Ministry of Higher Education
University of Al-Maarif
Medical Instruments Engineering Techniques Department

Power Electronic

For
Students of Third class

Lecture FOUR
Thyristors (SCR)

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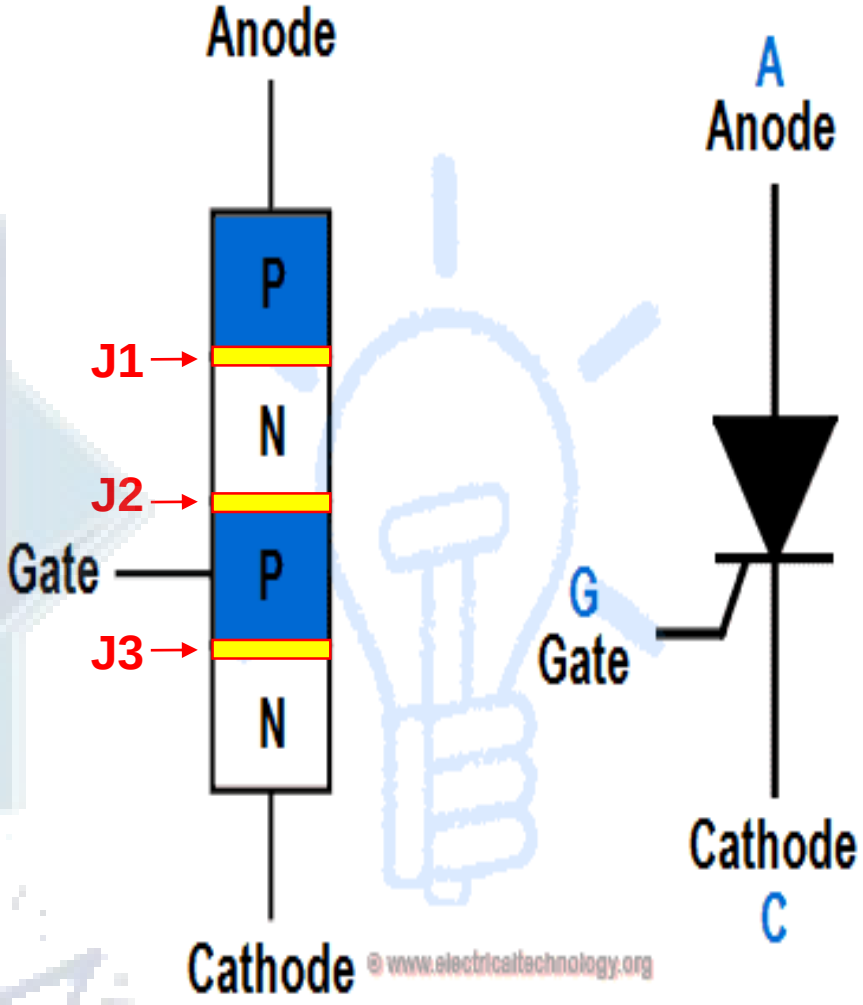
Sillicon Controlled Rectifier (SCR) or Thyristor

- Thyristor is, a **three terminal**, **four** layers solid state semiconductor device, each layer consisting of **alternately** N-type or P-type material, i.e; **P-N-P-N**.

- The conventional thyristor is also known by the name SCR (**Silicon Controlled Rectifier**).

