Power Electronic Devices:
SCR, TRIAC, DIAC

Four-Layer Three-Junction PNPN Devices

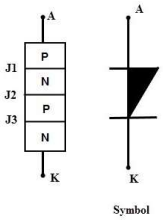
1. PNPN Diode (Shockley Diode)
2. Silicon Cpntrolled Rectifier (SCR)
3. TRIAC
4. DIAC

PNPN Diode (Shockley Diode)

•The Shockley diode or PNPN diode is a four layer (P-N-P-N), two terminals (namely anode and cathode) and **three junctions** semiconductor switching device.

• It is also called as **four layer diode**. It functions like a normal diode *without any trigger inputs*, In reverse biased condition, no current flows through it .

•In forward biased condition current flows through it when the voltage across it is more than the break over voltage of it.

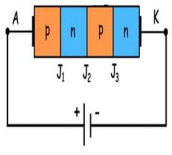


PNPN Diode(Shockley Diode) Operation: *Forward Bias*

•When an external voltage is applied to the device in such a way that anode is positive with respect to cathode ,junctions J1 and J3 are forward biased and J2 is reverse biased.

•Then the applied voltage appears across the reverse biased junction J2.Now current flowing through the device is only reverse saturation current.

•Until the voltage across the diode is less than the break over voltage, as an open switch this diode exhibits a very high resistance and allows no current to flow through it.

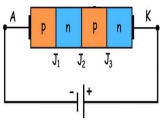


PNPN Diode(Shockley Diode) Operation.....

- Once the break over voltage VBO is reached (as the forward voltage is increased), it exhibits a very low resistance due to the breakdown of junction J2.
- The **current increases abruptly and the voltage drop across the device decreases sharply**. At this point ,the diode switches over from OFF to ON state.
- Once the device is fired into conduction , a minimum amount of current known a holding current, I_H , is required to flow to keep the device in ON state.
- **To turn the device OFF from ON state, the current has to be reduced below I_H by reducing the applied voltage close to zero** , i.e.Below holding voltage ,V_H. Thus the diode acts as a switch during forward bias condition.

PNPN Diode(Shockley Diode) Operation: *Reversed Bias*

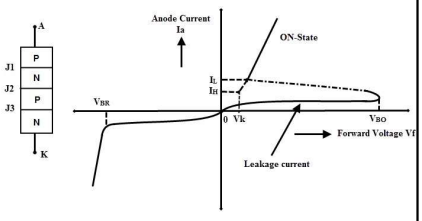
- When the anode is made negative with respect to the cathode, junctions J1 and J3 are reverse biased and junction J2 is forward biased. If the reverse bias voltage is increased (beyond the breakdown voltage of the Shockley diode), J1 and J3 are reverse biased, then the reverse current will flow through the diode.
- This reverse current produces the heat, further this could ruin the entire diode.
- Therefore, Shockley diode should never be operated in reverse biased condition with a voltage equal to the reverse breakdown voltage.



Characteristics of PNPN Diode

Latching Current I_L:It is the minimum current required to latch or trigger the device from its OFF state to its ON state.

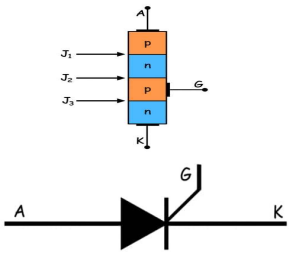
Holding Current I_H: It is the minimum value of current to hold the device in ON state.For turning the device OFF , the anode current should be lowered below I_H by increasing the external circuit resistance.



Thyristor or Silicon Controlled Rectifier (SCR)

- Silicon Controlled Rectifier (SCR) is a unidirectional semiconductor device made of silicon.
- It is a three-terminal Anode(A), Cathode(K) and the Gate(G),four-layer semiconductor device consisting of alternate layers of p-type and n-type material.
- Hence it has three pn junctions J1, J2 and J3. The Gate terminal(G) is attached to the p-layer nearer to the Cathode(K) terminal.

