Silicon Controlled Rectifier (SCR)

Lecture – 1

TDC PART – I

Paper - II (Group - B)

Chapter - 5

by:

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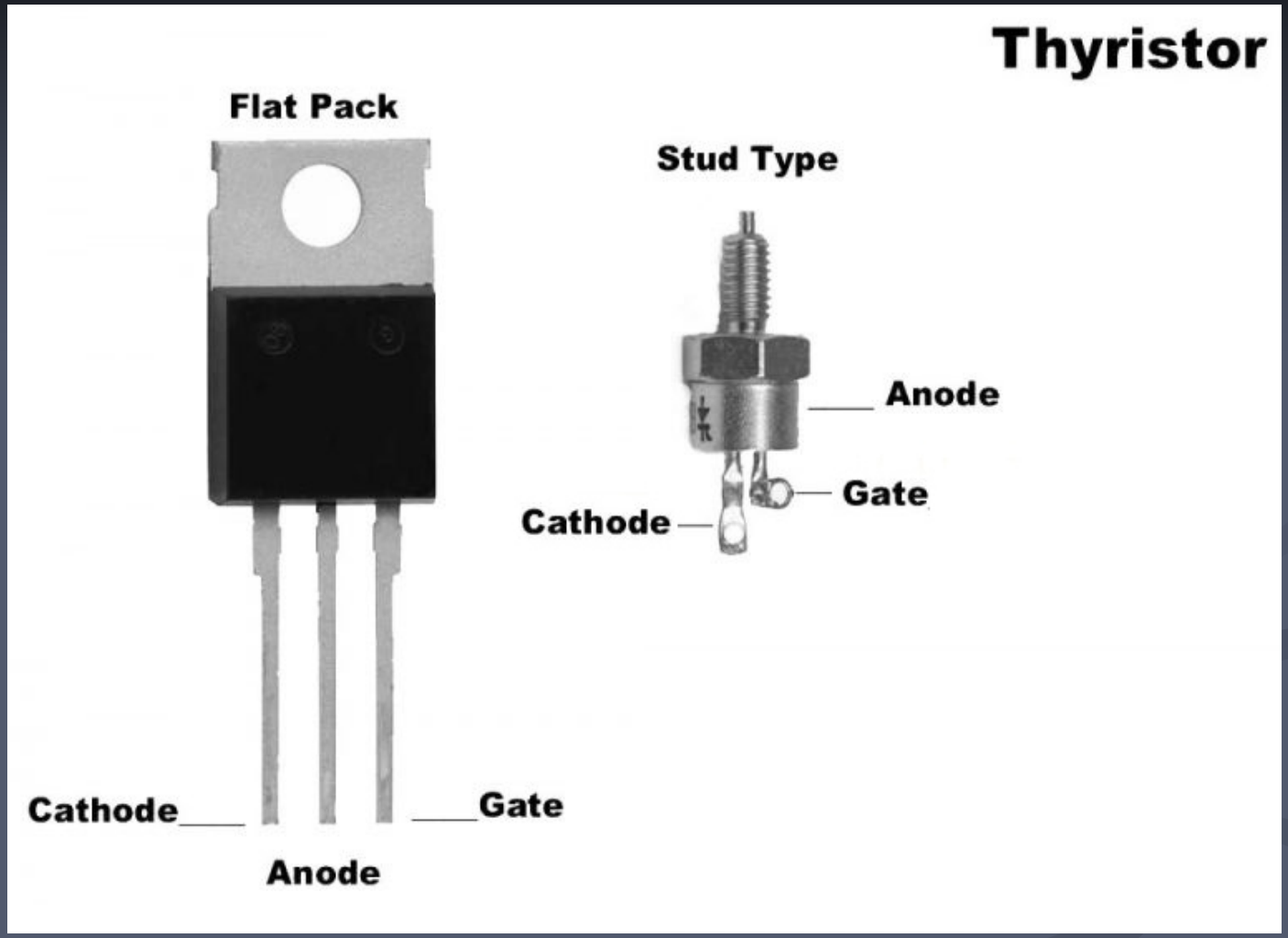
Introduction of SCR

