SCR

Silicon Controlled Rectifier Definition

A Silicon Controlled Rectifier is a 3 terminal and 4 layer semiconductor current controlling device. It is mainly used in the devices for the control of high power. Silicon controlled rectifier is also sometimes referred to as SCR diode, 4-layer diode, 4-layer device, or Thyristor. It is made up of a silicon material which controls high power and converts high AC current into DC current (rectification). Hence, it is named as silicon controlled rectifier.

What is Silicon Controlled Rectifier?

Silicon controlled rectifier is a unidirectional current controlling device. Just like a normal p-n junction diode, it allows electric current in only one direction and blocks electric current in another direction. A normal p-n junction diode is made of two semiconductor layers namely P-type and N-type. However, a SCR diode is made of 4 semiconductor layers of alternating P and N type materials.

Silicon Controlled Rectifier Symbol

A SCR diode consists of three terminals namely anode (A), cathode (K), Gate (G). The diode arrow represents the direction of conventional current.

Construction of Silicon Controlled Rectifier

A silicon controlled rectifier is made up of 4 semiconductor layers of alternating P and N type materials, which forms NPNP or PNPN structures. It has three P-N junctions namely J_1, J_2, J_3 with three terminals attached to the semiconductors materials namely anode (A), cathode (K), and gate (G). Gate is a terminal that controls the flow of current between anode and cathode. The gate terminal is also sometimes referred to as control terminal.

The anode terminal of SCR diode is connected to the first p-type material of a PNPN structure, cathode terminal is connected to the last n-type material, and gate terminal is connected to the second p-type material of a PNPN structure which is nearest to the cathode. The junction J_1 is formed between the first P-N layer, the junction J_2 is formed between the N-P layer and the junction J_3 is formed between the last P-N layer.

Modes of Operation in SCR

There are three modes of operation for a Silicon Controlled Rectifier (SCR), depending upon the biasing given to it.

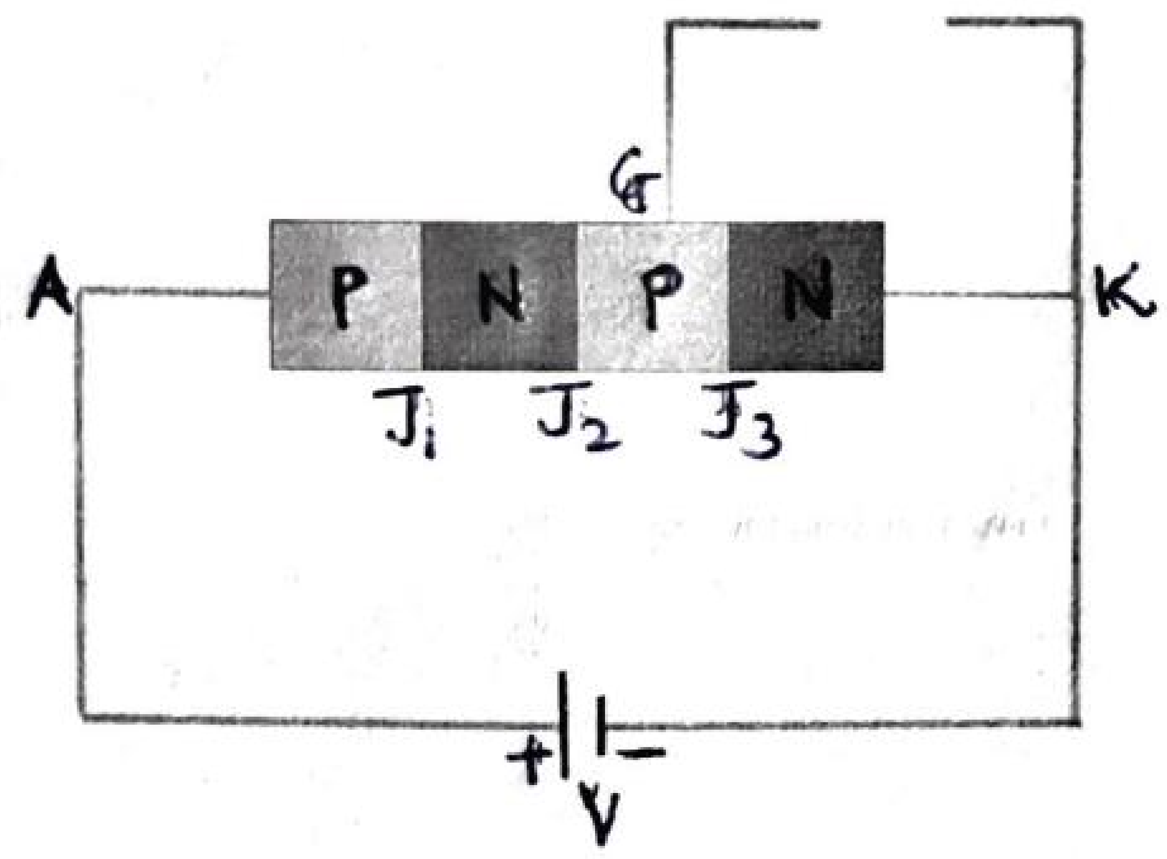
1) Forward Blocking Mode **(Off State)**

