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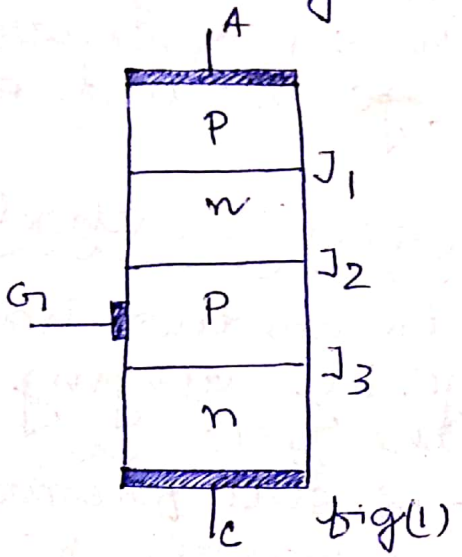
Semiconductor controlled rectifier (SCR)

The SCR is a semiconductor device made of silicon which combines the feathers of a rectifier and transistor. It is an important power device that is designed for handling high voltages & large current. The thyristor is mainly used for switching applications that require the device to change from an off or blocking state to an ON or conducting state or viceversa.



fig(1)

fig(2)

Four alternate p and n layers of silicon constitute the SCR structure as shown in fig(1) The terminal connected to the outer p-layer is known as the anode whereas the terminal connected to the outer n-layer is termed the cathode. The third terminal, called the gate, is connected to the base of the npn transistor. The circuit representation of an SCR is shown in fig(b).

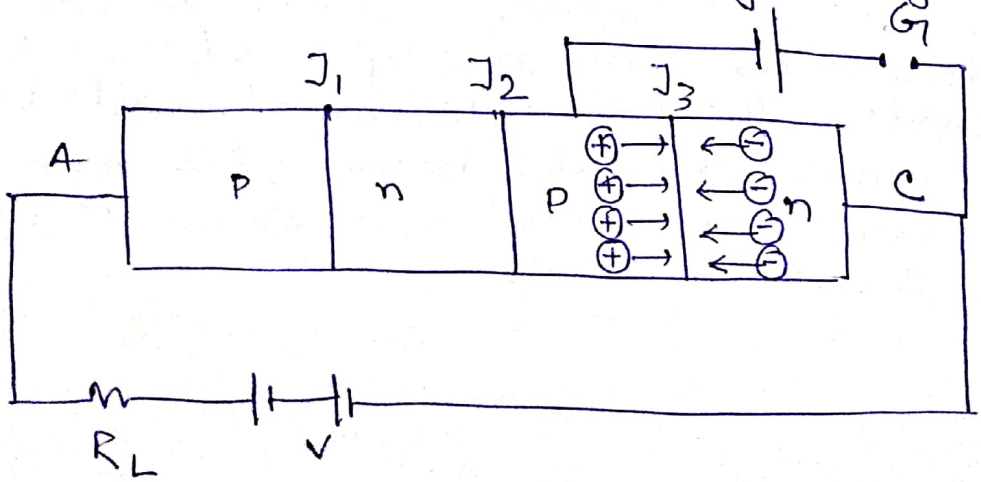
Working principle of SCR :-

a) When gate is open :-

The SCR ckt with gate open i.e no voltage is applied to the gate is shown in fig. It is seen that the junction J_1 and J_3 are forward bias & J_2 are reverse bias. Hence under the above condition no current flows through the SCR and the load resistance R_L. In this position the SCR is the 'cut off' state. If the applied voltage is slowly increase, a stage is reaches when the reverse biased junction J_2 breakdown and the whole applied voltage V appears as reverse biase across the junction J_2. Since the junction J_1 and J_3 are forward biased the SCR now conducts heavily and is said to be in the ON stage. The minimum applied voltage at which SCR conducts havily without the gate voltage is called BREAK OVER VOLTAGE.

