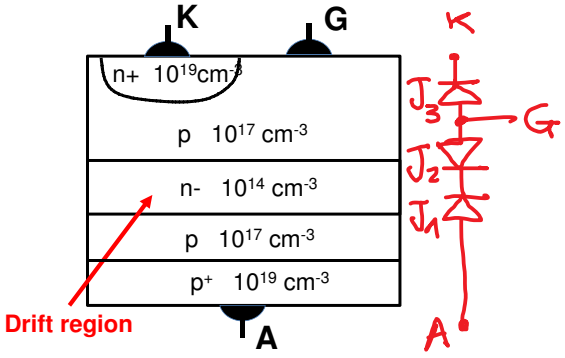
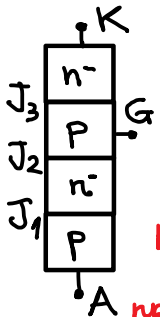
Tiristore (Thyristor)

- SCR – Silicon Controlled Rectifier – 1957 GE



Ideal thyristor

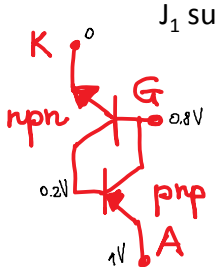


$V_{AK} > 0$ **Forward blocking**

J_2 supports V_{AK}

$V_{AK} < 0$ **Reverse blocking**

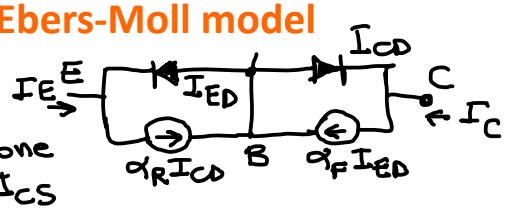
J_1 supports V_{AK}



$\alpha_{npn} \lesssim 1$ [0.9]
$\alpha_{pnp} < 0.1$

Two states:
OFF:BJTs in cutoff
ON: BJTs in sat.

Ebers-Moll model

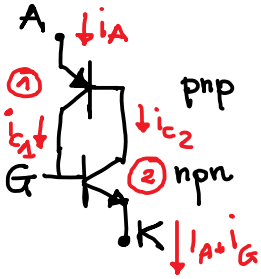


In active zone
$I_{CO} = -I_{CS}$

- $I_E = -I_{ED} - \alpha_R I_{CS}$
- $I_C = \alpha_F I_{ED} + I_{CS} = -\alpha_F I_{ED} + I_{CO}$

$I_{CO} = I_{CS}(1 - \alpha_F \alpha_R)$

Equivalent circuit



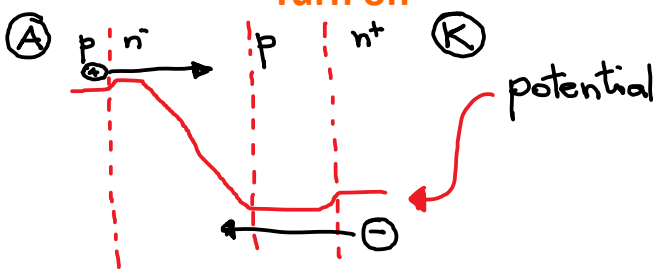
$i_A = i_{c_1} + i_{c_2}$

$\alpha_{pnp} i_A - I_{CO_1}$ $\quad$ $\alpha_{npn}(i_A + i_G) - I_{CO_2}$

$$i_A = \frac{\alpha_{npn} i_G - I_{CO_1} + I_{CO_2}}{1 - \alpha_{npn} - \alpha_{pnp}}$$

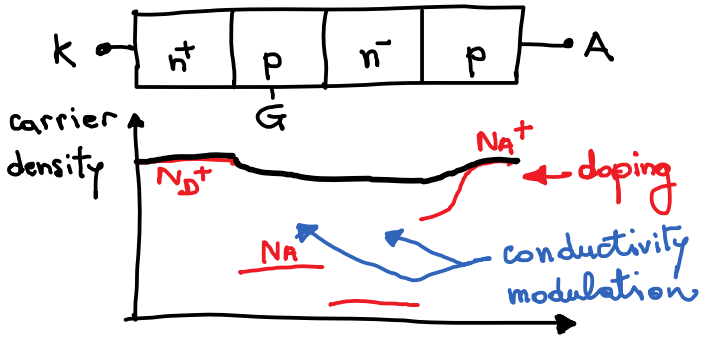
$\alpha_{npn} + \alpha_{pnp} < 1$: OFF
$\alpha_{npn} + \alpha_{pnp} \cong 1$: ON

Turn on



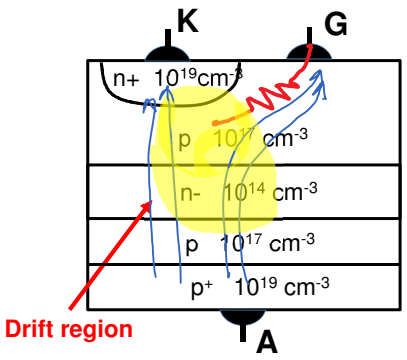
- If V_{AK} increases, the voltage drop in n- shrinks the base of the PNP transistor → α_{pnp} increases (an partly on the NPN transistor) → α_{npn} increases
- **Injection of electrons in the drift region causes more hole injection from the anode, to compensate excess charge → positive feedback**.