2) Forward Conducting Mode **(On State)**

3) Reverse Blocking Mode **(Off State)**

1) Forward Blocking Mode (Off State)

In this mode of operation, the positive voltage (+) is given to anode A (+), negative voltage (-) is given to cathode K (-), and gate G is open circuited as shown in the below figure. In this case, the junction J_1 and junction J_3 are forward biased whereas the junction J2 becomes reverse biased. Due to the reverse bias voltage, the width of depletion region increases at junction J_2. This depletion region at junction J_2 acts as a wall or obstacle between the junction J_1 and junction J_3. It blocks the current flowing between junction J_1 and junction J_3. Therefore, the majority of the current does not flow between junction J_1 and junction J_3. However, a small amount of leakage current flows between junction J_1 and junction J_3.



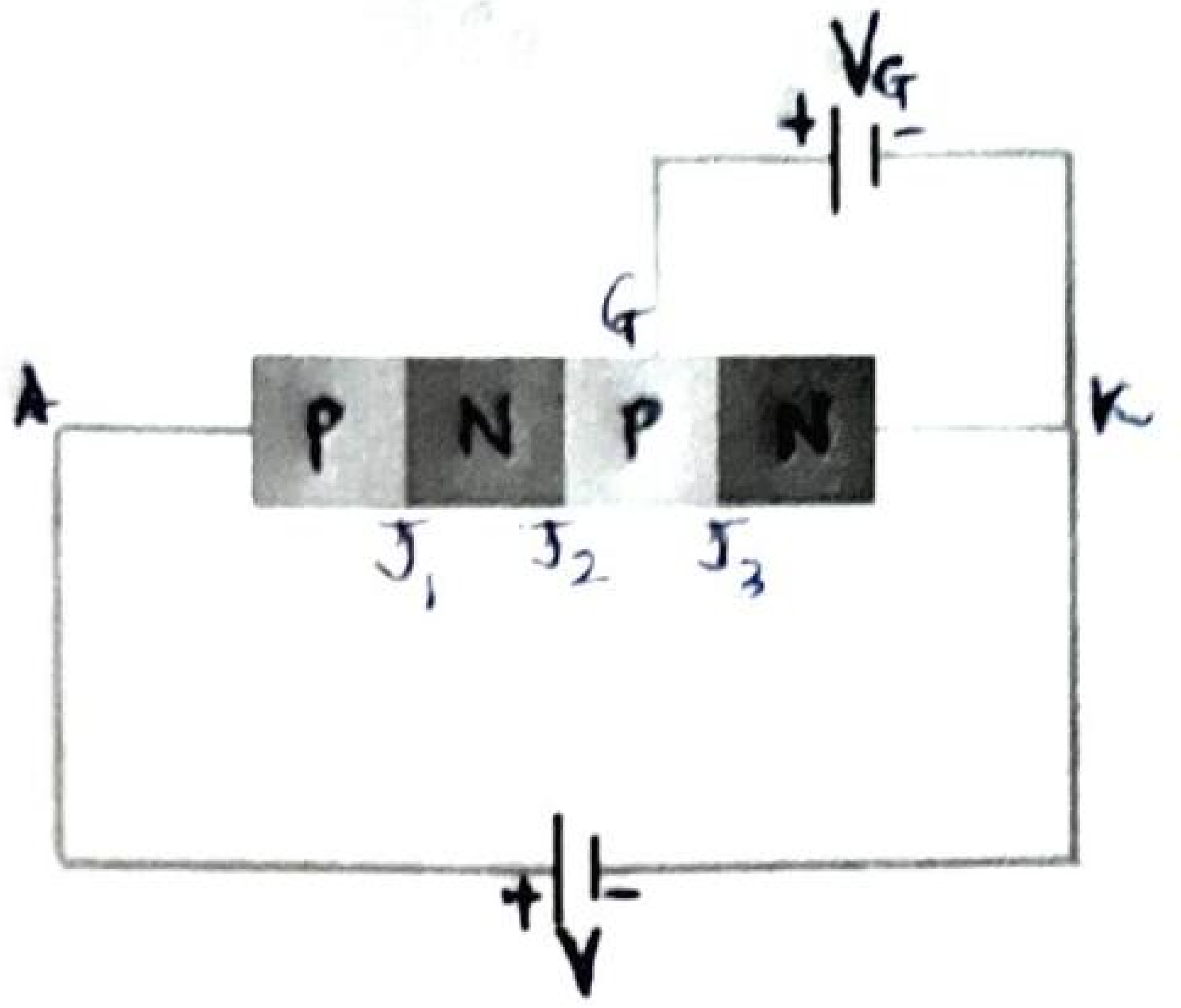
When the voltage applied to the SCR reaches a breakdown value, the high energy minority carriers causes avalanche breakdown. At this breakdown voltage, current starts flowing through the SCR. But below this breakdown voltage, the SCR offers very high resistance to the current and so it will be in off state. In this mode of operation, SCR is forward biased but still current does flows through it. Hence, it is named as Forward Blocking Mode.

2) Forward Conducting Mode (On State)

The Silicon Controlled Rectifier can be made to conduct in two ways:

i. By increasing the forward bias voltage applied between anode and cathode beyond the breakdown voltage
ii. By applying positive voltage at gate terminal.

In the first case, the forward bias voltage applied between anode and cathode is increased beyond the breakdown voltage, the minority carriers (free electrons in anode and holes in cathode) gains large amount of energy and accelerated to greater velocities. This high speed minority carriers collides with other atoms and generates more charge carriers. Likewise, many collisions happens with other atoms. Due to this, millions of charge carriers are generated. As a result depletion region breakdown occurs at junction J_2 and current starts flowing through the SCR. So the SCR will be in ON state. The current flow in the SCR increases rapidly after junction breakdown occurs.