b) Gate positive with respect to cathode :-

The SCR can be made to conduct havily at smaller applied voltage by applying a small positive potential to the gate as shown in fig. The junction J_3 is still forward biased whereas junction J_2 is reverse biased. The The electron from n-type layer start moving toward the left as shown in fig whereas the hole move from p type layer toward

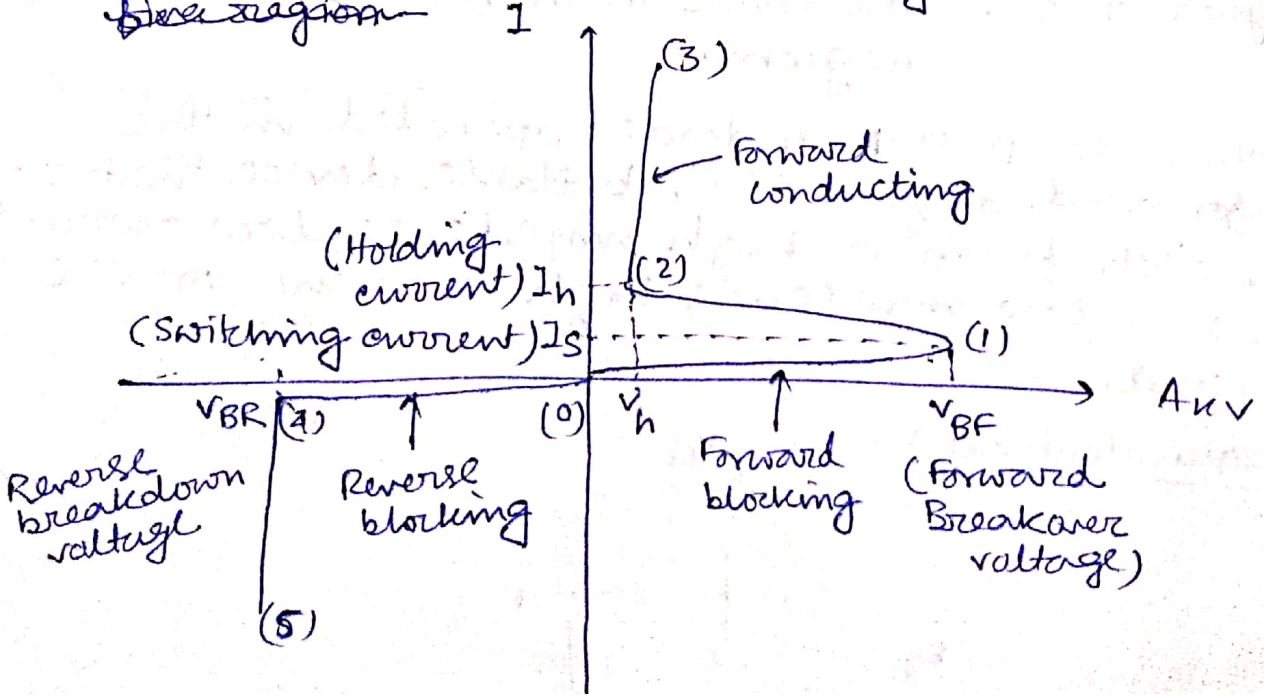


the right. As a result electron from junction J_3 are attracted across the junction J_2 and a gate current start flowing. As soon as the gate current flows the anode current increases. The increases anode current makes more electron available at the junction J_2. This process continuous and and in a small time the junction J_2 breakdown and the SCR start conducting heavily.

Once the SCR starts conducting the gate loses all control even if the gate voltage is removed the anode current does not decreases at all to stop conduction. i.e bring it to OFF condition. The only method is to reduce the applied voltage to almost zero. At this point the the internal transister comes out of saturation and open the SCR. The anode current under this condition is very small, is called the HOLDING CURRENT.