On state operation



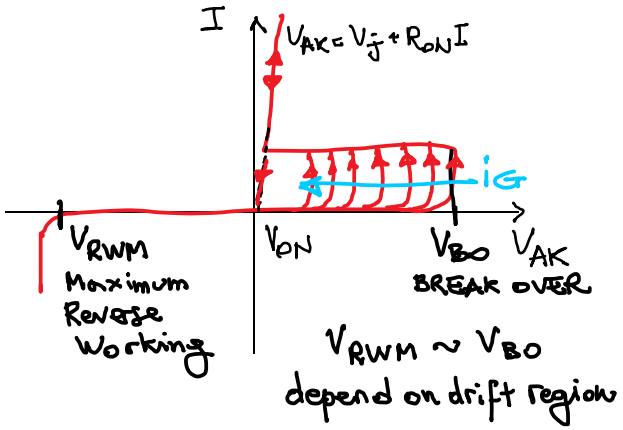
$V_{ON} = V_J + R_{ON} I$

Turn off

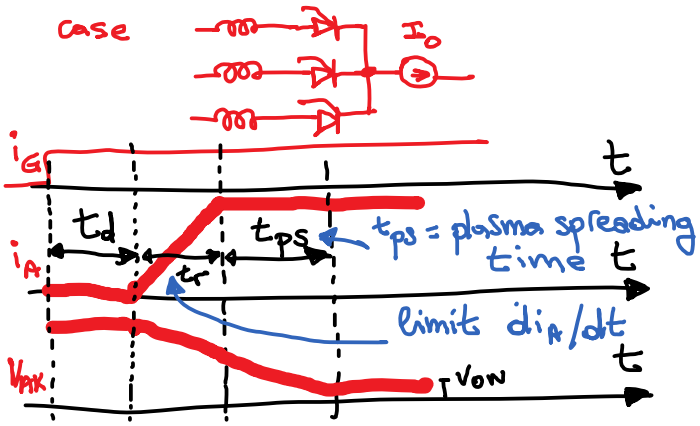


- Gate current cannot turn the SCR off
- Cathode area >> gate area
- Current crowding keeps pn+ junction forward bias
- SCR is turn off with $V_{AK} < 0$

