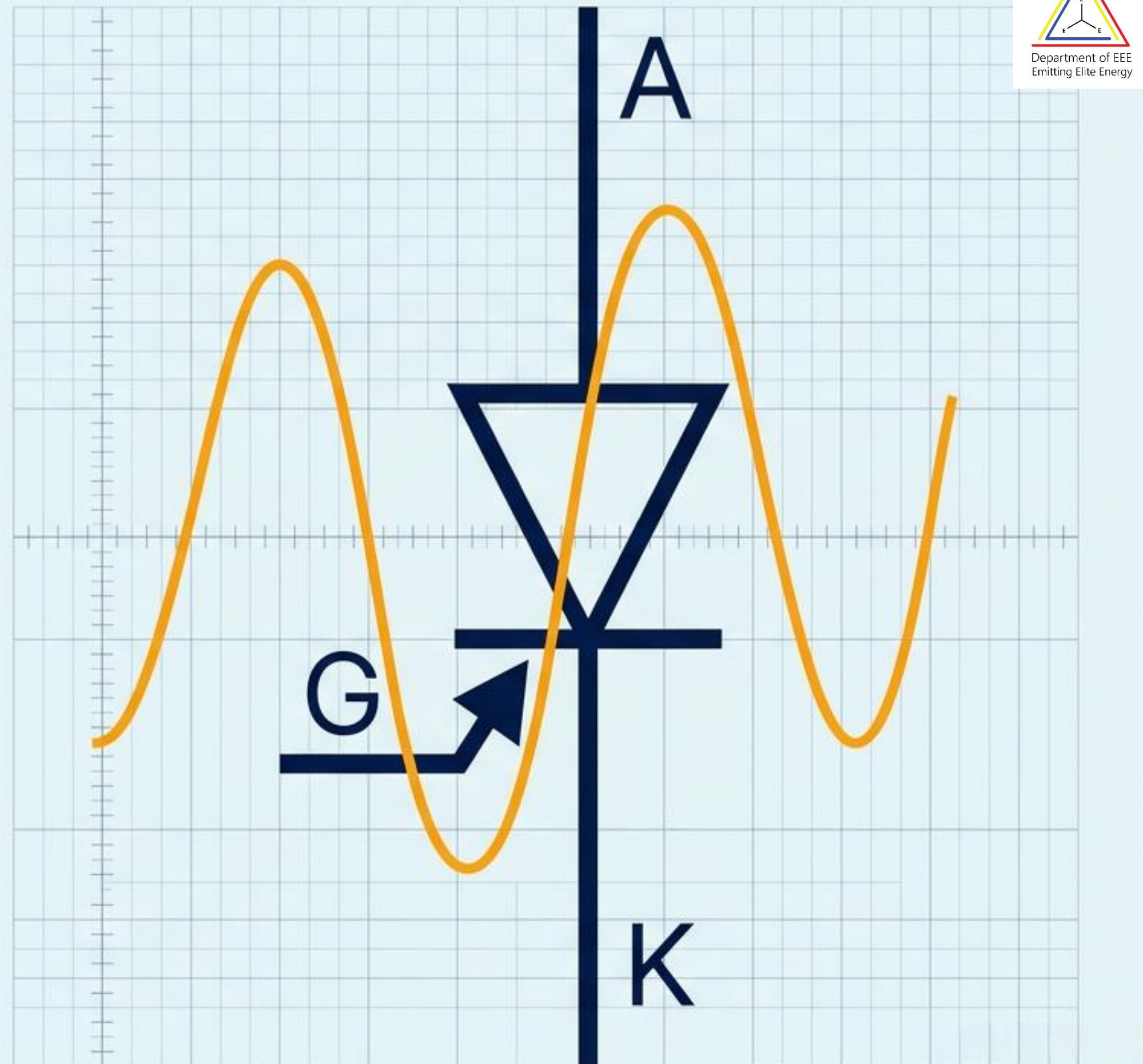


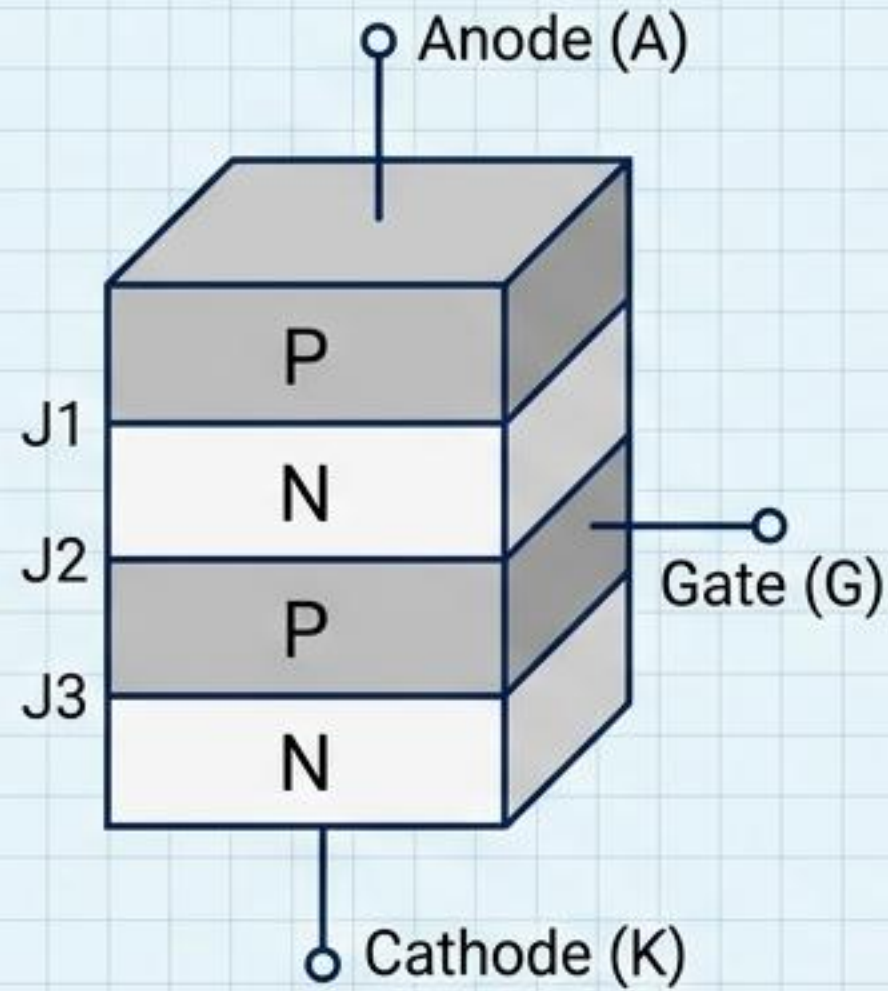
Thyristors and Thyristor Firing Circuits

Controlled Power Semiconductor
Devices and Triggering Techniques

Dr. Sathish K. R.
Assistant Professor
Department of Electrical and
Electronics Engineering (EEE)
ATME College of Engineering