- A Silicon Controlled Rectifier (SCR) is a four layer avalanche breakdown device. SCR is solid-state semiconductor devices whose working depends on the phenomenon of avalanche breakdown. SCR sometimes referred to by the generic name of **thyristor** which is a high power solid-state semiconductor switch whose bistable action depends on P-N-P-N regenerative feedback. SCR is a four-layer (P-N-P-N), three junctions and three terminal devices. It can be switched ON or OFF at an extremely fast rate. They are also referred to as **latching devices**. A latch is a kind of switch which initially once closed, remains closed until someone opens it.

- A **silicon controlled rectifier** or **semiconductor-controlled rectifier (SCR)** is a **four-layer (P-N-P-N), three terminal solid state semiconductor current-controlling devices. SCR is a unidirectional device** that allows the **current** in **one direction** and **opposes** in **another direction.** Basically, **it is a rectifier with a control element. It is a one way (unidirectional) device and conduction takes place from Anode to Cathode under proper forward biasing with Positive Gate trigger pulse.** Within the family of **P-N-P-N** devices, the **silicon controlled rectifier (SCR)** is unquestionably of the greatest interest today. **Silicon Controlled Rectifier (SCR)** is one of the oldest **members** of **thyristor family. It** is the most **widely used** as a **High Power Switching Device for power control in DC and AC applications today.** Hence **SCRs** are also called **Thyristor. In Fig (1)** Shown a High Power Stud type SCR device with extra length of terminal connections.

- **Fig (1)** Shown a High Power Stud Type SCR Device with Extra Length of Terminal Connections.

- Thus the term **thyristor** denotes family of semiconductor devices used for power control in DC and AC systems. One of the **oldest member** of this **thyristor family,** called **Silicon Controlled Rectifier (SCR),** is the most widely used device. At present, the use of SCR is so vast that over the years, the word **thyristor** has become synonymous with **SCR.** It appears that the term thyristor is now becoming more common then the actual term **SCR.** In **Fig (2)** Shown a Low Power Flat Pack (left side) and Stud Type (right side) SCR device with standard length of terminal connections.



- **Fig (2)** Shown a Low Power Flat Pack (left side) and Stud Type (right side) SCR Devices with Standard length of terminal connections.