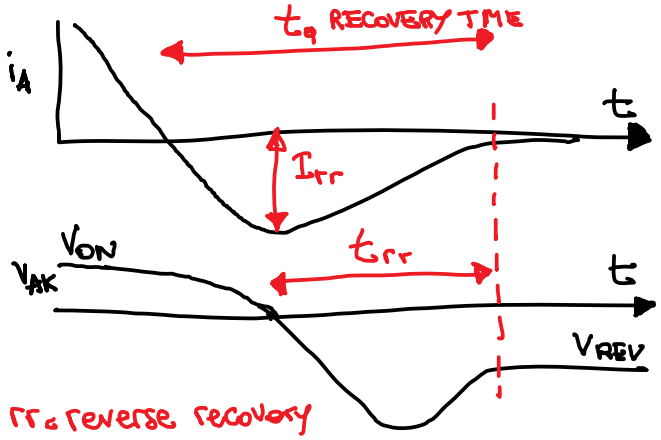
DC characteristics



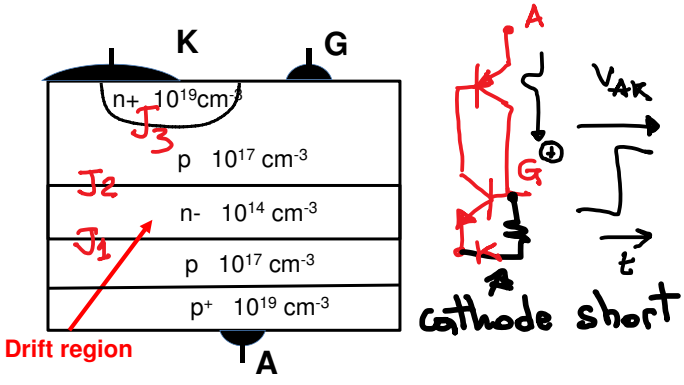
Turn on transient



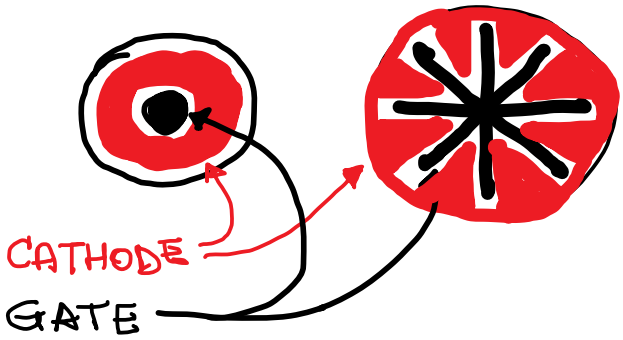
Turn off transient



Cathode short



Interdigitated gate-cathode

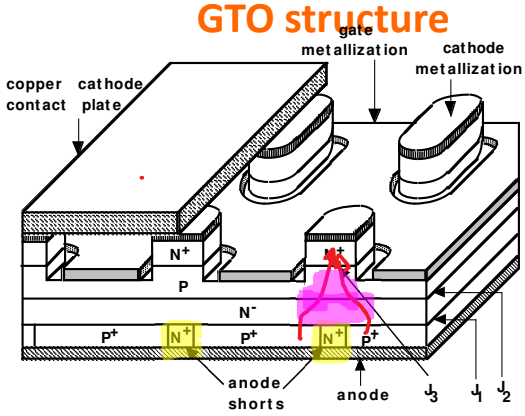


Gate Turn Off (GTO) thyristor

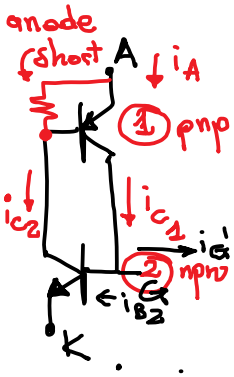
GTOs are turned off with negative i_g pulse

1. Highly interdigitated structure (1K cells)
2. Cathode islands
3. Anode short

GTO structure



Turn off



the anode short improves increased α_{pnp}

$\alpha_{pnp} = i_{C1} / i_A$

Q_2 in active region if $i_{B2} < \frac{i_{C2}}{\beta_{2sat}}$

$i_{B2} = i_{C1} - i'_G = \alpha_{pnp} i_A - i'_G < \frac{i_A(1-\alpha_{pnp})}{\beta_{npn}}$

$i'_G > i_A\left[\alpha_{pnp} - \frac{(1-\alpha_{pnp})}{\beta_{npn}}\right]$

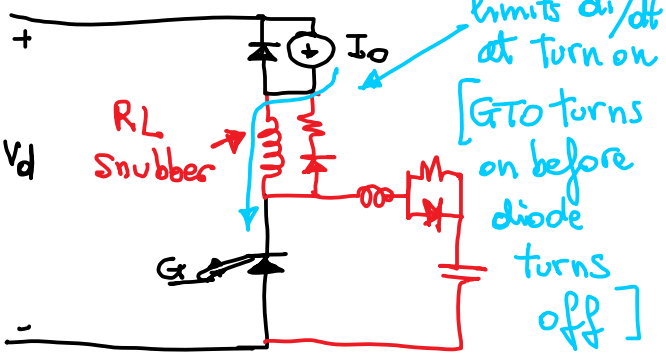
Turn off

- To reduce turn off $i_{G'}$ we must suppress α_{pnp}
- In order to suppress α_{pnp} we can
  - Use anode short → thyristor does not block $V_{AK} < 0$
  - Increase thickness and recombination in drift region → V_{ON} increases
- Typically

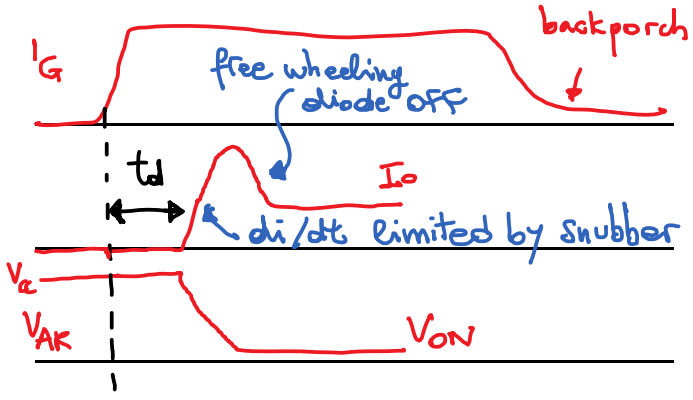
$$i'_G \approx \frac{1}{3} \div \frac{1}{5} i_A$$

GTO switching characteristics

- GTO is fast → requires **snubber circuits**



Turn on transient



GTO switching characteristics

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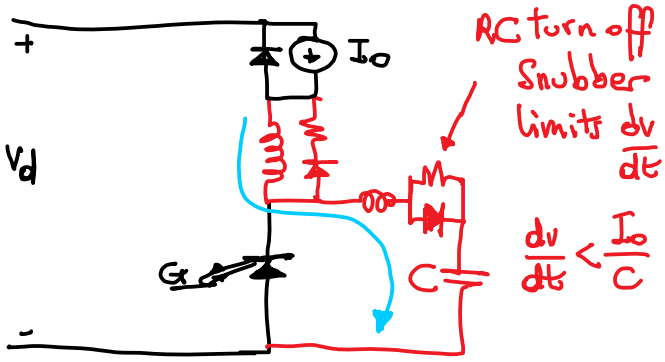

Turn off transient