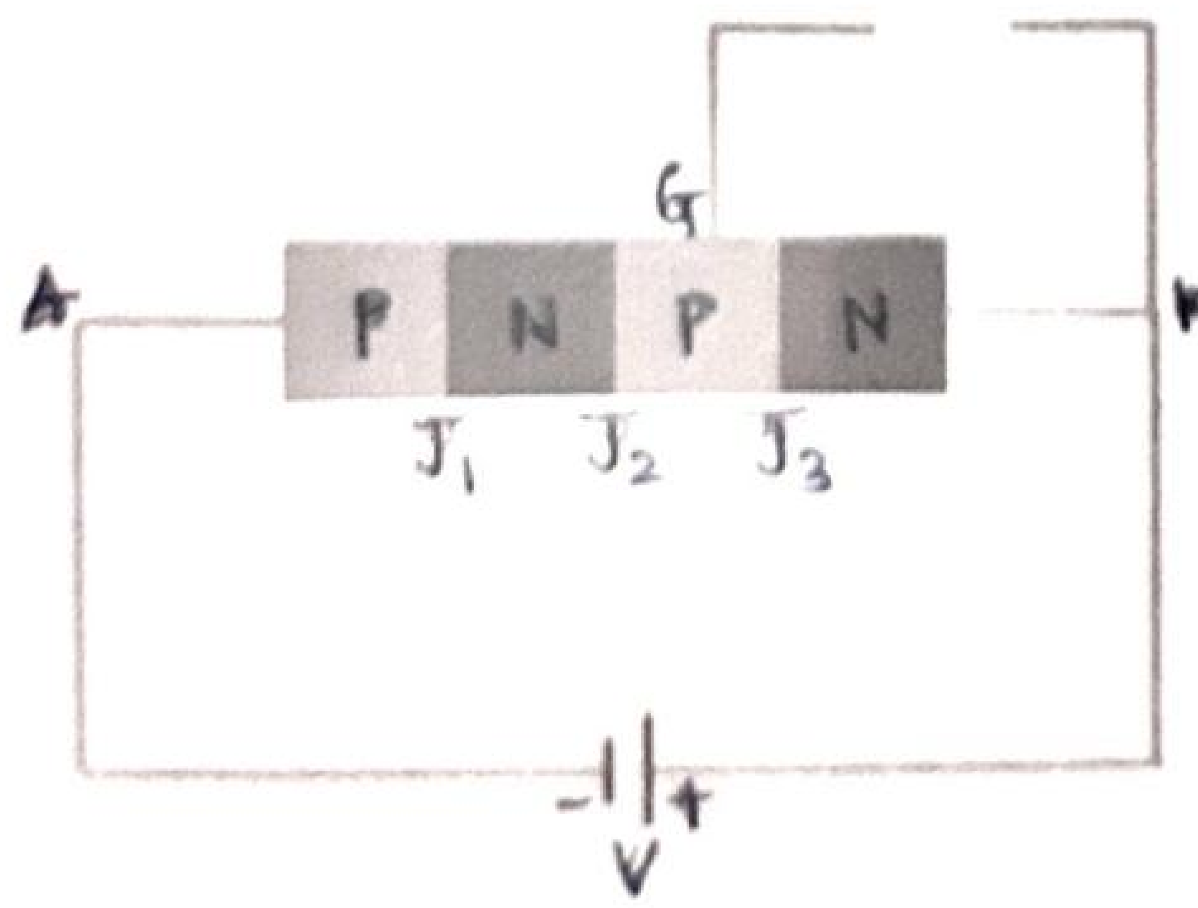


In the second case, a small positive voltage V_G is applied to the gate terminal. As we know that, in forward blocking mode, current does not flows through the circuit because of the wide depletion region present at the junction J_2. This depletion region was formed because of the reverse biased gate terminal. So this problem can be easily solved by applying a small positive voltage at the Gate terminal. When a small positive voltage is applied to the gate terminal, it will become forward biased. So the depletion region width at junction J_2 becomes very narrow. Under this condition, applying a small forward bias voltage between anode and cathode is enough for electric current to penetrate through this narrow depletion region. Therefore, electric current starts flowing through the SCR circuit.

In second case, we no need to apply large voltage between anode and cathode. A small voltage between anode and cathode, and positive voltage to gate terminal is enough to brought SCR from blocking mode to conducting mode. In this mode of operation, SCR is forward biased and current flows through it. Hence, it is named as Forward Conducting Mode.