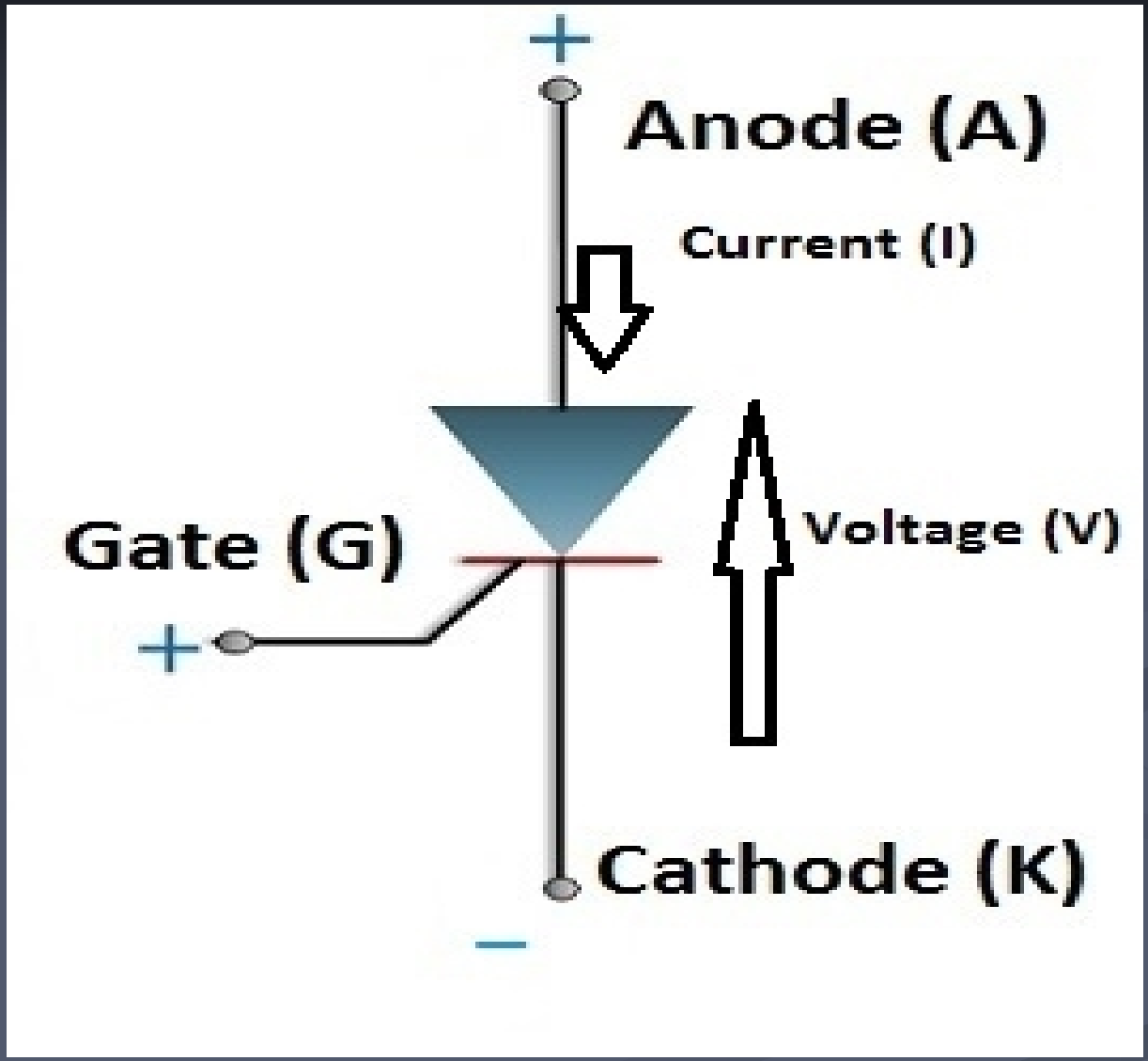
- Actually **Thyristor** or **SCR** is a **semiconductor equivalent** of **"Thyratron Tube".** A **thyristor** has **characteristics similar** to a "**Thyratron Tube".** But from the **construction point of view**, a **thyristor (a P-N-P-N device)** belongs to **transistor (PNP or NPN device) family.** The **name thyristor** is **derived by a combination of the capital latter from "THYRatron"** and **"transISTOR".** This **means** that **thyristor is a solid state device** like a **transistor** and has **characteristic similar** to that of a **Thyratron Tube.**

- The idea for the **thyristor** is not new. The idea for the device was first put forward in **1950 by William Shockley,** one of the **inventors of the transistor.** Although some later the mechanism for the operation of thyristor also called SCR was analysed further in 1952 by Ebers. **Then in 1956 Bell Labotories** were the **first to fabricate a silicon based semiconductor device called Thyristor**. Its **first prototype** was **introduced by GEC Company (USA) in 1957.** The **first silicon controlled rectifiers** became **available in the early 1960s** where it started to gain a significant level of popularity for power switching.

- When **GE launched first time their devices,** they **used the term silicon controlled rectifier, or SCR,** because it only conducted in one direction and was controllable. They used the name **SCR** as a **trade mark** for **their products.** Later the device appeared in the market under different name such as **SCR**, **Thyristor, Thyrode etc. GEC Company (USA)** did a great deal of pioneering work about the utility of thyristors in industrial applications. The multilayer P-N-P-N devices with zero, one, or two gates constitute the basic Thyristor. Later on many other devices having characteristics similar to that of a thyristor were developed. But today the thyristor family includes other similar multilayer devices also.