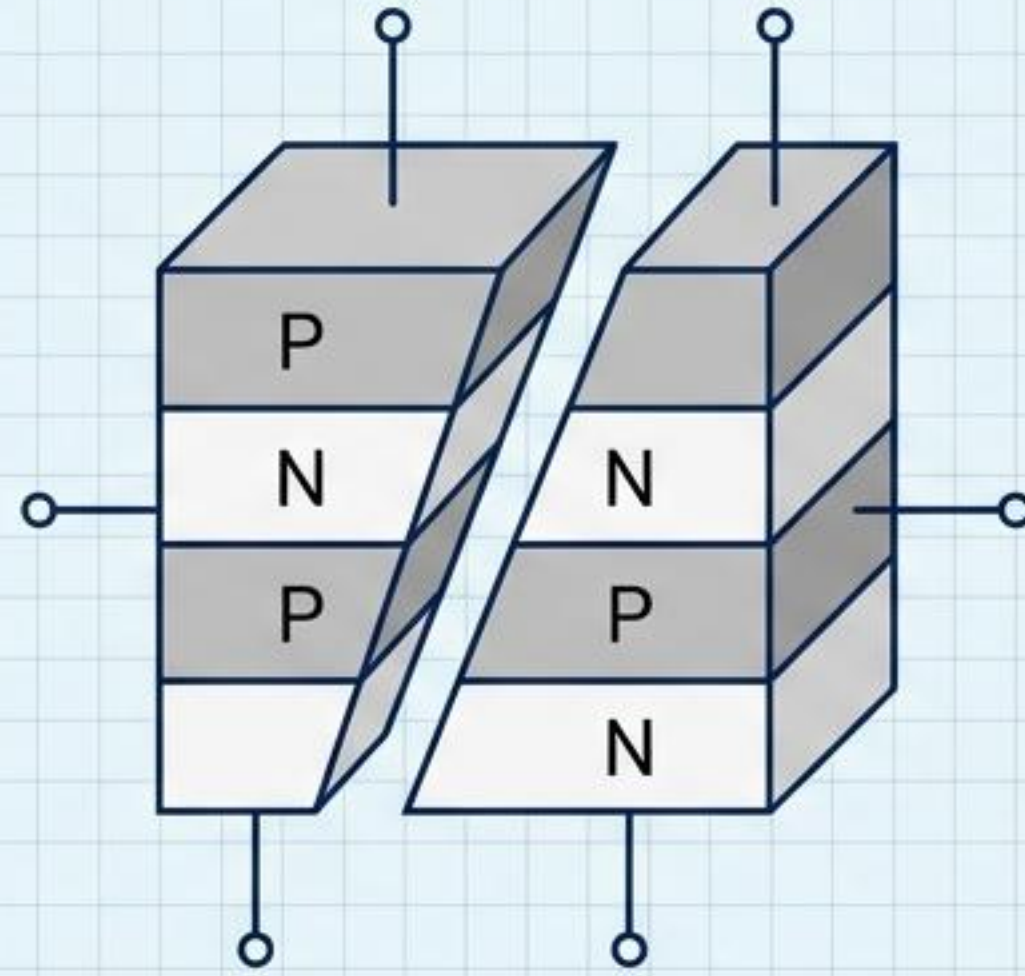


Anatomy of the SCR: Construction & Regenerative Action



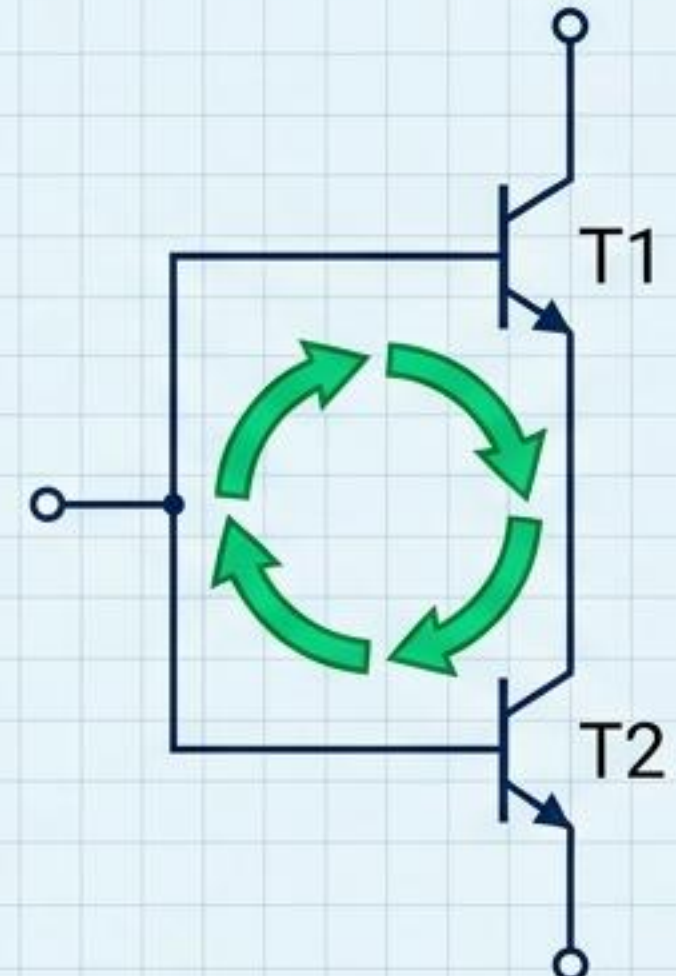
Structure

Four layers (PNPN), three junctions, three terminals.