I - V characteristics :-

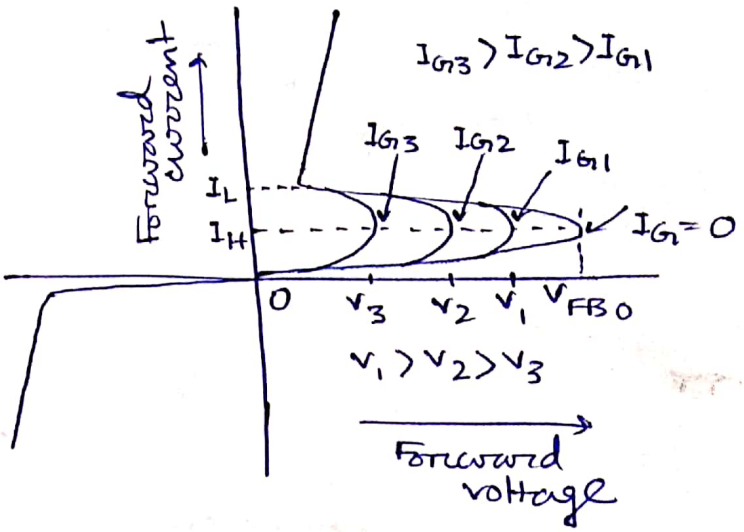
The basic current voltage characteristics of a p-n-p-n diode is shown in fig. ~~It exhibits three regions~~



(A)

When anode is made positive with respect to cathod junction J_1 and J_3 are forward biased and junction J_2 is reverse biased and only the leakage current will flow through the device. The SCR is then said to be in the forward blocking state or off state. The leakage current is very small and negligible. In forward mode, SCR does not conduct unless the forward voltage exceeds certain value, called the forward breakover voltage, V_{FBO}.

If a positive gate current is supplied the SCR can become conducting at a voltage much lesser than forward breakover voltage. The larger the gate current, lower the breakover voltage as shown in figure. With sufficiently large gate current, the SCR behaves identical to PN rectifier. Once the SCR is switch on, the forward voltage drop across it is suddenly reduced to very small value, say about 1 volt. In the conducting mode or on state, the current through the SCR is limited by the external impedence.



But when the cathode is made positive with respect to anode, junction J_1 and J_3 are reverse biased, a small reverse leakage current will flow through SCR, of the order of few microamperes. The SCR is said to be in the reverse blocking state. But if the reverse voltage is increased beyond a certain value, called the reverse breakdown voltage, V_{RBD}, avalanch breakdown take place. Forward breakover voltage V_{FBO} is usually higher than reverse breakover voltage V_{RBD}.

The change over from off state to on state, called turn on, can be achived by increasing the forward voltage beyond V_{FBO}. A more convenient and useful method of turning on the device employs the gate drive. If the forward voltage is less than the forward breakover voltage, V_{FBO}, it can be turned on by applying a positive voltage between the gate and cathode. This method is called the gate control.

Once SCR has been switched on, it has no control on the amount of current flowing through it. The current through the SCR is entirely controlled by the external impedance connected in the circuit and applied voltage. There is a minimum forward current that must be maintained to keep the SCR in conducting state. This is called the holding current of SCR. If the current through the SCR is reduced below the level of holding current, the device returns to off-state or blocking state.

