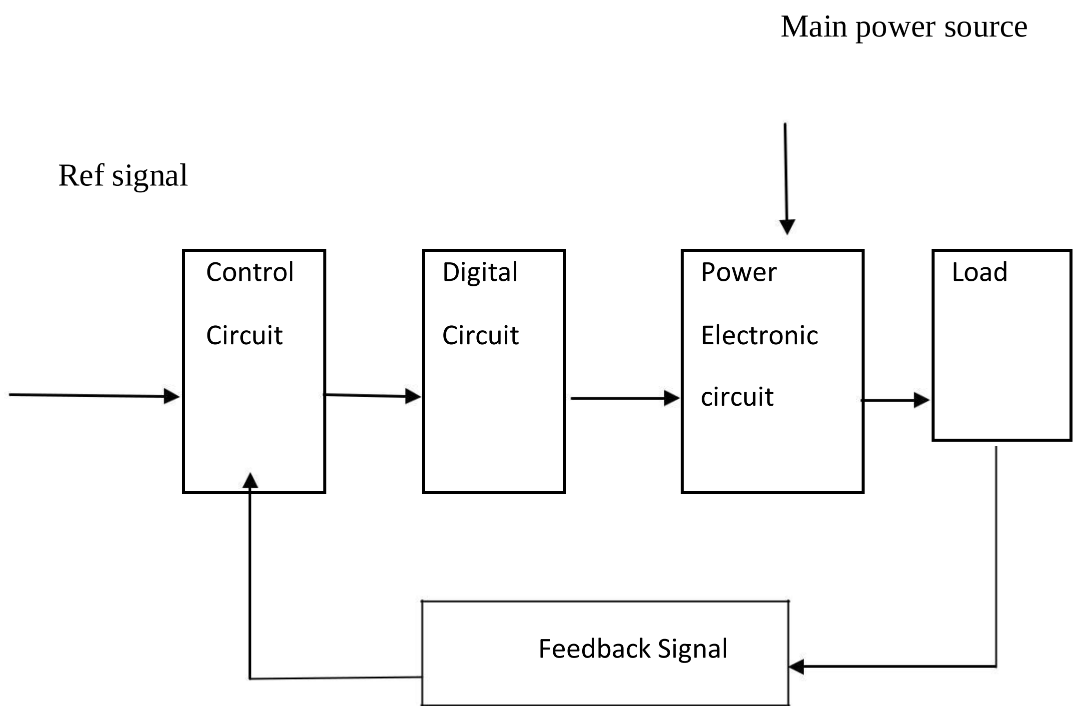
POWER ELECTRONICS

The control of electric motor drives requires control of electric power. Power electronics have eased the concept of power control. Power electronics signifies the word power electronics and control or we can say the electronic that deal with power equipment for power control.



Power electronics based on the switching of power semiconductor devices. With the development of power semiconductor technology, the power handling capabilities and switching speed of power devices have been improved tremendously.

<u>Power Semiconductor Devices</u>

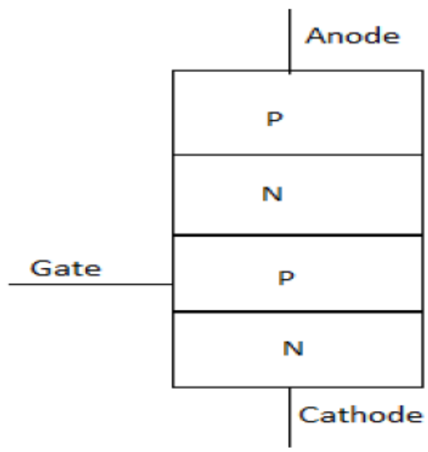
The first SCR was developed in late 1957. Power semiconductor devices are broadly categorized into 3 types:

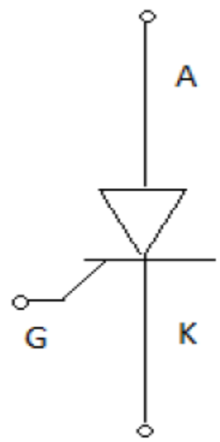
1. Power diodes (600V,4500A)

2. Transistors
3. Thyristors(10KV,300A,30MW)

Thyristor is a four layer three junction pnpn semiconductor switching device. It has 3 terminals these are anode, cathode and gate. SCRs are solid state device, so they are compact, possess high reliability and have low loss.