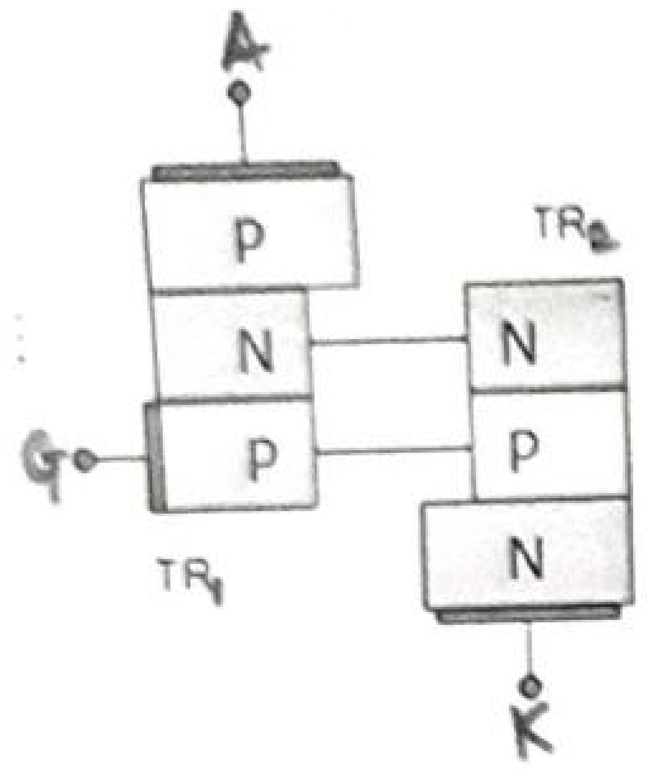
3) Reverse Blocking Mode (On State)

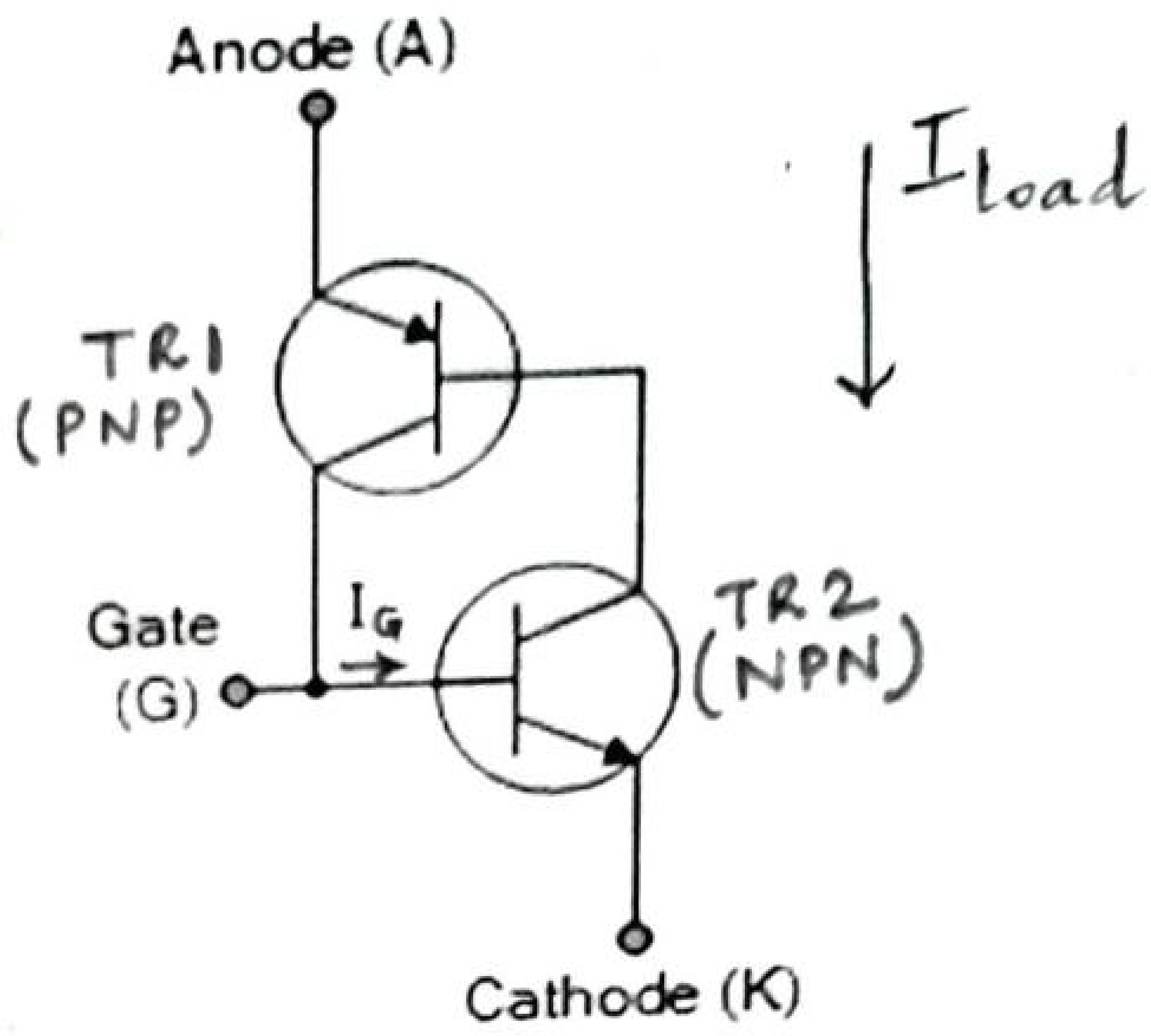
In this mode of operation, the negative voltage (-) is given to anode (+), positive voltage (+) is given to cathode (-), and gate is open circuited as shown in the below figure. In this case, the junction J_1 and junction J_3 are reverse biased whereas the junction J2 becomes forward biased.