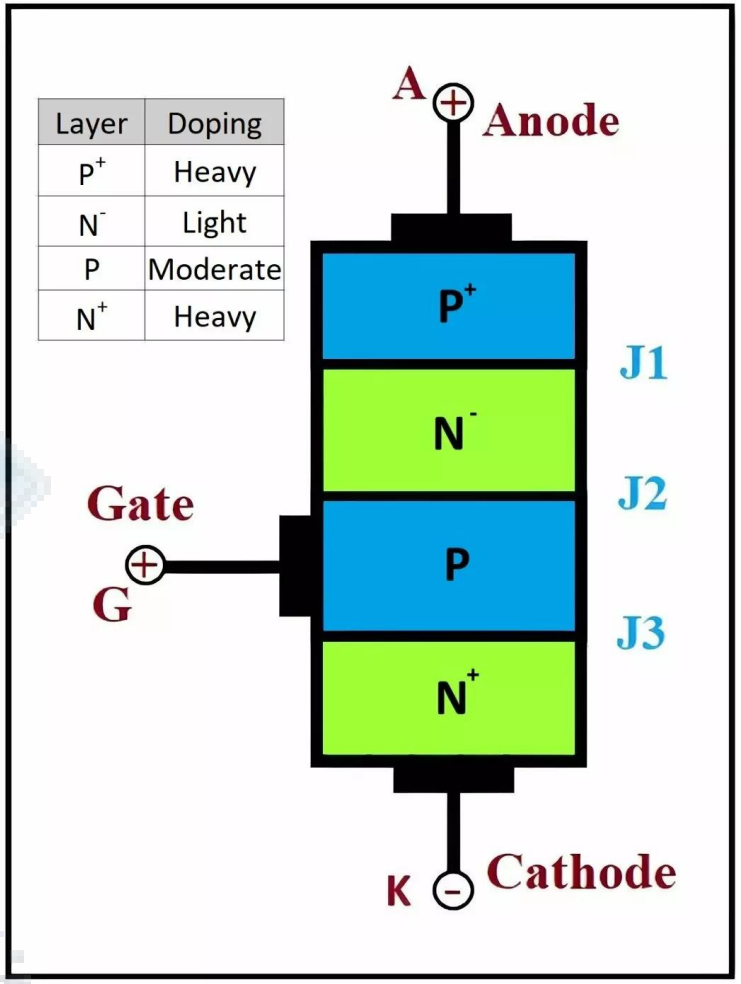
- They are operated as **bistable switches**, operating from non conducting state to conducting state.

- Thyristors can be assumed as **ideal switches** for many application, but the practical thyristors exhibit certain characteristics and limitations.



Thyristor (SCR) Structure & Symbol

- It can handle **high currents** and **high voltages**, with better switching speed and improved breakdown voltage.
- Typical rating are **1.5kA** & **10kV** which responds to **15MW** power handling capacity.
- This power can be controlled by **a gate** current of about **1A** only.

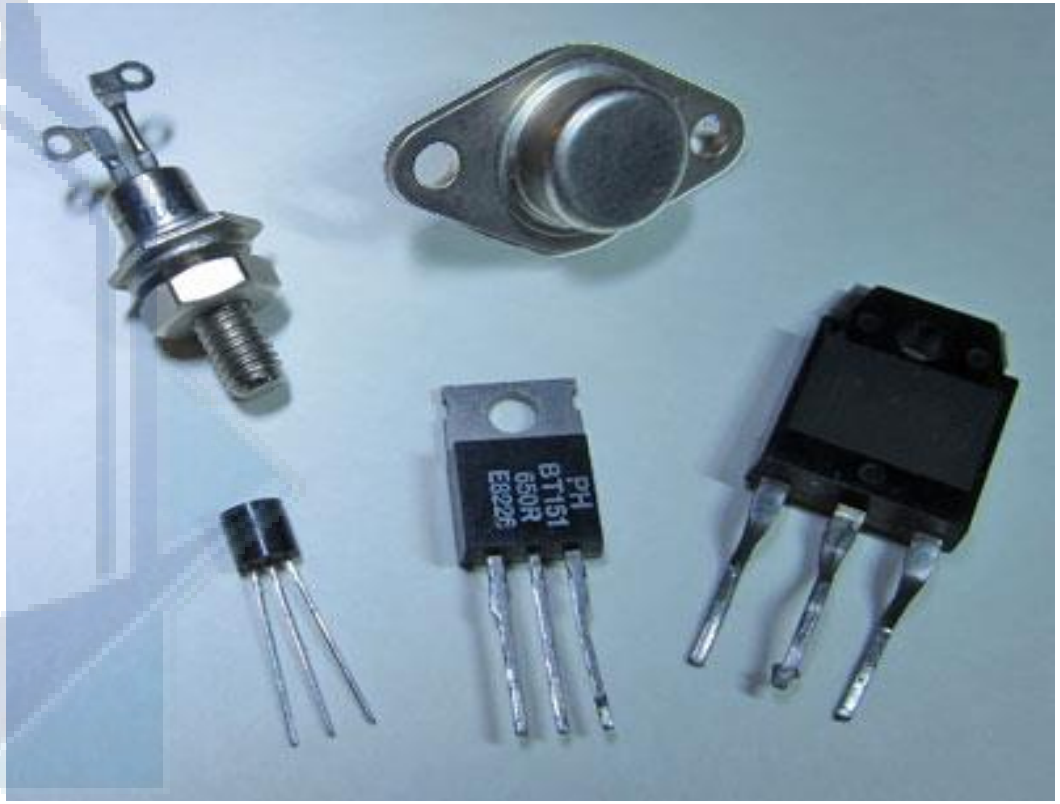


Thyristor act as switches:-

- It **conducts** when **gate** receives a ***current pulse***, and continue to conduct as long as forward biased (till device voltage is not reversed)
- They stay ON once they are triggered, and will go OFF only **if** current is too low or when triggered off.