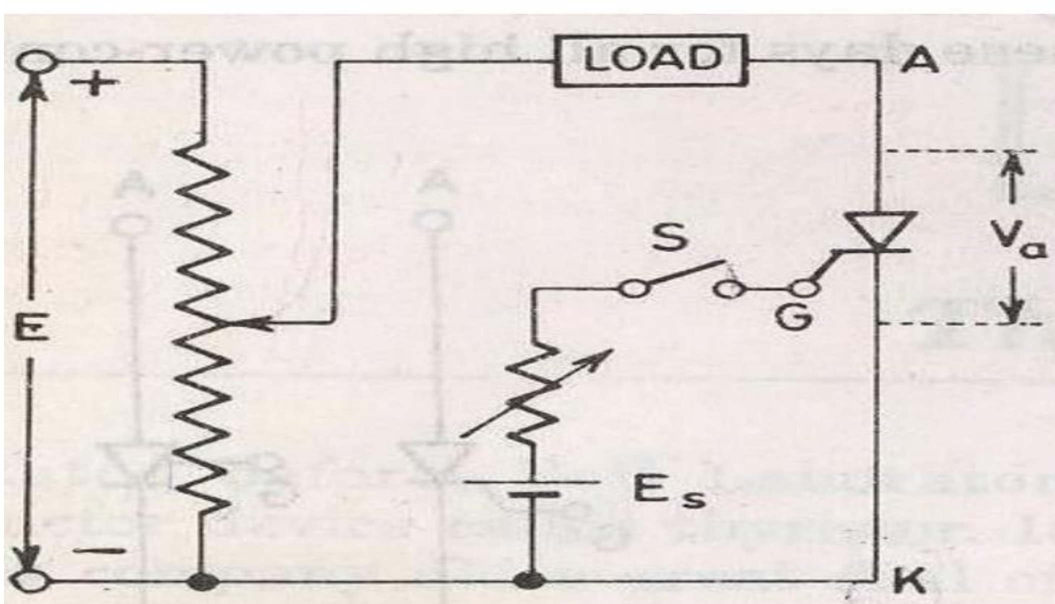
SCR is made up of silicon, it act as a rectifier; it has very low resistance in the forward direction and high resistance in the reverse direction. It is a unidirectional device.





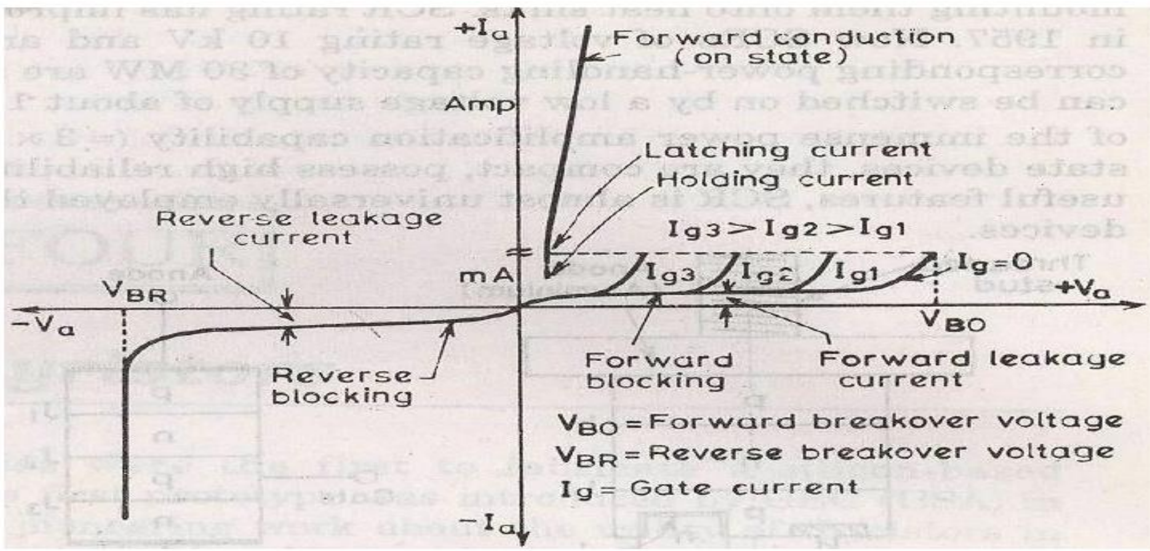
Static V-I characteristics of a Thyristor

The circuit diagram for obtaining static V-I characteristics is as shown



Anode and cathode are connected to main source voltage through the load. The gate and cathode are fed from source ES.

