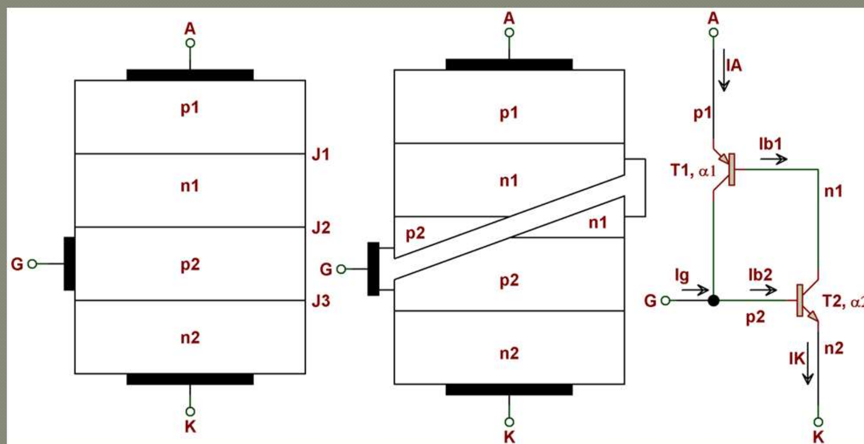
Two Transistor Model



Cross-section of the SCR showing its two transistor model derivation.

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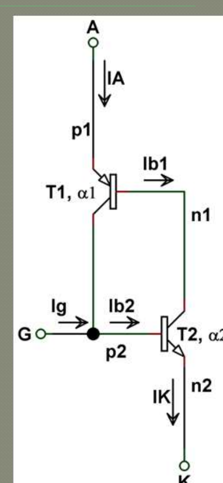
Regenerative Process

- The application of a positive voltage at Anode can not turn on the SCR, because the junction J_2 is reverse biased and Blocking.
- Base-Collector junctions of both the transistors are reverse biased and both transistors are off.



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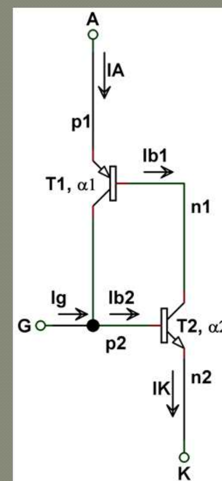
Regenerative Process

- The collector current of T_2 provides the base current for T_1.
- The collector current of T_1 along with gate current supplies the base drive for T_2.



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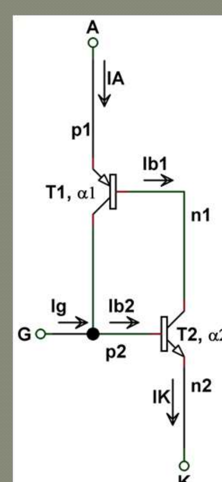
The On State

- As the two transistor drive each other into saturation, the excess carrier concentrations in their base regions reach high level injection.
- At this point doping concentrations in the base regions are no longer relevant, and the SCR behaves as a three layer PIN diode.



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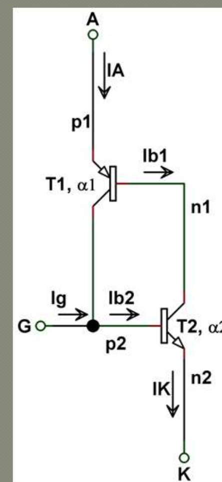
The On State

- The two middle layers corresponds to the i-region.
- The forward voltage across the i-region is inversely proportional to the recombination rate.



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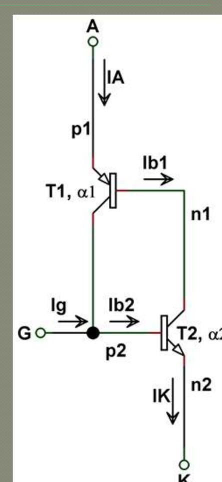
Regenerative Process

- Base current of each transistor is β times its collector current.
- The regenerative turn on process can be initiated, if a short pulse of current is applied at the gate terminal



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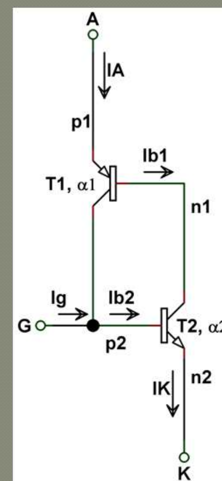
Regenerative Process

- As long as the product
  $\beta_1 \beta_2 > 1$

the two transistors will drive each other harder and harder until they saturate.



