Figs 4.46 4.47 pg 89

Lowest cost SW | First Pe- SW

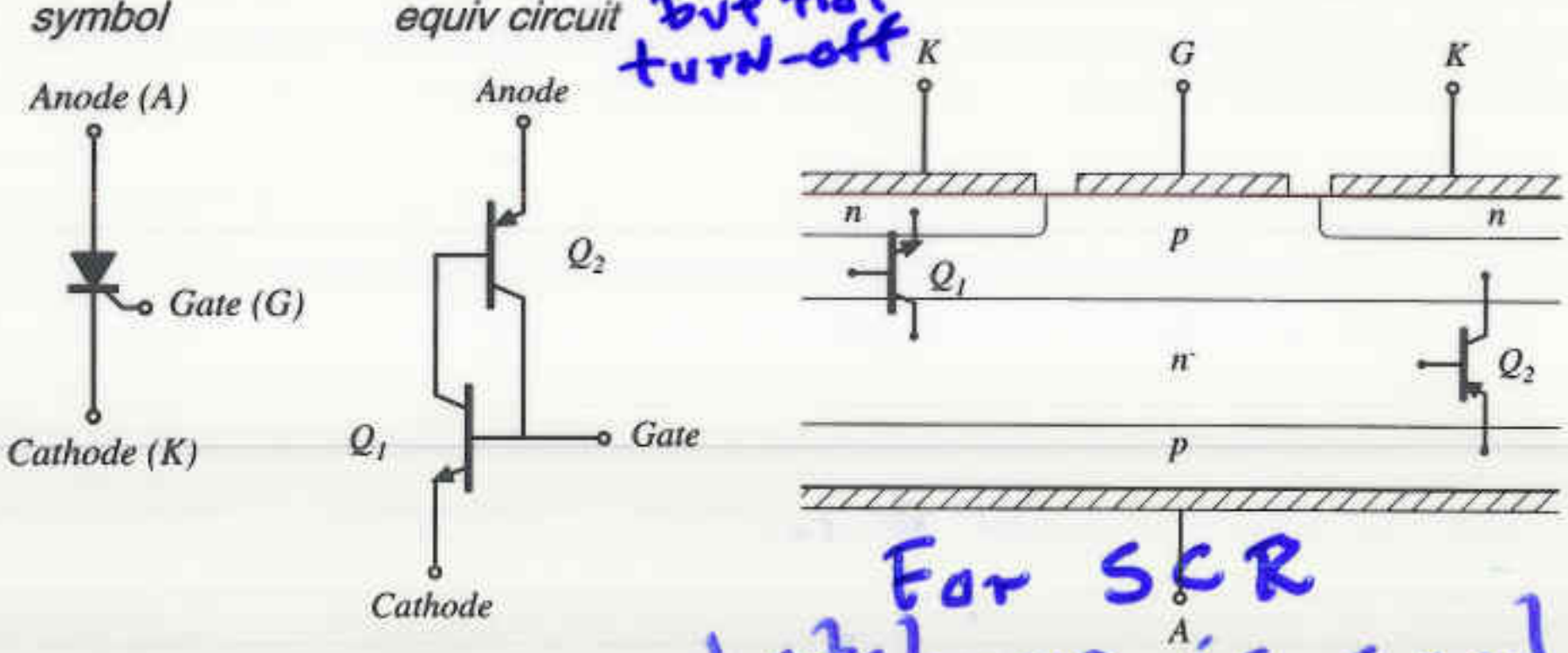
4.2.5. Thyristors (SCR, GTO, MCT)

OLD

only active turn-ON but not turn-off

New Generation active (turn-off) (turn-ON)

The SCR



For SCR Latch-up is good!