A typical SCR V-I characteristic is as shown below:



V_{BO}=Forward breakover voltage
V_{BR}=Reverse breakover voltage
I_g=Gate current
V_a=Anode voltage across the thyristor terminal A,K.
I_a=Anode current
It can be inferred from the static V-I characteristic of SCR. SCR have 3 modes of operation:
1. Reverse blocking mode
2. Forward blocking mode (off state)
3. Forward conduction mode (on state)

1. Reverse Blocking Mode

When cathode of the thyristor is made positive with respect to anode with switch open thyristor is reverse biased. Junctions J_1 and J_2 are reverse biased where junction J_2 is forward biased. The device behaves as if two diodes are connected in series with reverse voltage applied across them.

- A small leakage current of the order of few mA only flows. As the thyristor is reverse biased and in blocking mode. It is called as acting in reverse blocking mode of operation.

Now if the reverse voltage is increased, at a critical breakdown level called reverse breakdown voltage V_{BR},an avalanche occurs at J_1 and J_3 and the reverse current increases rapidly. As a large current associated with V_{BR} and hence more losses to the SCR.

This results in Thyristor damage as junction temperature may exceed its maximum temperature rise.

2. Forward Blocking Mode

When anode is positive with respect to cathode, with gate circuit open, thyristor is said to be forward biased.

Thus junction J_1 and J_3 are forward biased and J_2 is reverse biased. As the forward voltage is increases junction J_2 will have an avalanche breakdown at a voltage called forward breakover voltageV_{BO}. When forward voltage is less then V_{BO}thyristor offers high impedance. Thus a thyristor acts as an open switch in forward blocking mode.

3. Forward Conduction Mode

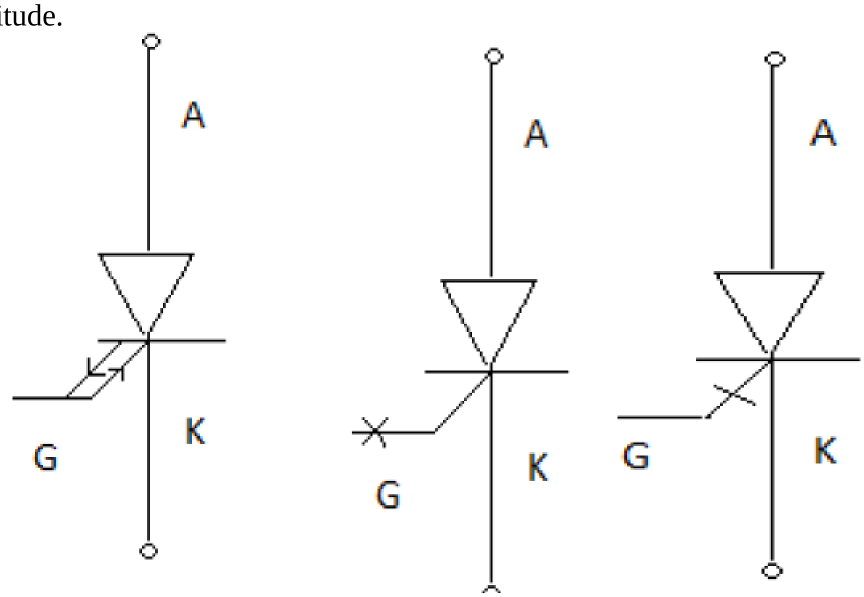
Here thyristor conducts current from anode to cathode with a very small voltage drop across it. So a thyristor can be brought from forward blocking mode to forward conducting mode:

1. By exceeding the forward breakover voltage.
2. By applying a gate pulse between gate and cathode.

During forward conduction mode of operation thyristor is in on state and behave like a close switch. Voltage drop is of the order of 1 to 2mV. This small voltage drop is due to ohmic drop acrossfour layers of the device.