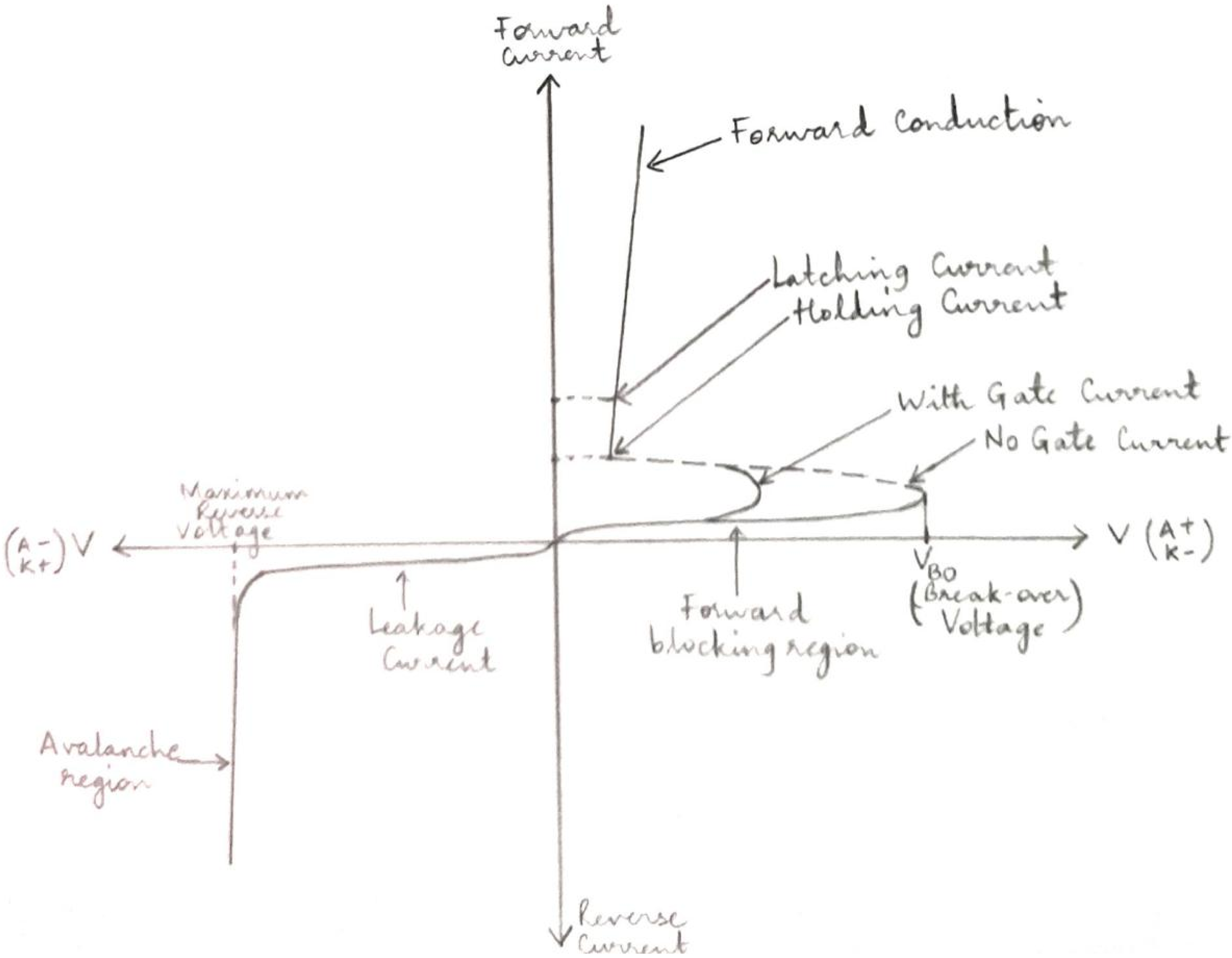
As the junctions J_1 and junction J_3 are reverse biased, no current flows through the SCR circuit. But a small leakage current flows due to drift of charge carriers in the forward biased junction J_2. This small leakage current is not enough to turn on the SCR. So the SCR will be in OFF state.