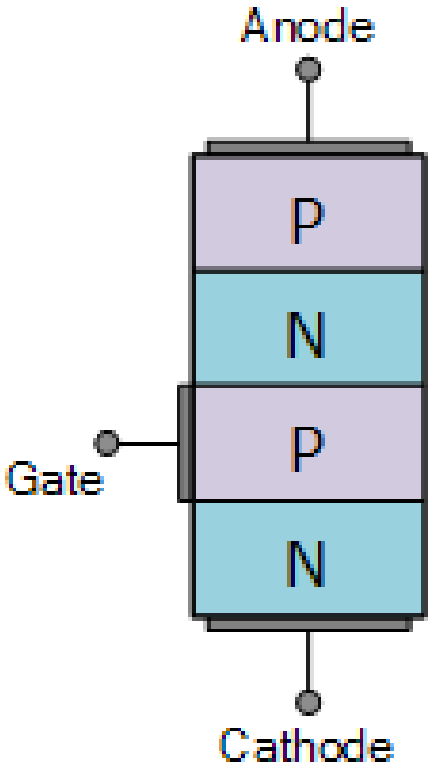
Types of Thyristor

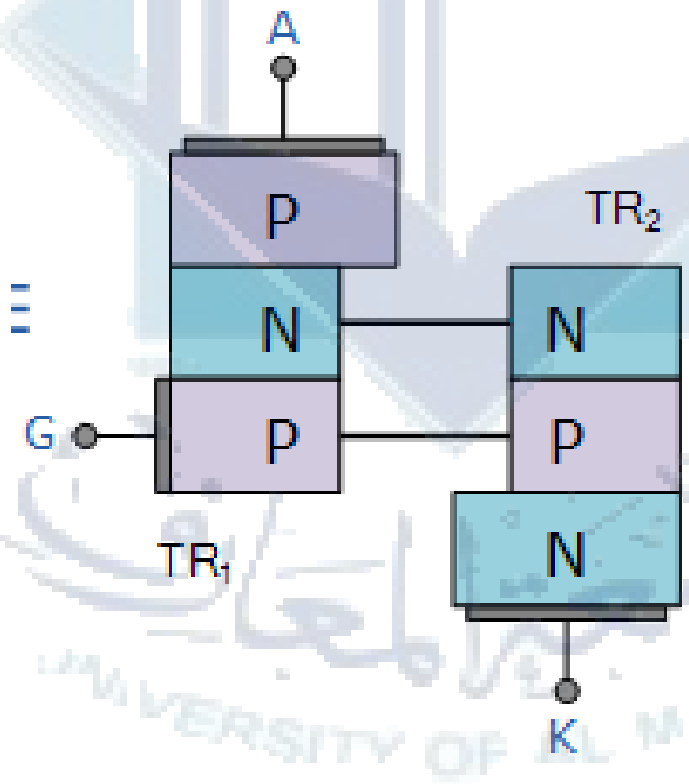
1. Forced-commutated thyristor
2. Line-commutated thyristor
3. Gate-turn-off thyristor (GTO)
4. Reverse-conducting thyristor (RCT)
5. Static induction thyristor (SITH)
6. Gate-assisted turn-off thyristor (GATT)
7. Light-activated silicon-controlled rectifier (LASCR)
8. MOS-controlled thyristor (MCT)