GTO (Gate turn off thyristor)

A gate turn off thyristor is a pnpn device. In which it can be turned ON like an ordinary SCR by a positive gate current. However it can be easily turned off by a negative gate pulse of appropriate magnitude.



Conventional SCR are turned on by a positive gate signal but once the SCR is turned on gate loses control over it. So to turn it off we require external commutation circuit. These commutation circuits are bulky and costly. So due to these drawbacks GTO comes into existence.

The salient features of GTO are:

1. GTO turned on like conventional SCR and is turned off by a negative gate signal of sufficient magnitude.

2. It is a non latching device.

3. GTO reduces acoustic and electromagnetic noise.

It has high switching frequency and efficiency.

A gate turn off thyristor can turn on like an ordinary thyristor but it is turn off by negative gate pulse of appropriate magnitude.

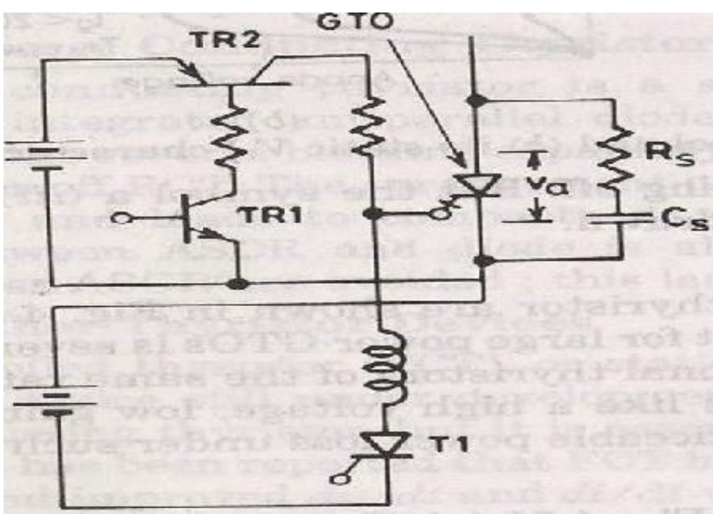
Disadvantage

The negative gate current required to turn off a GTO is quite large that is 20% to 30 % of anode current

Advantage

It is compact and cost less

Switching performance:



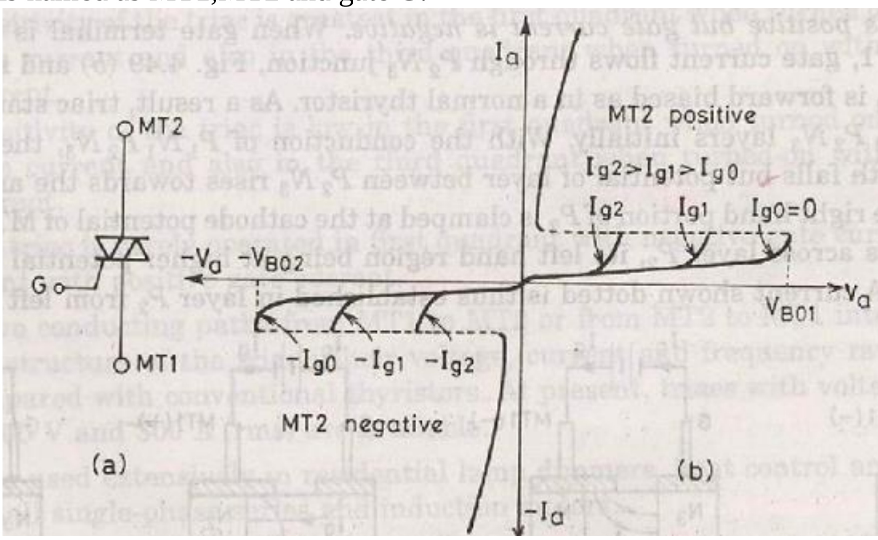
1. For turning ON a GTO first TR1is turned on.
2. This in turn switches on TR2 so that a positive gate current pulse is applied to turn on the GTO.
3. Thyristor T_1 is used to apply a high peak negative gate current pulse.

