Power Converters

Lecture-4

The Thyristor

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Thyristor

- The name Thyristor is a generic term for bipolar device consisting of four layers and operate as a switch.
- Numerous members of thyristor family exists i.e. SCR, GTO, TRIAC etc.
- As far as structure is concerned the simplest is the SCR and most complicated is TRIAC.

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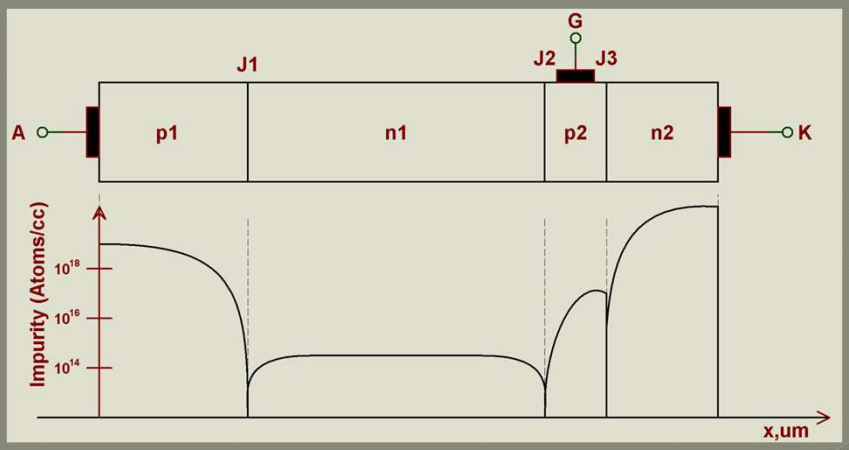
SCR
Basic Structure

The basic structure of an SCR with doping profile.



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SCR
Basic Structure

- The SCR is a four layer ($p^+ n^- p\ n^+$) device.
- Low rating (10-100A), device is built on a small die of silicon wafer.
- High rating (100-4000A), the SCR is built on an entire wafer.

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SCR
Basic Structure

- The *Cathode* is the heavily doped
- n-region on the top of the device.

- The *Anode* is heavily doped p-region on the bottom of the device.

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SCR
Physical Structure

- The P-region (p_2) under the cathode is the gate.

- The gate of the device is connected to the metal contact on the top of the die.

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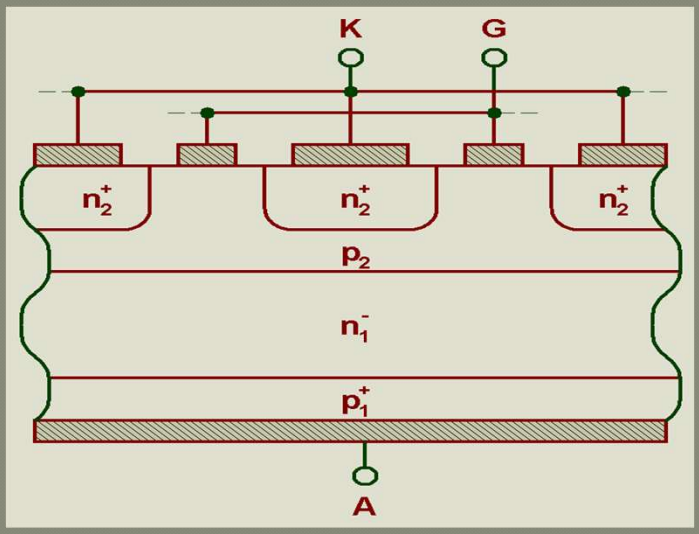
SCR

Physical Structure



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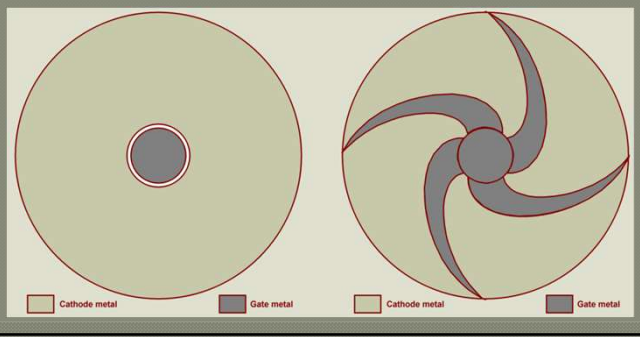
Top View of the Structure

- This is the top view of two different gate geometries.
- The center-gate type is for low frequency SCRs.
- The involute-gate is used for high frequency SCRs.



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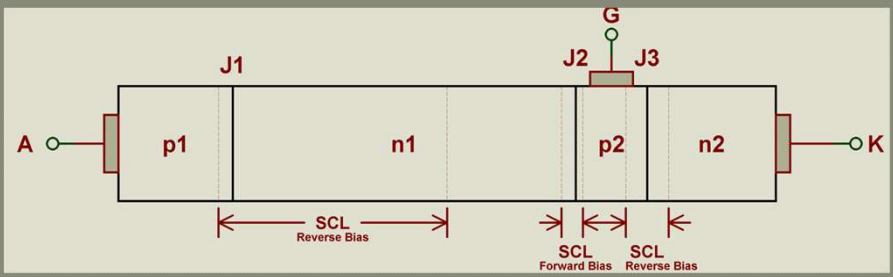
SCR Operation

- The SCR junctions are labeled as J_1, J_2, J_3, and each of the four layers as p_1, n_1, p_2, n_2.