The Latching Phenomenon

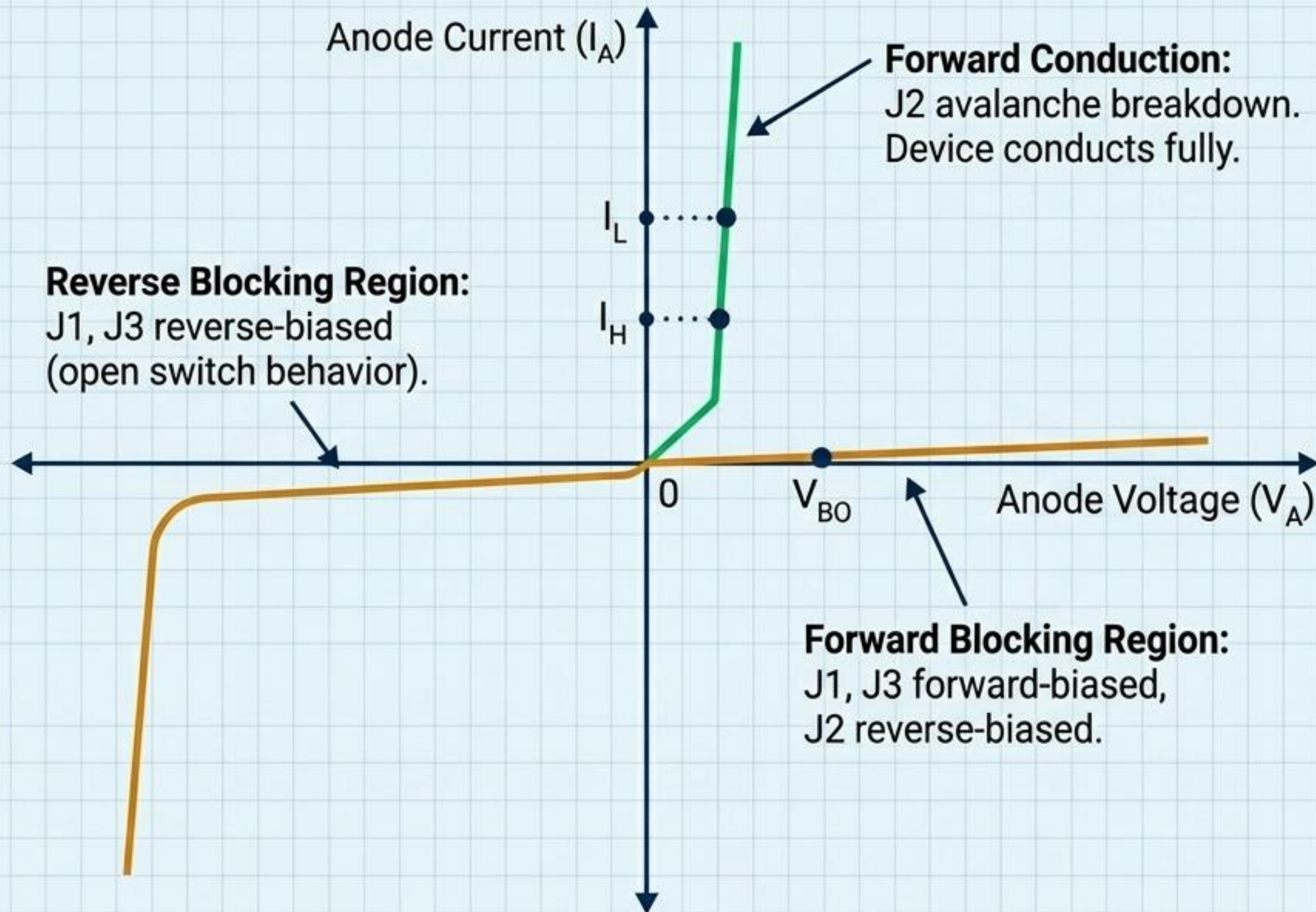
The device acts as cross-coupled PNP and NPN transistors. Gate current (I_g) triggers T2, which drives T1, creating a self-sustaining loop.