TRIAC

As SCR is a unidirectional device,the conduction is from anode to cathode and not from cathode to anode. It conducts in both direction.It is a bidirectional SCR with three terminal.

TRIAC=TRIODE+AC

Here it is considered to be two SCRS connected in anti parallel.As it conducts in both direction so it is named as MT1,MT2 and gate G.



SALIENT FEATURES

1.Bi directional triode thyristor

2.TRIAC means triode that works on ac

3.It conduct in both direction

4.It is a controlled device

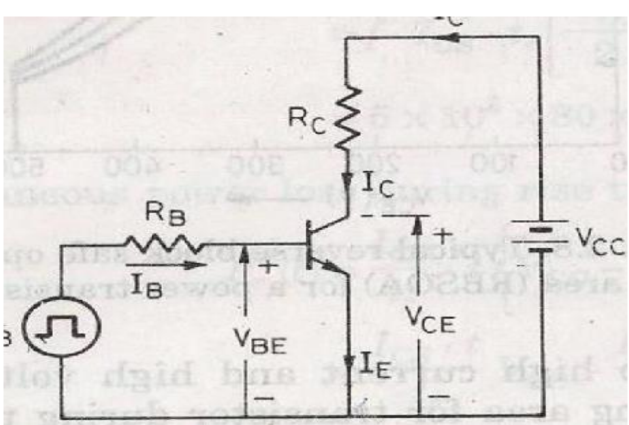
5.Its operation is similar to two devices connected in anti parallel with common gate connection.

6.It has 3 terminals MT1,MT2 and gate G

Its use to control of power in ac.

POWER BJT

Power BJT means a large voltage blocking in the OFF state and high current carrying capability in the ON state. In most power application, base is the input terminal. Emitter is the common terminal. Collector is the output terminal.



POWER BJT CONSTRUCTION
The maxium collector emitter voltage that can be sustained across the junction, when it is carrying substantial collector current.
Vceo=maxium collectorand emitter voltage that can be sustain by the device.
Vcbo=collector base breakdown voltage with emitter open

PRIMARY BREAKDOWN

It is due to convention avalanche breakdown of the C-B junction and its associated large flow of current.The thickness of the depletion region determines the breakdown voltage of the transistor.The base thickness is made as small as possible,in order to have good amplification capability. If the thickness is too small, the breakdown voltage is compromised.So a compromise has to be made between the two.

THE DOPING LEVELS-

1.The doping of the emitter layer is quite large.

2.The base doping is moderate.

3.n- region is lightly doped.

4.n+ region doping level is similar to emitter.

1.THICKNESS OF DRIFT REGION-

It determines the breakdown length of the transistor.

2.THE BASE THICKNES –

Small base thickness- good amplification capability

Too small base thickness- the breakdown voltage of the transistor has ti be compromised.

For a relatively thick base,the current gain will be relatively small.so it is increase the gain.Monolithicesigns for darlington connected BJT pair have been deveploed.

SECONDARY BREAKDOWN

Secondary breakdown is due to large power disspation at localized site within the semi conductor.