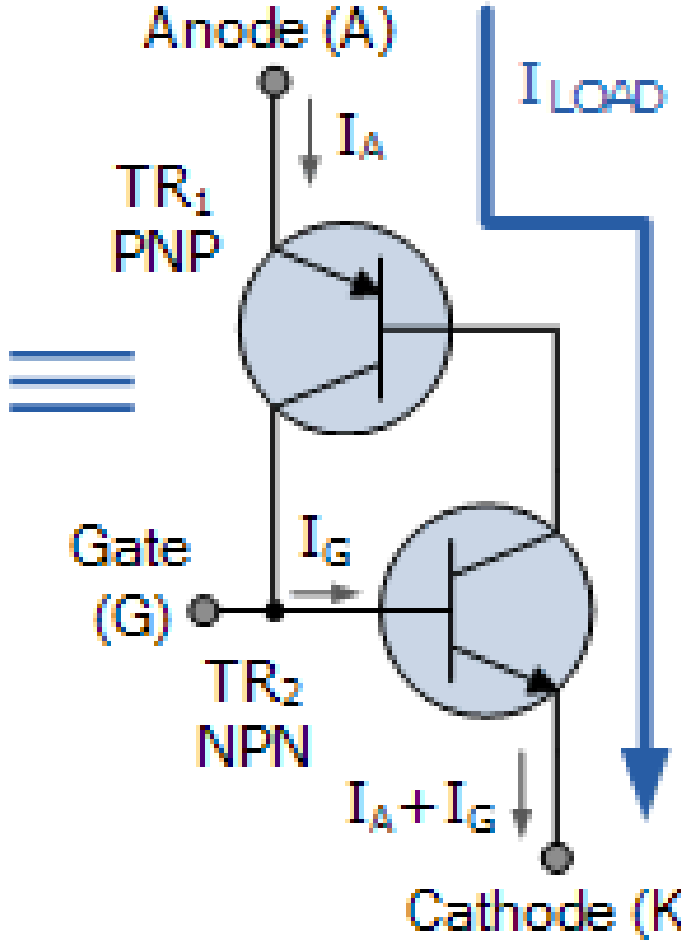


Thyristor equivalent circuit

- The operation of the thyristor can be understood by considering its internal (pnpn) structure **as a two-transistor arrangement.**
- When the gate current (IG = 0), both transistors Q1 and Q2 are **off**, and the thyristor operates in the **off state.**
- When there is gate current (**IG has a value**), both transistors Q1 and Q2 **turn on**, and the thyristor operates in the **on state** and stays in this condition.
- **Q1** is a **pnp** transistor, and **Q2** is an **npn** transistor.