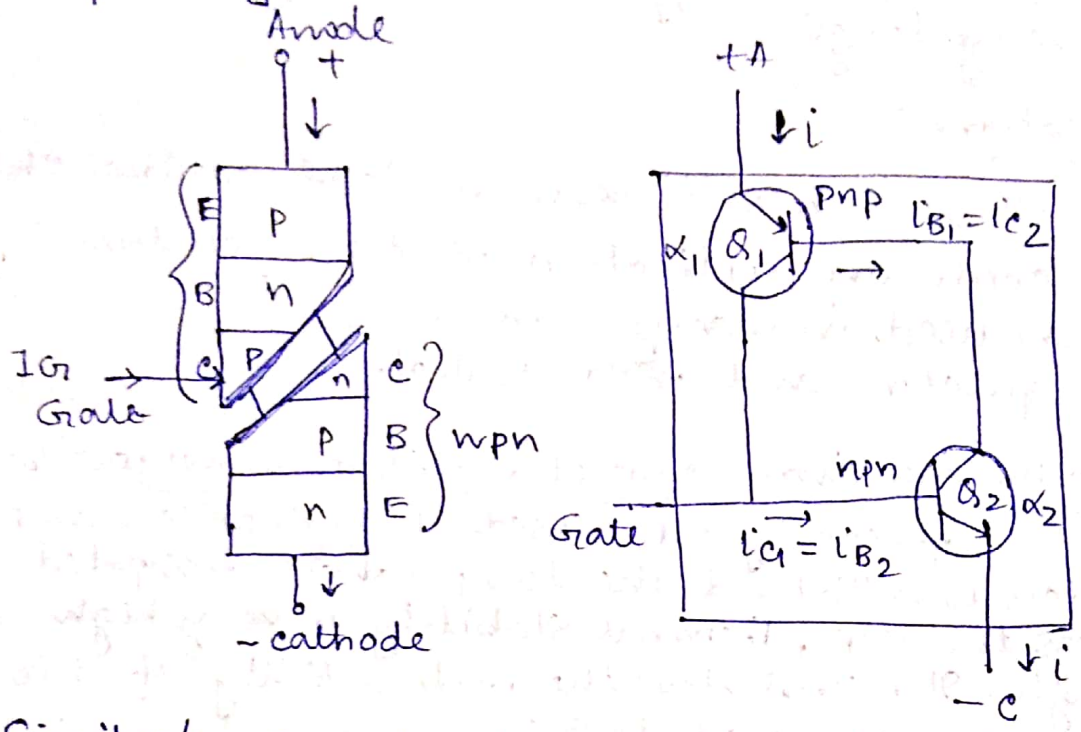
Alternatively the SCR can be switched off by applying negative voltage to the anode, the SCR naturally will be switched off. The SCR takes certain time to switch off. The time, called the turn off time.

Dynamic characteristics :- Turn on characteristics:

The turn-on time characteristic shows the variation

Two transistor analogy :-

The P-N-P-N device can be considered as two coupled transistor T_1 & T_2 form the emitter-base and collector-base junction of p-n-p transistor respectively.



Similarly T_2 and T_3 forms the collector base and emitter base junction of n-p-n transistor. In this analogy the collector region of the npn is in common with the base region of the pnp region and the base of the npn serves as the collector region of pnp. The two transistor analogy shown in fig.

The collector current i_{C_1} of the pnp transistor drives the base of npn and the base current i_{B_1} of the pnp is ~~does~~ drives the collector of npn.

$$\therefore i_{C_1} = \alpha_1 i + I_{CO_1} = i_{B_2}$$

$$i_{C_2} = \alpha_2 i + I_{CO_2} = i_{B_1}$$

But the sum of i_{C_1} & i_{C_2} is the total current through the device,

$$i_{C_1} + i_{C_2} = i$$

(8)

$$i(\alpha_1+\alpha_2)+I_{CO1}+I_{CO2}=I$$

$$\Rightarrow I=\frac{I_{CO1}+I_{CO2}}{1-(\alpha_1+\alpha_2)}$$

when $(\alpha_1+\alpha_2)$ is very close to unity the current I is very large.

- **Application :-**

i) Power switch and is in various control ckt.
ii) A common application is the light-dimmer switch used in many home.
iii) Regulators and motor control.

- **Why Germanium control rectifier is not possible?**

Generally SCR is used at high power amplifier, inorder to withstand the temperature dissipated across the SCR, thermal stability is very high enough. It means that thermal stability of Si is very high compared to Ge.

The leakage current of silicon is less when compared with the leakage current of Ge. Hence SCR's are made up of Si than Ge.

- **Equivalent circuit :-**