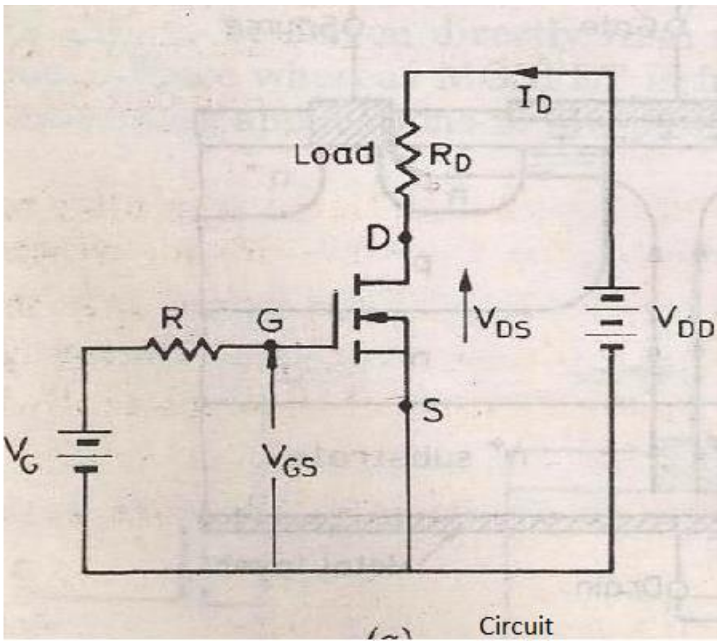
PHYSICS OF BJT OPERATION-

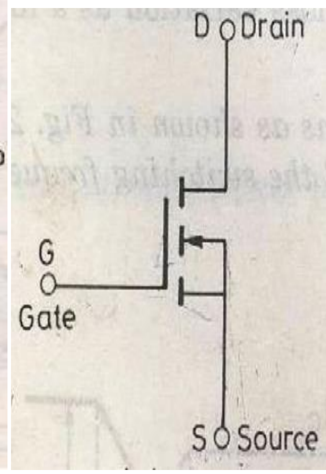
The transistor is assumed to operate in active region. There is no doped collector drift region. It has importance only in switching operation, in active region of operation.

B-E junction is forward biased and C-B junction is reverse biased. Electrons are injected into base from the emitter. Holes are injected from base into the emitter.

POWER MOSFET

A power MOSFET has three terminal device. Arrow indicates the direction of current flow. MOSFET is a voltage controlled device. The operation of MOSFET depends on flow of majority carriers only.





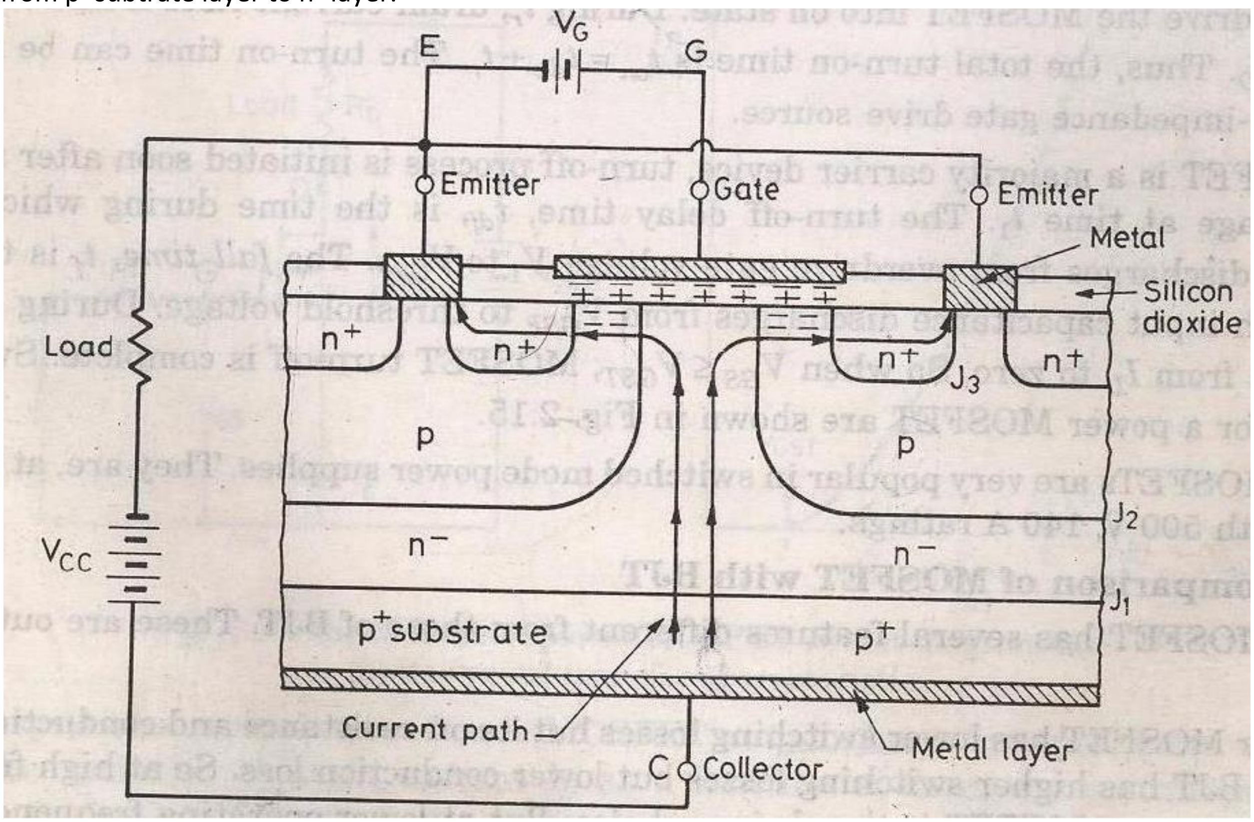
Insulated Gate Bipolar Transistor (IGBT)