- These multilayer semiconductor devices, with their characteristics identical with that of a thyristor, are **Silicon Controlled Rectifire (SCR**), **Shockley Diode, Bidirectional Triode Thyristor (Triac), Bidirectonal Diode Thyristor (Diac), Silicon Controlled Switch (SCS), Programmable Unijunction Transistor (PUT), Silicon Bilateral Switch (SBS), Silicon Unilateral Switch (SUS) also known as Complementary SCR, Light Activated SCR (LASCR), Light Activated Switch (LAS), Light Activated SCS (LASCS), UJT** etc, that are all capable of acting like very fast solid state AC switches for controlling large AC voltages and currents. So this make SCR is very handy solid state devices for controlling AC motors, lamps and for phase control. This whole family of above semiconductor devices is **given the name Thyristor.** Basically, **Silicon Controlled Rectifier (SCR),** also called **Thyristor,** is one of the **prominent members** of the **thyristor family.**

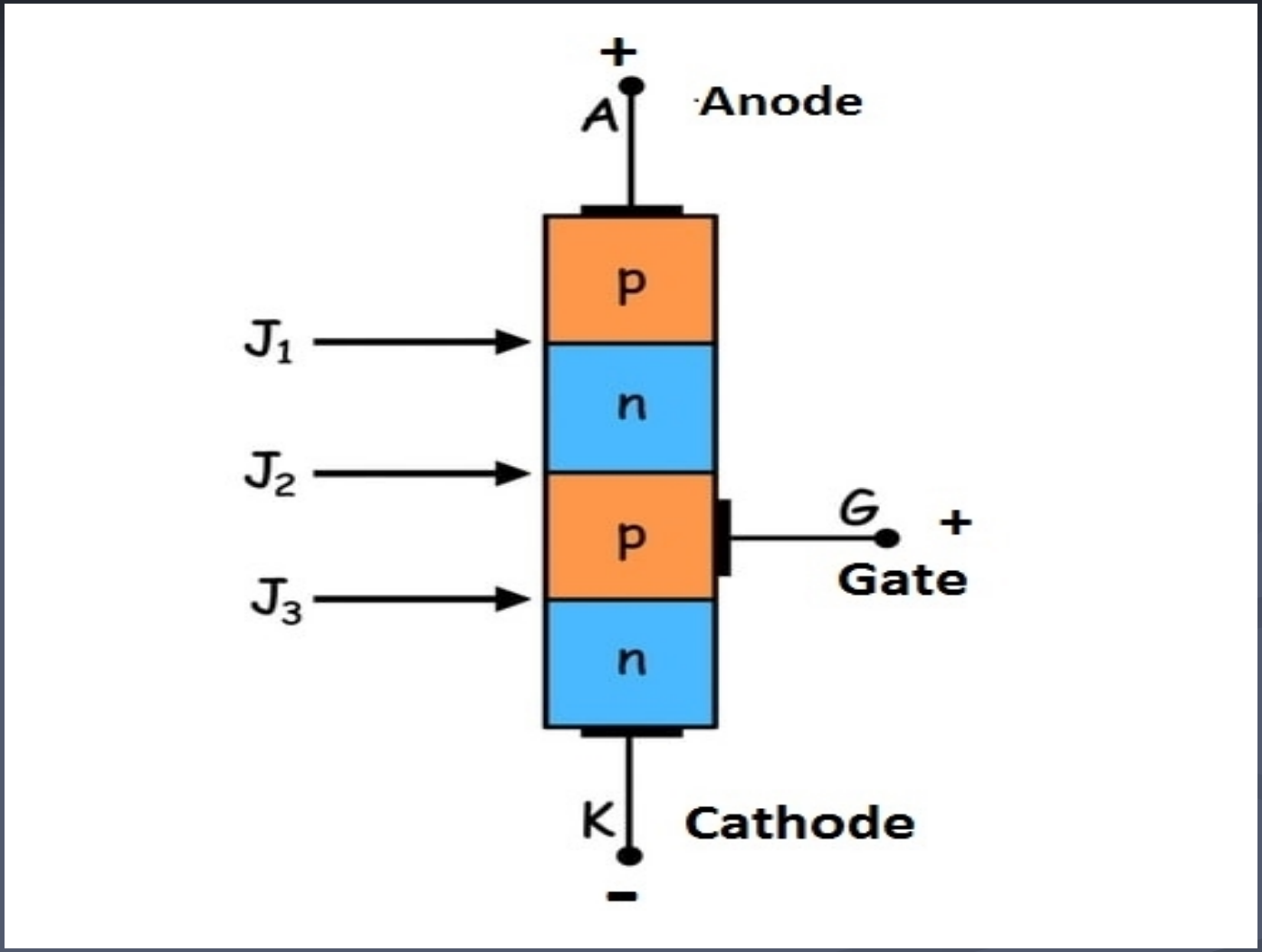
- **Silicon Controlled Rectifier (SCR)** is a **multi-layer semiconductor device,** hence the **"silicon"** part of its name. It requires a **gate signal** to **turn it "ON",** the **"controlled"** part of the name and **once "ON"** it **behaves like** a **rectifying diode,** the **"rectifier"** part of the name. **Fig (3)** shows the silicon controlled rectifier, SCR or thyristor symbol used for circuit diagrams to emphasis its rectifier characteristics while also showing the control gate. As a result the thyristor circuit symbol shows the traditional diode symbol with a control gate entering near the junction. **In Fig (3)** Shown a SCR Circuit symbol.