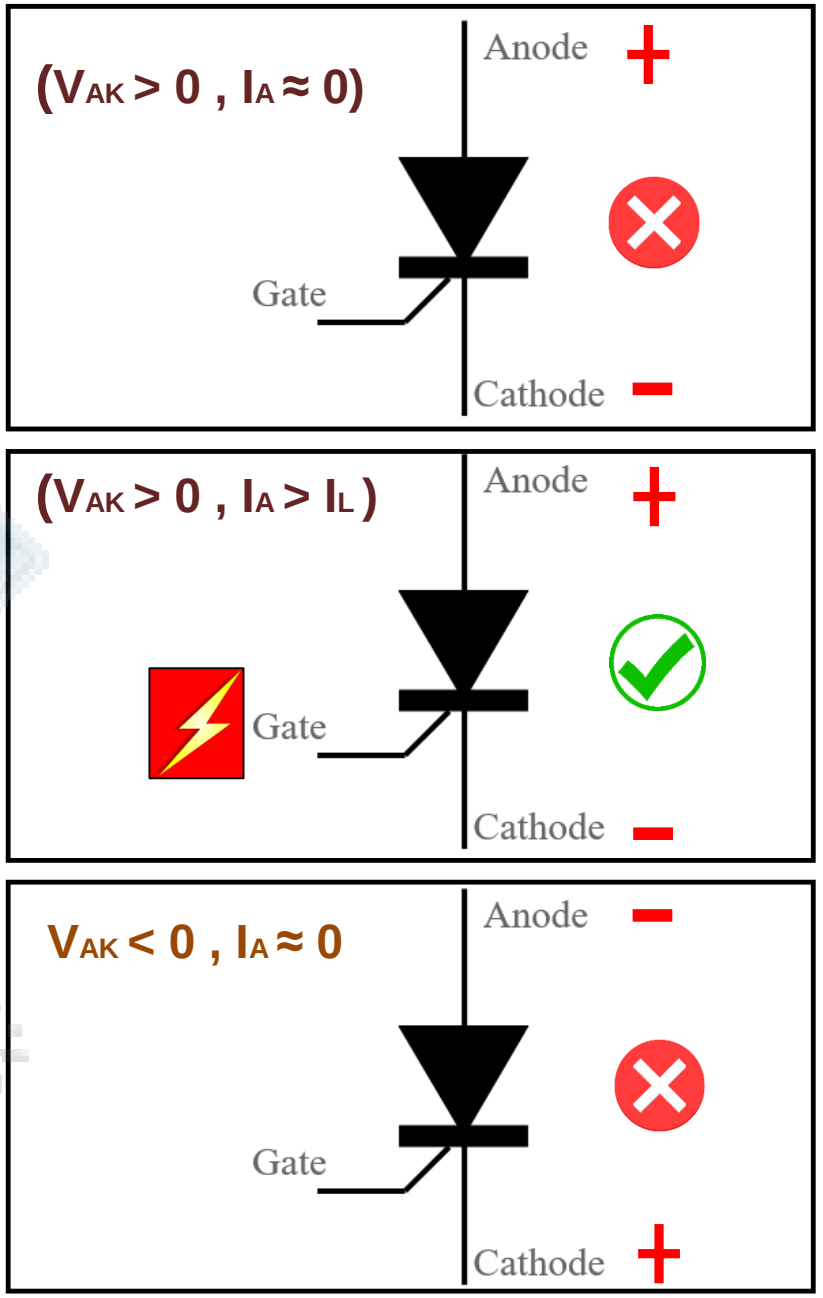
States of Thyristor

There are **three** states of thyristors.

1. **Forward blocking mode**: when there is positive anode-to-cathode voltage, but there is no gate input to triggered the thyristor into the conduction state.

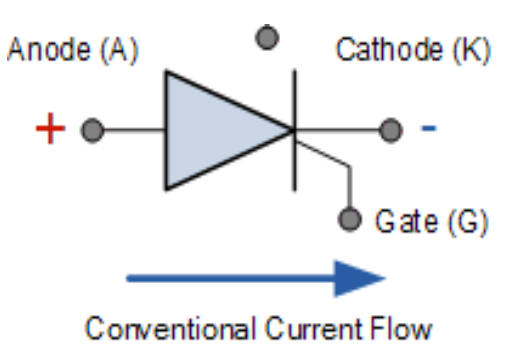
2. **Forward conduction mode**: when the thyristor is triggered into the conduction state and the forward current is maintained above the 'holding current'.

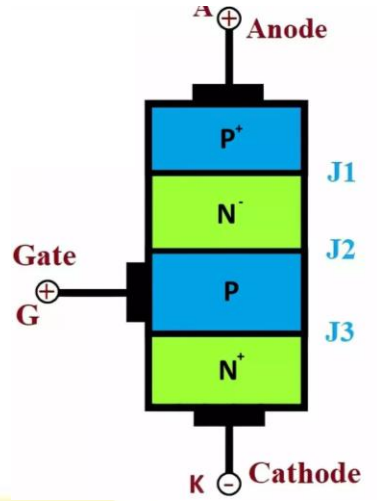
3. **Reverse blocking mode:** When there is a negative voltage applied to the anode with respect to the cathode, the thyristor blocks the current flow like a normal diode.