IGBT has high input impedance like MOFFSET and low on state power lose as in BJT.

INSULATED GATE BIPOLAR TRANSISTOR(IGBT)-

BASIC CONSTRUCTION-

The n+ layer substrate at the drain in the power MOSFET is substituted by p+ layer substrate and called as collector. When gate to emitter voltage is positive,n- channel is formed in the p- region.This n-channel short circuit the n- and n+ layer and an electron movement in n channel cause hole injection from p+subtrate layer to n- layer.



IGBT Characteristics

Here the controlling parameter is gate emitter voltage As IGBT is a voltage controlled device.

When V_{GE} is less than V_{GET} that is gate emitter threshold voltage IGBT is in off state.

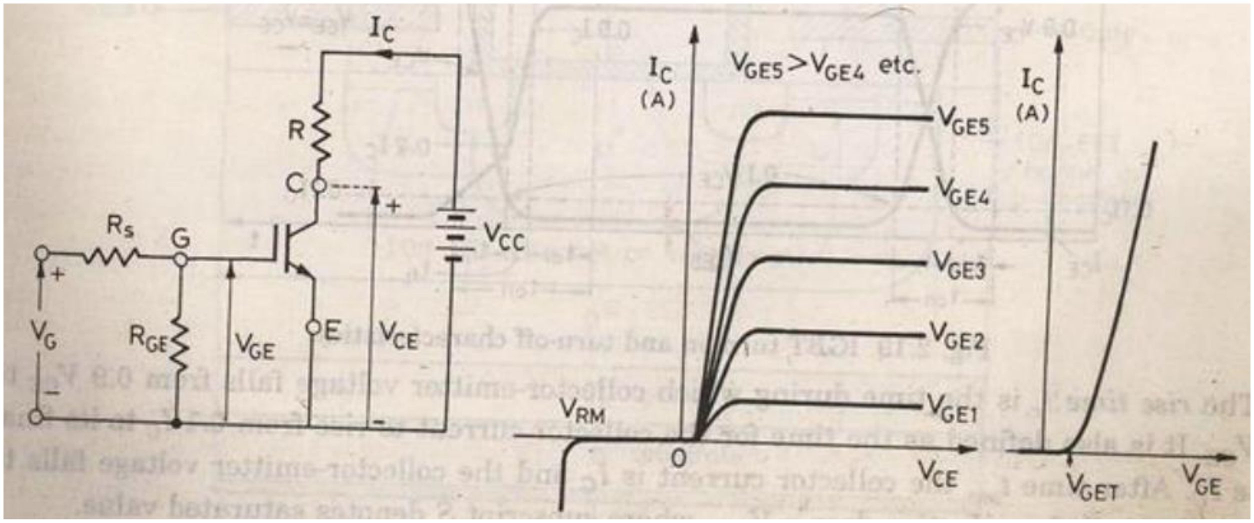


Fig. a (Circuit diagram for obtaining V-I characteristics) Fig. b (Static V-I characteristics) Fig. c (Transfer characteristic)

Snubber:-

Power semiconductors are the heart of power electronics equipment. Snubbers are circuits which are placed across semiconductor devices for protection and to improve performance. Snubbers can do many things:

· Reduce or eliminate voltage or current spikes

· Limit dI/dt or dV/dt

· Shape the load line to keep it within the safe operating area (SOA)

· Transfer power dissipation from the switch to a resistor or a useful load

· Reduce total losses due to switching

· Reduce EMI by damping voltage and current ringing

There are many different kinds of snubbers but the two most common ones are the resistor capacitor (RC) damping network and the resistor-capacitor-diode (RCD) turn-off snubber.