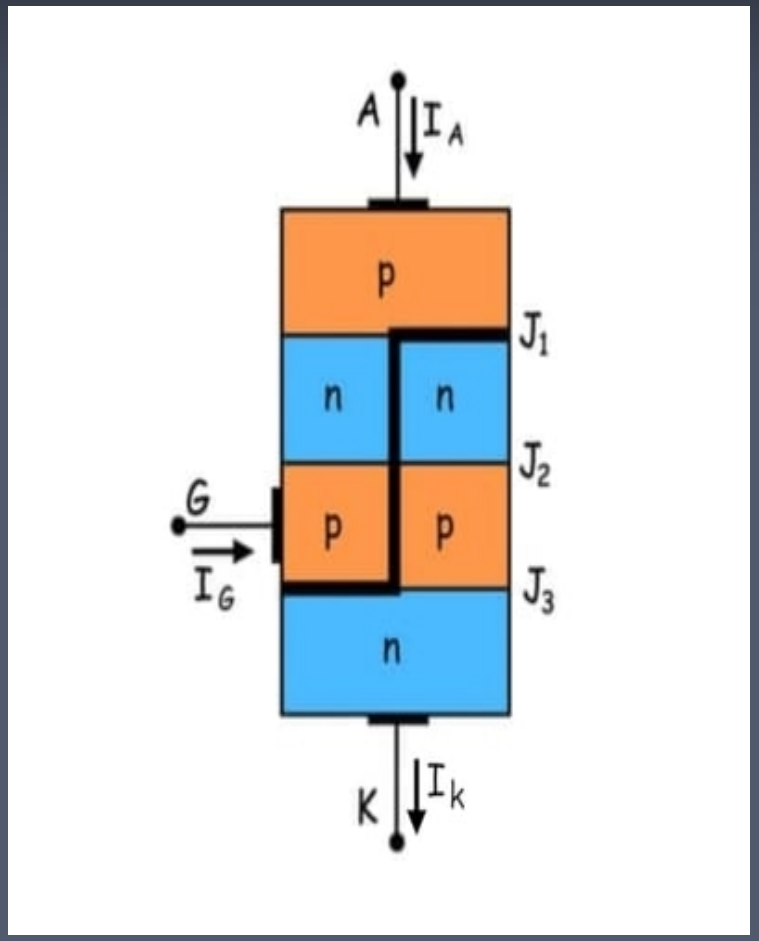
- **Fig (3)** Shown a SCR Circuit symbol.