For CMOS latch is bad effect

Fig 4.42 pg 90

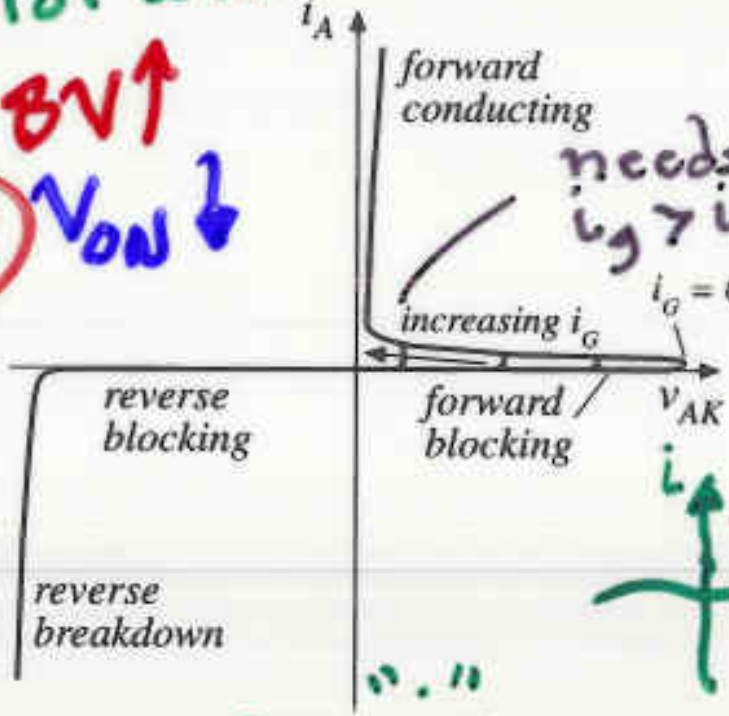
The Silicon Controlled Rectifier (SCR)

- Positive feedback —a latching device
- A minority carrier device
- Double injection leads to very low on-resistance, hence low forward voltage drops attainable in very high voltage devices
- Simple construction, with large feature size
- Cannot be actively turned off
- A voltage-bidirectional two-quadrant switch
- 5000-6000V, 1000-2000A devices

Best of both!