EQUIVALENT CIRCUIT OF SCR





If no voltage is applied at the Gate terminal, there is no base current in transistor TR_2. Therefore, no current flows in the collector of TR_2 and hence that of TR_1.
Under such conditions, the SCR is OFF.
However, on the application of a gate voltage, a small gate current will flow through the base of TR_2 which means its collector current will increase.
The collector current of TR_2 is the base current of TR_1. Therefore, collector current of TR_1 increases.
But collector current of TR_1 is the base current of TR_2. This action is accumulative since an increase of current in one transistor causes an increase of current in the other transistor.
As a result of this action, both transistors are driven into saturation, and hence heavy current flows through the load R_L.
Under such conditions, the SCR is said to be ON and current flows from anode to cathode.



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DEFINITIONS:

Forward Breakover Voltage V_{BO} : Refers to the minimum required forward voltage (no gate applied) to switch the SCR to the ON state.

Maximum Reverse Voltage : Refers to maximum reverse bias voltage that can be applied to the SCR after which it breaks down.

Latching current : is the minimum Anode current required (after it enters ON state) to maintain the SCR in the ON state even after the removal of the Gate trigger.

Latching current is like pick up current which helps the SCR to get ON as soon as triggering signal of gate is removed and keep it in ON condition.

Holding current : is the minimum value of current that must be there to provide a path between anode and cathode to flow anode current and thus maintain a SCR in the ON state.

Maximum ON state voltage: Refers to the maximum voltage that appears across a SCR while in conduction.

Minimum Gate trigger current: Refers to minimum gate current that requires to trigger the SCR.

Maximum Gate Trigger current: Refers to maximum current that can be applied to the gate terminal of the SCR to trigger and beyond which the device gets damaged.

Forward & Reverse Blocking Regions: These are the regions corresponding to the OFF state of the SCR.

ADVANTAGES:

1. Requires very small amount of gate voltage
2. High voltage and high current ratings

DISADVANTAGES:

1. External circuits are required to bring the SCR back into the OFF state
2. Operates only at low frequencies
3. Requires supplementary protection circuits

APPLICATIONS:

1. Power switching
2. Phase control
3. Battery chargers
4. Inverter circuits

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