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Break Over Voltage

- The SCR does not breakdown in the forward direction, instead it turns on.
- This process is known as Breaking over and the voltage at which it occurs is called the break over voltage V_{BO}.
- The breaking over process starts due to forward leakage current, I_A of the SCR which must be kept small to save it from Beak over.

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Break Over Voltage

- It can be shown that the SCR leakage current is

$$I_A = \frac{I_{CO1} + I_{CO2}}{1 - (\alpha_1 + \alpha_2)} \qquad \text{---------------} \ (1)$$

- To keep the I_A small, the loop gain,

$$(\alpha_1 + \alpha_2) << 1$$

- If $(\alpha_1 + \alpha_2) = 1$, the equation (1) shows that SCR will enter into sustained breakdown.

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Break Over Voltage

- The leakage current of the SCR increases with temperature.
- Therefore at elevated temperature, the thermally generated leakage current can be sufficient to increase the SCR loop gain such that turn on occur.
- If α_2 is made smaller than α_1, the reverse and forward breakdown voltages are nearly same.

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SCR *dv/dt* Rating

- The SCR can also turn on by means of high ***dv/dt*** across anode and cathode.
- The increasing voltage is supported by J_2.
- The associated SCL width increases and a charging current flows across the anode and cathode junctions, causing hole and electron injection respectively.

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SCR *dv/dt* Rating

- The same mechanism occurs at the cathode when gate current is applied; hence if the terminal ***dv/dt*** is large enough, SCR turns on.

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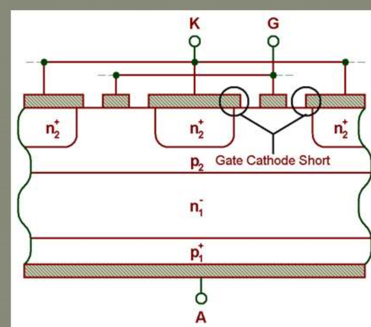
Gate Cathode Short

- A structural modification is used to reduce temperature sensitivity of the device and to increase the rating by introducing gate cathode shorts.



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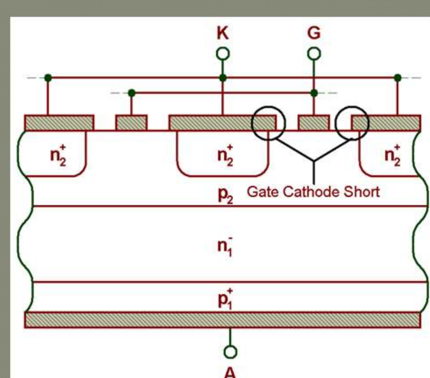
Gate Cathode Short

- The effect of this short is like placing a resistor across the base-emitter junction of T_2.



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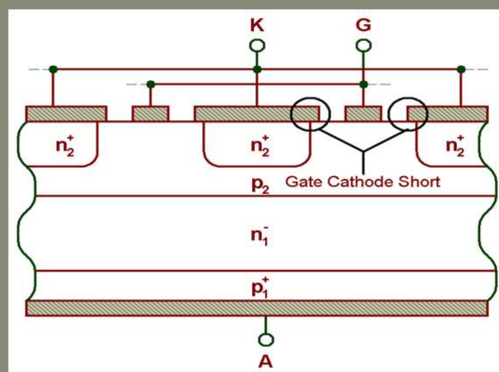
Gate Cathode Short

- The cathode electron injection efficiency is effectively reduced thereby decreasing α_2 which results in V_{BO} and **dv/dt** rating.



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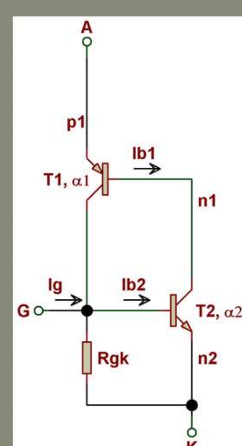
Function of Cathode Short

- In the forward blocking state, J_2 leakage current will forward bias base-emitter of T_2.
- As this junction voltage rises, the cathode short diverts some of the leakage current of p_2 base reducing the current that is multiplied by the transistor action, in effect the gain of T_2 is reduced.