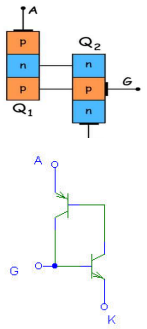
Structure and Symbol



Two Transistor Analogy of SCR

SCR is the combination of one pnp transistor (Q_1) and one npn transistor (Q_2). Here, the emitter of Q_1 acts as the anode terminal of the SCR while the emitter of Q_2 is its cathode. Further, the base of Q_1 is connected to the collector of Q_2 and the collector of Q_1 is connected to the base of Q_2. The gate terminal of the SCR is connected to the base of Q_2, too.

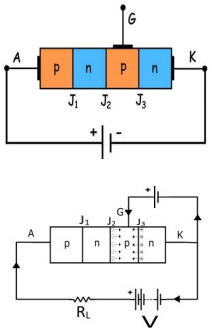
In operation the collector of Q2 drives the base of Q1, while the collector of Q1 feeds feedback to the base of Q2. β1 (Beta) is the current gain of Q1, and β2 is the current gain of Q2. The gain of this positive feedback loop is their product, β1 times β2. When the product is less than one, the circuit is stable; if the product is greater than unity, the circuit is regenerative. A small negative current applied to terminal G will bias the NPN transistor into cutoff, and the loop gain is less than unity.



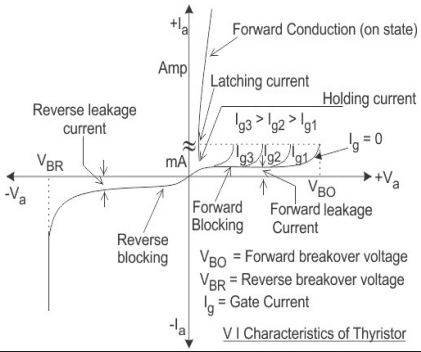
Characteristics of SCR

• SCR acts as a switch when it is forward biased. When the gate is open i.e. gate current I_G = 0,Operation of SCR is similar to PNPN diode.

• When gate voltage is applied the junction J3 is forward biased and junction J2 is reverse biased. Thus, the electrons from n – type layer starts moving across the junction J3 toward p –type material and the holes from p –type material towards the n – type material. Due to the movement of holes and electrons across the junction J3 the gate current starts flowing. Because of gate current the anode current increases. The increased anode current makes the more electrons available at the junction J2. As a result of this process, in a small time, the junction J2 breaks down and the SCR is turn ON.

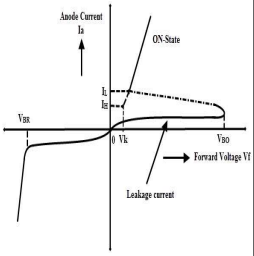


Characteristics of SCR.....



Characteristics of SCR.....

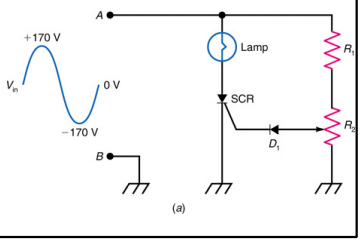
- With very large positive gate current break over voltage may occur at a very low voltage such that the characteristics of SCR is similar that of ordinary PN diode.
- As the voltage at which the SCR is switched on can be controlled by varying gate current I_G,it is commonly referred as controlled switch.
- Once SCR is turned on , the gate loses control,i.e the **gate cannot be used to switch the device off .**
- One way to turn the device off is lowering the anode current below the holding current I_H by reducing the supply voltage below holding voltage V_H,keeping the gate open.



Applications of SCR

Relay control, Motor control, Phase control, Heater Control, Battery charger, Inverters, Regulated power supplies and as static switches.

- SCRs are frequently used to control the amount of power that is delivered to a load.
- Figure shows a circuit where an SCR is used to control the amount of load current supplied to a lamp.



Power Controll Using SCR

- Figure (b) shows the load and SCR voltage waveforms for R_2 (in Fig. (a)) set so that the SCR fires when the input signal reaches its peak value at **90°**.
- Fig. (c) shows the load and SCR voltage waveforms for R_2 (in Fig. (a)) set so that the SCR fires when the input signal reaches **45°**.