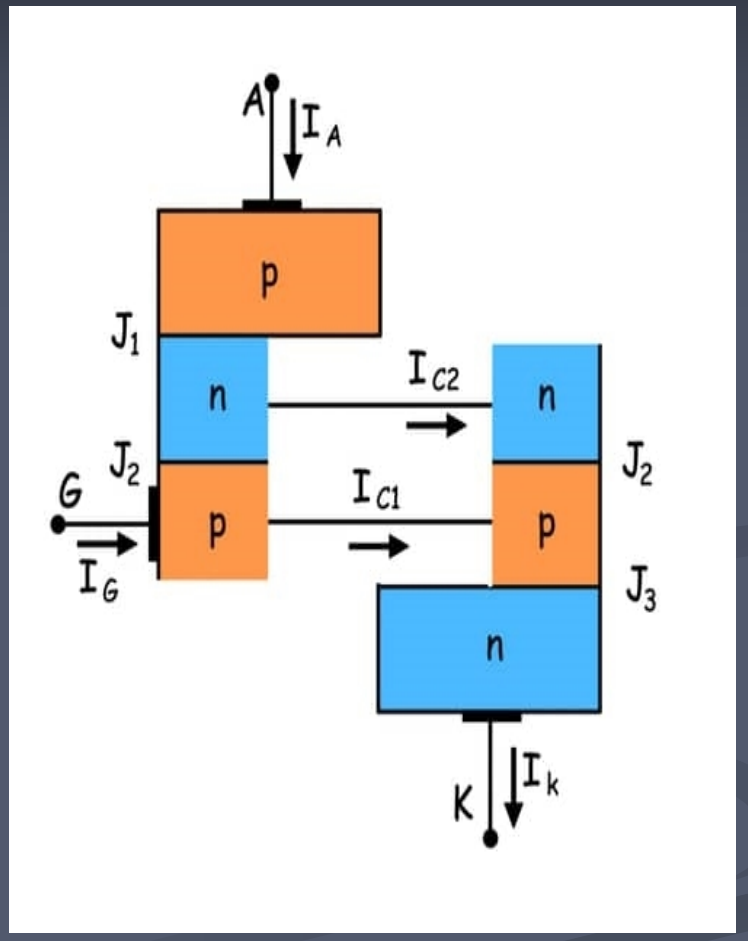
- In fact the circuit symbol for the **thyristor** (Shown in **Fig (3)**) **suggests** that this device **acts like a controlled rectifying diode.** However, **unlike** the junction diode which is a two layer **(P-N) semiconductor device,** or the commonly used **bipolar junction transistor** which is a **three layer (P-N-P, or N-P-N)** switching device, the **Thyristor** is a **four layer (P-N-P-N)** semiconductor device that contains **three P-N junctions** namely **J1, J2, and J3,** with **three terminals,** namely, **the Anode (A), the Cathode (K), and the Gate (G), Fig (4)** Shown schematic diagram of a SCR.

- The operation of the thyristor (SCR) can be best explained by assuming it to be made up of two transistors connected back-to-back as a pair of complementary regenerative switches as shown in **Fig (5).** Interestingly enough, the SCR looks like two PNP and NPN transistor connected in a back to back manner. **It is called two transistor model of SCR.** Two transistor model is obtain by bisecting the two middle layers along the dotted line in two separate halves as shown in **Fig (5).** The principle of SCR (thyristor) operation can be explained with the use of its two transistor model also called two transistor analogy. The two transistor model of SCR is shown in **Fig (5)** below.