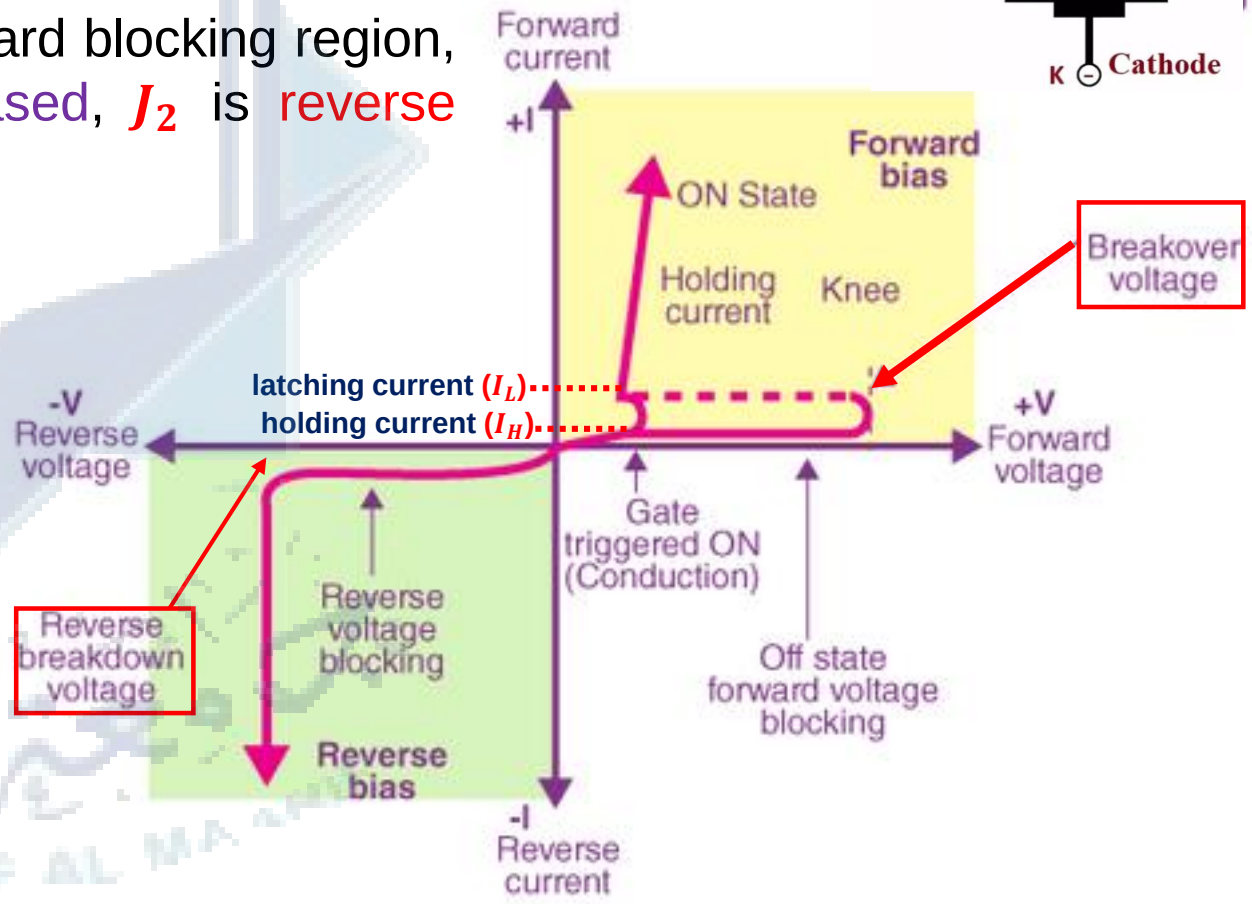
I-V characteristics of Thyristor

The static V-I characteristics of an SCR are divided into three regions:





- Reverse Blocking Region ($V_{AK} < 0$, $I_A \approx 0$): When the anode is negative, the thyristor is reverse biased, allowing only a small leakage current. If the reverse voltage exceeds **reverse breakdown voltage V_{BR}**, an avalanche occurs, increasing current sharply.
- Forward Blocking Region ($V_{AK} > 0$, $I_A \approx 0$):In the forward blocking region, the anode is positive, J_1 and J_3 are forward biased, J_2 is reverse biased, and only a small leakage current flows.
- Forward Conduction Region ($V_{AK} > 0$, $I_A > I_L$):When the forward voltage increases to the **breakover voltage** (V_{BO}), the SCR switches to low impedance, causing a voltage drop and large current flow. Gate current turns the SCR on before, with lower voltage for higher gate currents. Once the anode current exceeds the latching current (I_L), the gate is no longer needed. The SCR turns off if the current drops below the holding current (I_H).