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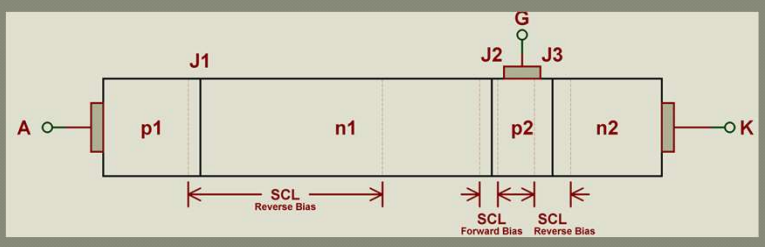
SCR Operation

The Off State

- When the SCR is off, it can block a reverse voltage or a forward voltage.

- when SCR is blocking Reverse voltage. V_{AK} is negative, J_1 & J_3 are reverse biased.



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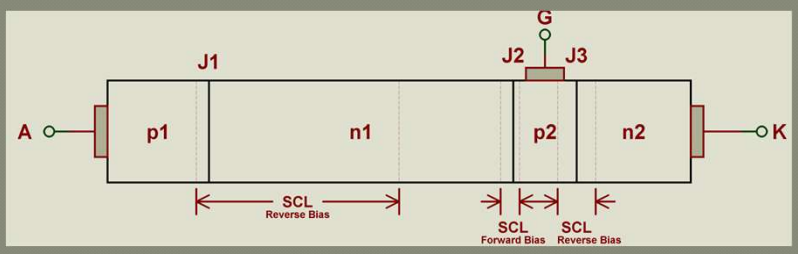
SCR Operation

The Off State

- The doping on each side of J_3 is very heavy, so breakdown voltage of J_3 is relatively low.



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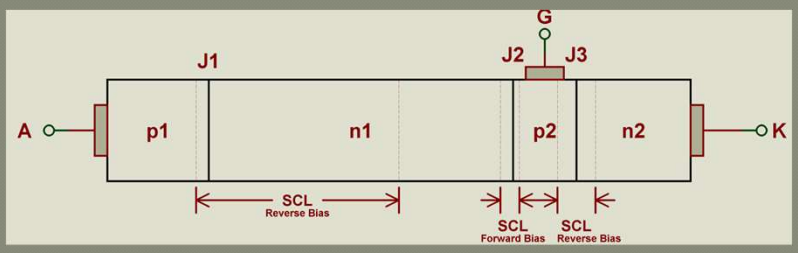
SCR Operation

The Off State

- n_1 region is long and lightly doped, therefore, J_1 can block large reverse voltage.
- The SCL at J_1 grows mostly into n_1 region.



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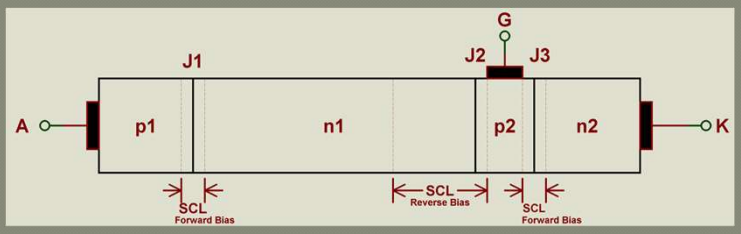
SCR Operation

The Off State

- When V_{AK} is positive, J_1 & J_3 are forward biased and J_2 is reverse biased.



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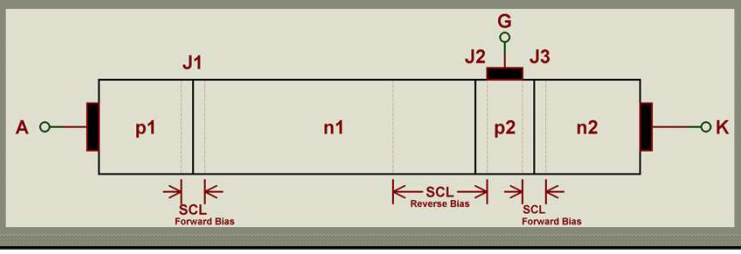
SCR Operation

The Off State

- J_2 withstands all the applied voltage.
- As the n_1 region is more lightly doped than p_2 region, the SCL again grows into the n_1 region.



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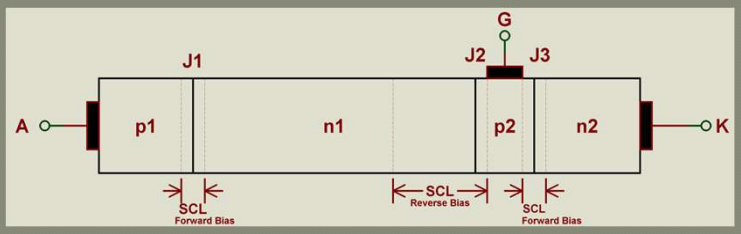
SCR Operation

The Off State

- The n_1 region is used to block both polarities of voltage when SCR is off.
- The doping level & length of n_1 region must be chosen to give the desired breakdown voltage.



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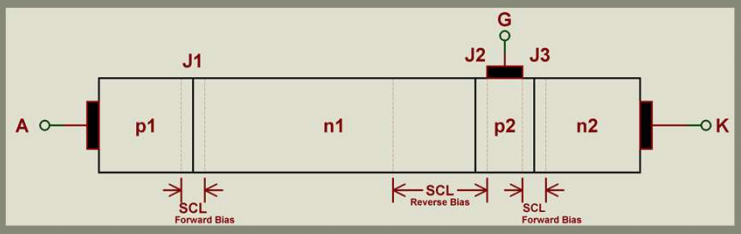
SCR Operation

The Off State

- The breakdown of n_1 can be either due to punch through or due to avalanche.
- Most SCRs are designed with n_1 long enough to cause the avalanche to be the breakdown mechanism.



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Turn 'on' Process

- If V_{AK} is positive, the SCR will block the voltage when the gate is open.
- A momentary gate current can turn 'on' the SCR and it will remain 'on' even if the gate current is made zero.
- This latching of the SCR can be understood from the two transistor model.

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