BV ↑

V_{ON} ↓



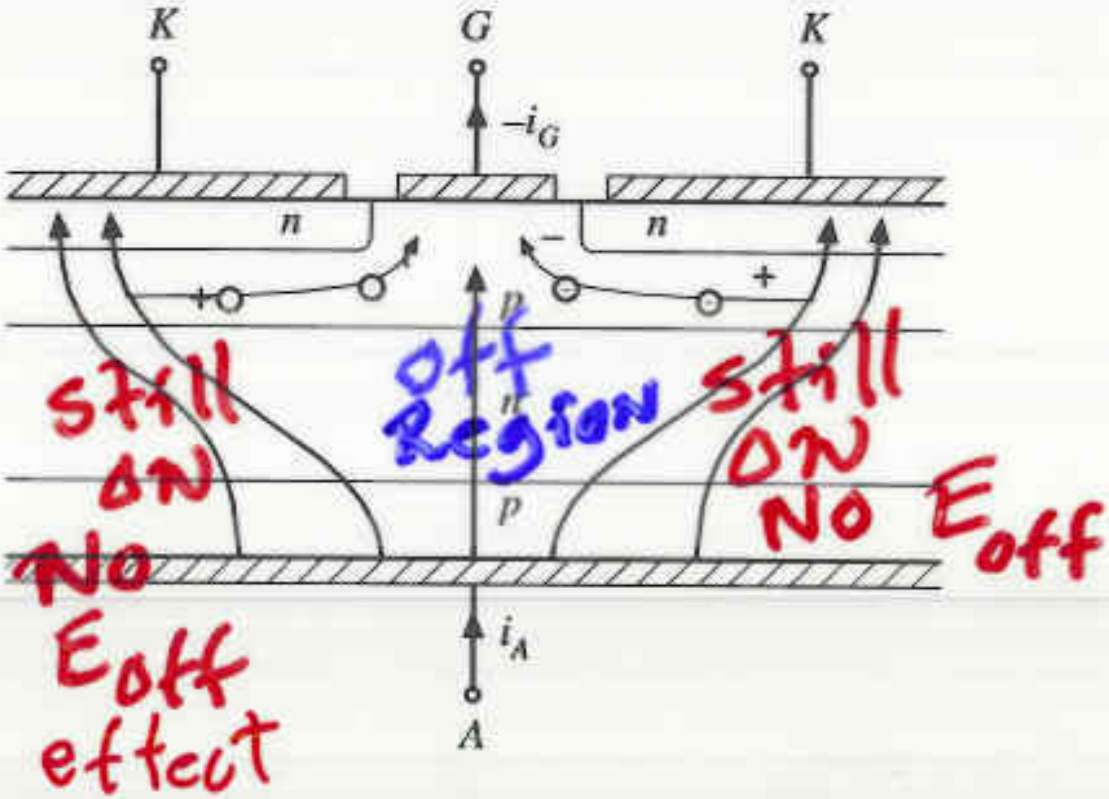
Needs a v zero crossing to turn-off

MW switch for power mains

Fig 4.43 p 91

Why the conventional SCR cannot be turned off via gate control

- Large feature size
- Negative gate current induces lateral voltage drop along gate-cathode junction
- Gate-cathode junction becomes reverse-biased only in vicinity of gate contact

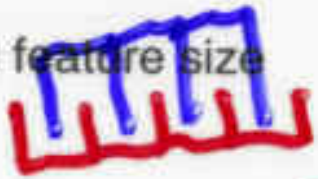


New Device Design

The Gate Turn-Off Thyristor (GTO)

$I_{ON} = 4000\,A$, $V_{off} = 5000\,V$

- An SCR fabricated using modern techniques —small feature size
- Gate and cathode contacts are highly interdigitated
- Negative gate current is able to completely reverse-bias the gate-cathode junction



Active control of t_{off}

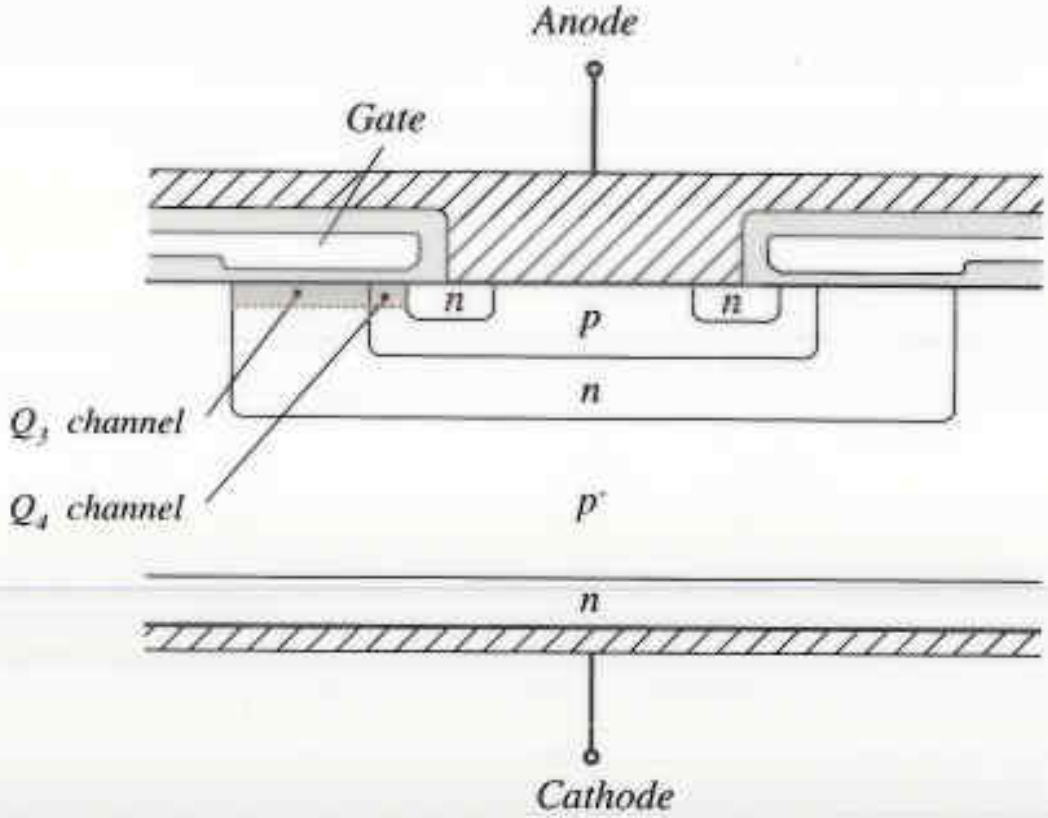
Turn-off transition:

- Turn-off current gain: typically 2-5
- Maximum controllable on-state current: maximum anode current that can be turned off via gate control. GTO can conduct peak currents well in excess of average current rating, but cannot switch off

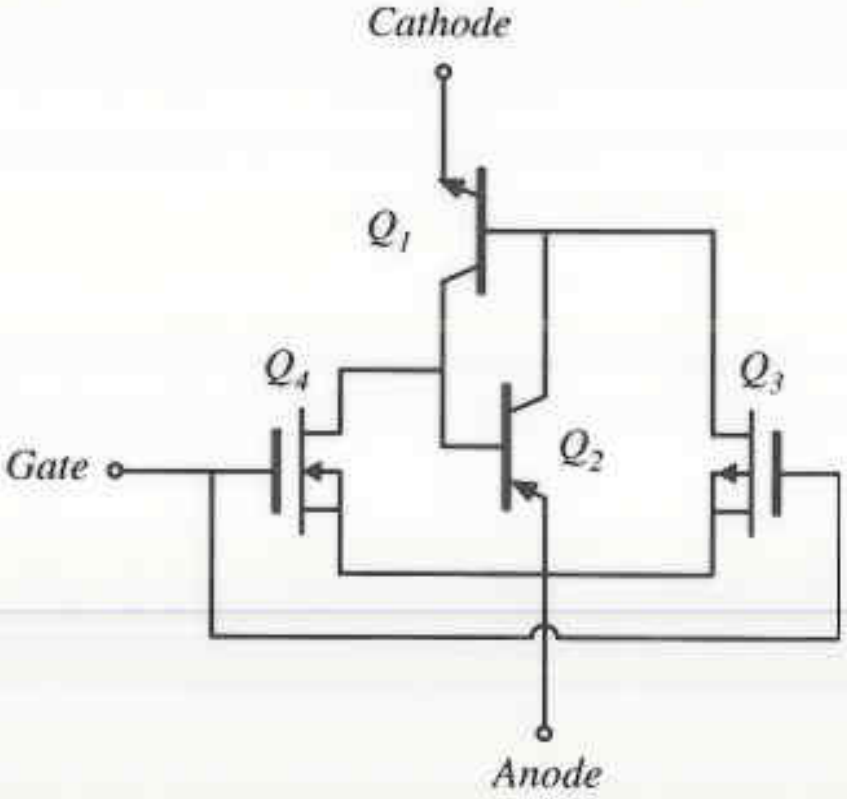
You pay to turn-off $\simeq 1/3 I_{ON}$ but only briefly limited I_{ON}

The MOS-Controlled Thyristor (MCT)

- Still an emerging device, but some devices are commercially available
- p-type device
- A latching SCR, with added built-in MOSFETs to assist the turn-on and turn-off processes
- Small feature size, highly interdigitated, modern fabrication



The MCT: equivalent circuit



- Negative gate-anode voltage turns p-channel MOSFET Q_3 on, causing Q_1 and Q_2 to latch ON
- Positive gate-anode voltage turns n-channel MOSFET Q_4 on, reverse-biasing the base-emitter junction of Q_2 and turning off the device
- Maximum current that can be interrupted is limited by the on-resistance of Q_4

Summary: Thyristors

- The thyristor family: double injection yields lowest forward voltage drop in high voltage devices. More difficult to parallel than MOSFETs and IGBTs
- The SCR: highest voltage and current ratings, low cost, passive turn-off transition
- The GTO: intermediate ratings (less than SCR, somewhat more than IGBT). Slower than IGBT. Slower than MCT. Difficult to drive.
- The MCT: So far, ratings lower than IGBT. Slower than IGBT. Easy to drive. Second breakdown problems? Still an emerging device.