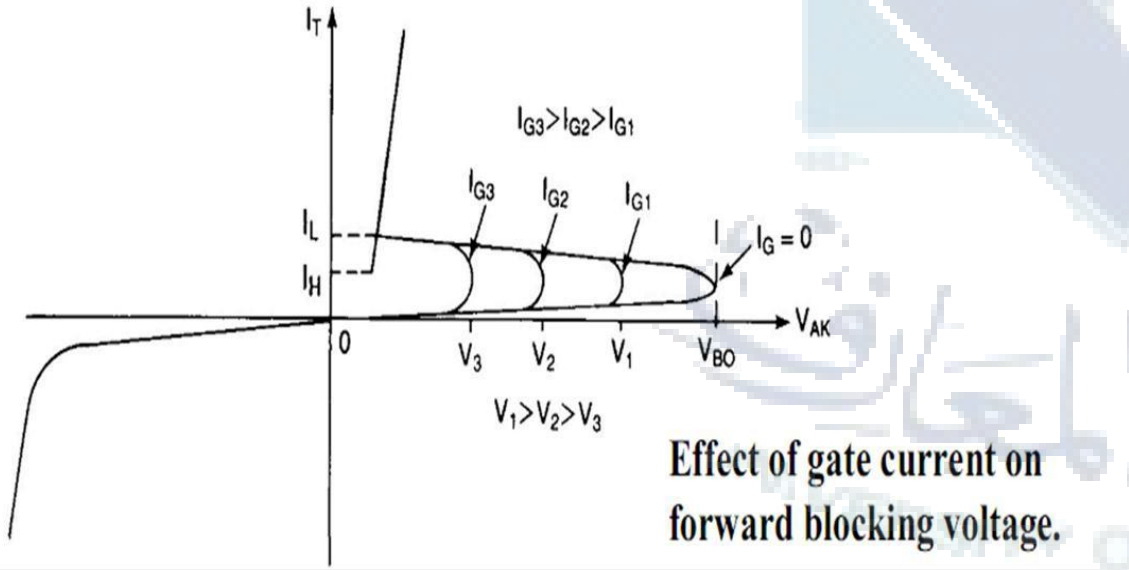
Thyristor Turn-On:

(a) Forward voltage triggering (VAK = VBO)

If the forward anode-to-cathode voltage exceeds the breakdown voltage (VBO), leakage current may cause regenerative turn-on, which can be destructive and should be avoided.

(b) gate triggering (IG > 0)

A positive gate current applied to a forward-biased thyristor turns it on, reducing the forward blocking voltage as the gate current increases.



Effect of gate current on forward blocking voltage.

(c) high instantaneous voltage ($\frac{dv}{dt}$ >>0)

A high rate of rise of anode-cathode voltage (dv/dt) can charge capacitive junctions enough to turn on the thyristor, potentially damaging it. Protection against high dv/dt is necessary, and manufacturers specify the maximum allowable dv/dt for thyristors.

(d) Temperature triggering (Temp > >0)

Increasing temperature raises leakage current through J2, potentially turning on the SCR at high temperatures.

(e) Light triggering (Light)

Light striking a thyristor's junctions increases electron-hole pairs, potentially turning it on. Light-activated thyristors are triggered by exposure to light on silicon wafers.

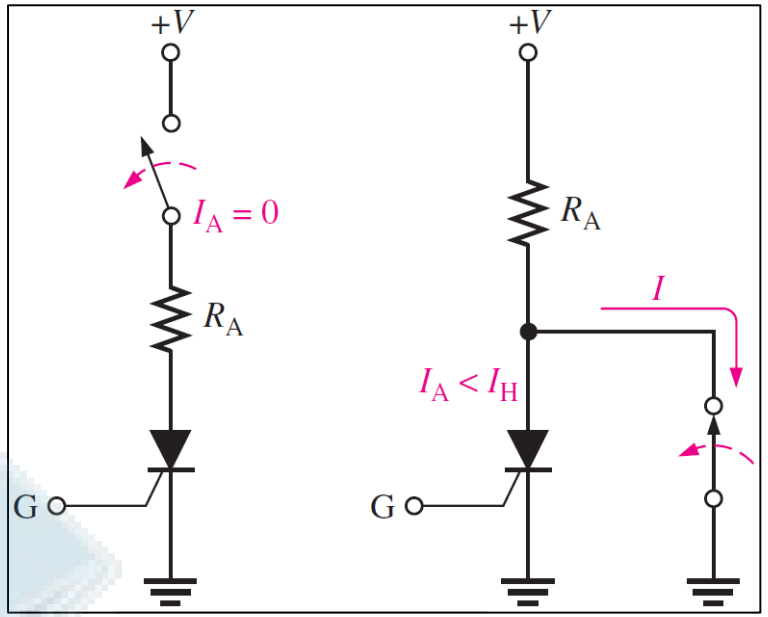
Thyristor Turn-Off:

There are Two ways to turn off thyristor:

- **Anode Current Interruption**

A thyristor which is in the on-state can be turned off by reducing the forward current (Anode Current) to a **level below** the holding current I_H.

$$I_A < I_H$$



- **Forced Commutation**

Force commutation uses an **external circuit** to momentarily force current in the **opposite direction** to forward conduction.