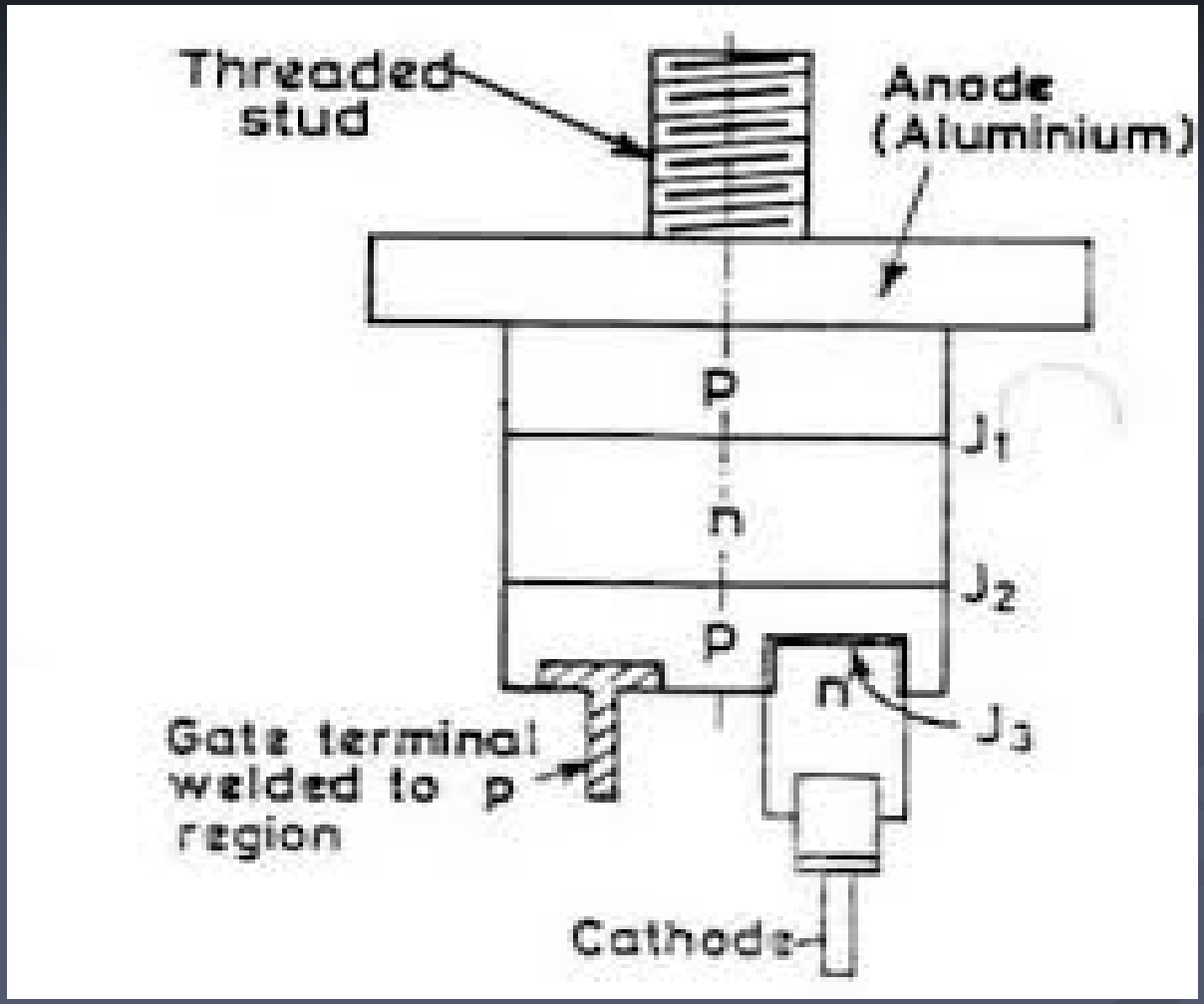
- **Fig (4)** Shown Schematic diagram of a SCR .





- **Fig (5)** Shows Two Transistor Model of a SCR.

