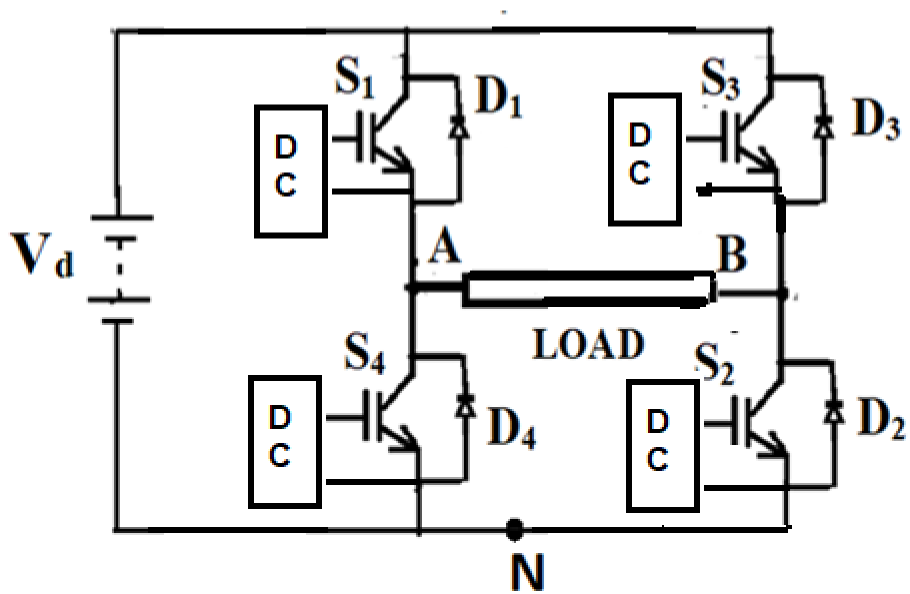


- Maximum junction temp= 150^{0}C

- Manufacturer specifies maximum rate of rise of reapplied collector emitter voltage in order to avoid latch up

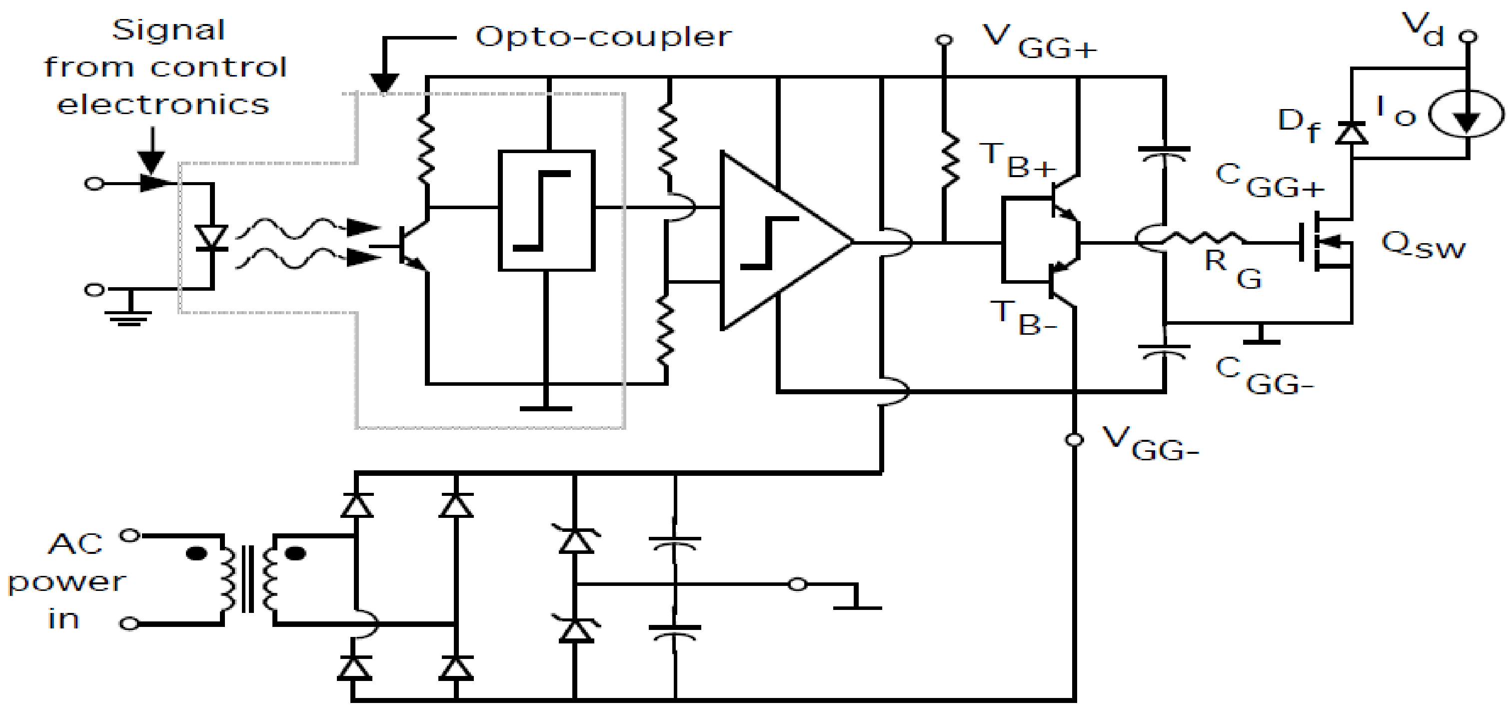
Driver circuit

- DC => Driver circuit
- Control signal is applied wrt emitter(Source)
- Each driver circuit ground should be separate
- All driver circuit has same ground then devices S2 and S4 will be shorted



Driver circuit

- Driver circuit for one device



Conclusion

- IGBT is most widely used device for DC-to-DC converters and Inverters
- Performance of IGBT is in between MOSFET and power transistor
- It is much faster than Power transistor but slower than MOSFET
- Turn on speed of IGBT can be controlled by rate of change of gate – source voltage
- SOA is rectangle so RC snubber is not required

THANKS !

Any Questions?