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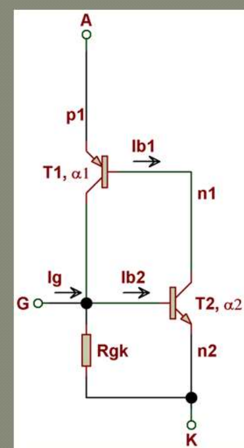
Function of Cathode Short

- The designer will make $0.7/R_{gk}$ larger than the maximum leakage current expected when SCR is in forward blocking state.



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Latching Current

- To turn on the SCR, we need T_2 to contribute to the regenerative process.
- This contribution will not occur until the current flowing through the SCR is $0.7/R_{gk}$.
- Because this value of current is usually exceeded by I_g, the SCR will turn on by the gate drive.

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Latching Current

- But if the gate drive is removed, the regenerative process stops and the SCR returns to its off state.

- The Anode current level required for the SCR to remain on when the gate drive is removed is called the latching current I_L.

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Holding Current

- Similarly, if the SCR is on and the gate drive has been removed, the anode current must fall below than a critical level to turn off the SCR because of the failure of the regenerative process.
- The anode current at which this occurs is called the holding current, I_H.
- Our simple description here suggests that

$$I_L=I_H=0.7/R_{gk}.$$

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Holding Current

- However, R_{gk} is slightly different for the turn-on and turn-off processes owing to the differences in excess charge concentrations in the p_2 region.
- For a 100A device, I_L and I_H are typically in the range of 100 to 300mA , with $I_H < I_L$.

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Latched SCR

- An important property of the SCR is that once latched on, the gate control is lost.
- The SCR can not turned off through gate.
- SCR turn off can only be achieved by reducing the anode current externally to a level below which the loop gain is significantly less than unity.

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GTO

The Gate Turn of Tyristor

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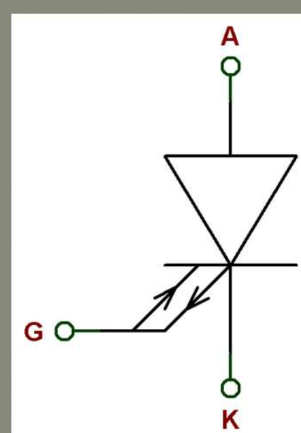
GTO
The Gate Turn Off Thyristor

- GTO, is one of the new power semiconductor device.
- Introduced in the 1970's but was not established until the 1980's.



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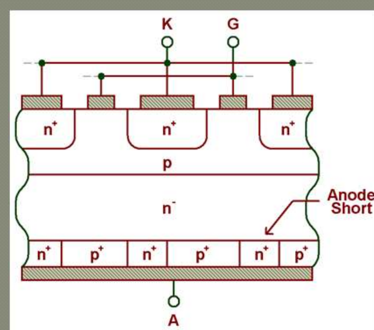
GTO

The Gate Turn Off Thyristor

- Research and development has led to the present day range of devices, with peak turn-off current in the range of 300A to 4000A and rated forward blocking voltages of between 1300V and 6000V.



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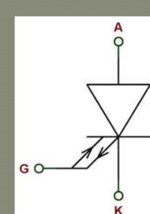
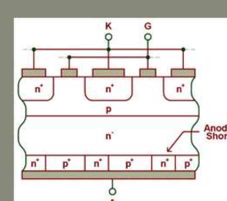
GTO

- The gate terminal has two arrowheads, on the circuit symbol of GTO indicating current flow in both directions, since the GTO can also be turned off with a negative gate current signal.





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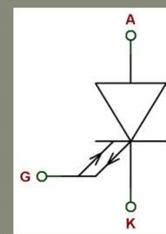
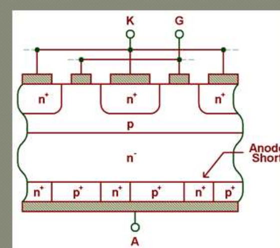
GTO

- The difference in the structure of GTO from the SCR is the Anode short which helps to stop the regeneration process with negative gate pulse.



- However, Anode short gives rise to an asymmetrical voltage blocking characteristics.



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Thank you

For your attention

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