- **SCR** is a **unidirectional device** that **allows** the **current** in one direction and **opposes** in **another direction**. Basically, it is a **rectifier** with a **control element.** It is a **unilateral device** and **conduction** takes place from **Anode to Cathode under proper forward biasing** with **Positive Gate trigger pulse.** In fact, it consists of **two P-N diodes** connected **back-to-back** with a **Gate connection.** It is widely used as a Switching Device in power control applications. It is a three-terminal device, consisting of three PN junctions which can be switched "ON" and "OFF" at an extremely fast rate. It can control loads by switching current OFF and ON up to many thousand times a second. It can switch ON for variable length of time duration during half cycles, thereby delivering selected amount of power to the load. Thus, it possesses the advantages of a RHEOSTATE as well as a SWITCH with none of their disadvantages. In **Fig (6)** Shown Schematic Internal Diagram of a Low Power Stud type SCR.



- **Fig (6)** Shown Schematic Internal Diagram of a Low Power Stud Type SCR.

- An **SCR** is so called because **silicon is used for its construction** and its o**peration as a rectifier** (very low resistance in the forward conduction and very high resistance in the reverse direction) **can be controlled.** As the terminology indicates, the **SCR** is a controlled rectifier, **construction of a silicon semiconductor material** with a **third terminal for control purposes.** Silicon was chosen because of it provides good thermal conductivity as well as a high voltage and current capability. Interestingly enough, SCR device is made of silicon only because leakage current in silicon is much smaller then that in germanium and it is necessary that leakage current should be minimum possible, as this device is used as a switch.

- Like the two terminal diode rectifier, thyristor or SCR is a unidirectional device that allows the current in one direction and opposes in another direction. Like the diode, SCR is a unidirectional device that blocks the current flow from cathode to anode, which means it will only conduct current in one direction only. But Unlike the two terminal uncontrolled rectifier diode, as they conduct current during forward bias condition from Anode (A) to Cathode (K) without any control, a thyristor (SCR) also blocks the current flow from Anode (A) to Cathode (K) until it is triggered into conduction by a proper Gate (G) signal between Gate (G) and Cathode (K) terminals.

- Which means the thyristor can be made to operate as either an open-circuit switch or close-circuit switch like as a rectifying diode. Once triggered into conduction by its gate terminal, a thyristor will remain conducting (passing current) always. Therefore in DC circuits and some highly inductive AC circuits the current has to be artificially reduced by a separate switch or turn off circuit. In other words, thyristors can operate only in the switching mode and cannot be used for amplification. Hence, the thyristor is also called as **controlled rectifier or silicon controlled rectifier (SCR).**

- **The** basic operation of the **SCR** is different from that of an ordinary two-layer semiconductor diode in that a third terminal, called Gate (G) determines when the rectifier switches from the open-circuit to short-circuit state. It is not enough simply to forward-bias the anode -to-cathode region of the device. It is require proper Positive Gate (G) to cathode (K) voltage for switching from non-conducting state to conducting state. In the **conduction state** the **dynamic resistance of the SCR is typically 0.01 to 0.1 ohms** and **non-conduction state reverse resistance is typically 100 kilo ohms or more.**

- Today **Performance rating** of **SCR** has improved considerably since its introduction in **1957.** Now SCRs of **voltage rating 10KV** and an **RMS current rating of 3000A** with corresponding **power-handling capacity of 30MW** are available. Such a high power thyristor (SCR) can be **switched "ON" by a low Gate (G) to Cathode (K) voltage supply of about 1V to 10V** and this gives us an idea of the **Immense Power Handling Capability** of this device in **high voltage AC and DC transmission line and systems.** As **SCRs** are solid state devices, they have various unique feature like **high current** and **voltage rating**, good trigger sensitivity, static operation, large power gain, long life, high reliability, low loss, very little maintenance and low cost of fabrication (due to advancement in the field of fabrication technology) have given thyristor a **colourful reception in every field.** Because of these useful features, SCR is almost universally employed these days for all DC and AC high power-controlled devices.

to be continued .....