Result

Once the internal feedback loop begins, the gate loses control. The device remains ON even if the gate signal is removed.

Static V-I Characteristics: Modes of Operation



Diagnostic Callout Box

V_{BO} (Forward Breakover Voltage):

The voltage threshold that forces conduction. Increasing Gate Current (I_g) lowers this threshold.

Latching Current (I_L):

Minimum anode current required to maintain conduction immediately after turn-ON.

Holding Current (I_H):

Minimum current to keep the device ON ($I_L > I_H$).

Controlling State: Turn-ON (Triggering) and Turn-OFF (Commutation)

Turn-ON (Triggering)

Transitioning from forward blocking to conduction.



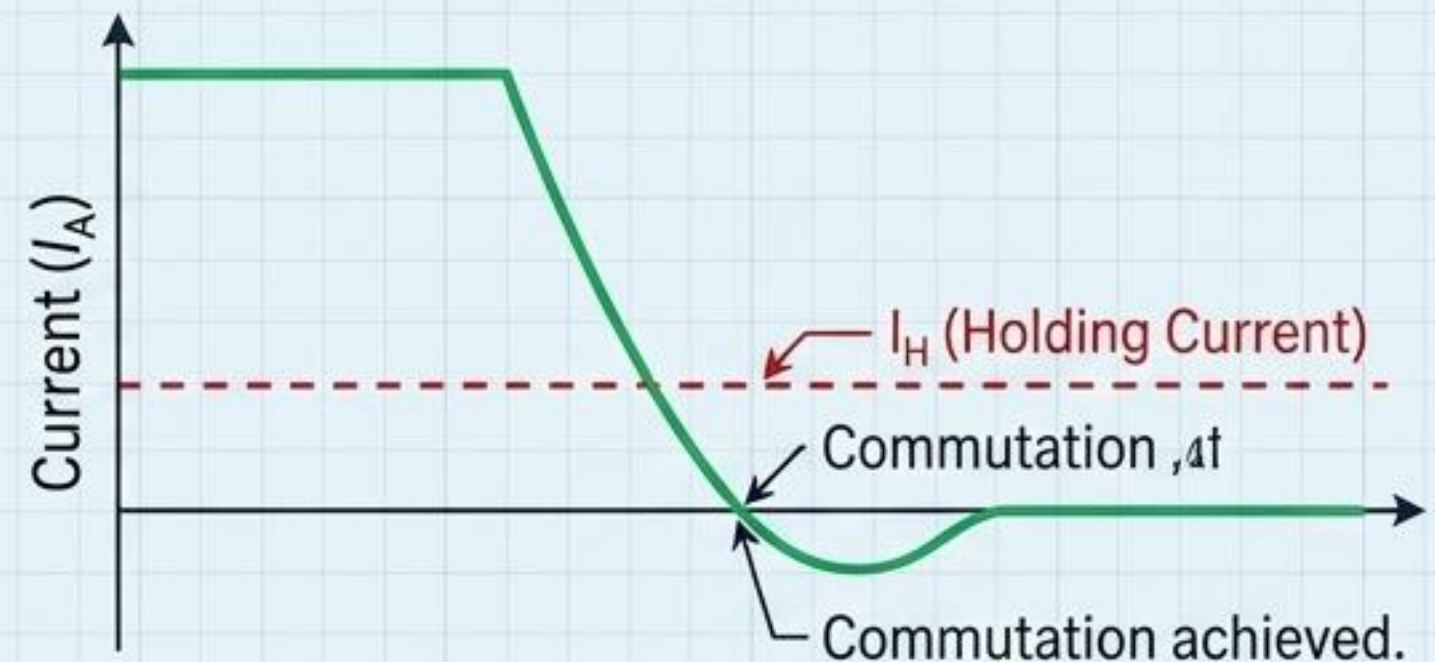
Gate Triggering: Provides precise, efficient control.



Alternative (often unintended) triggers: Thermal, Light (LASCR), Forward Voltage, and dv/dt .

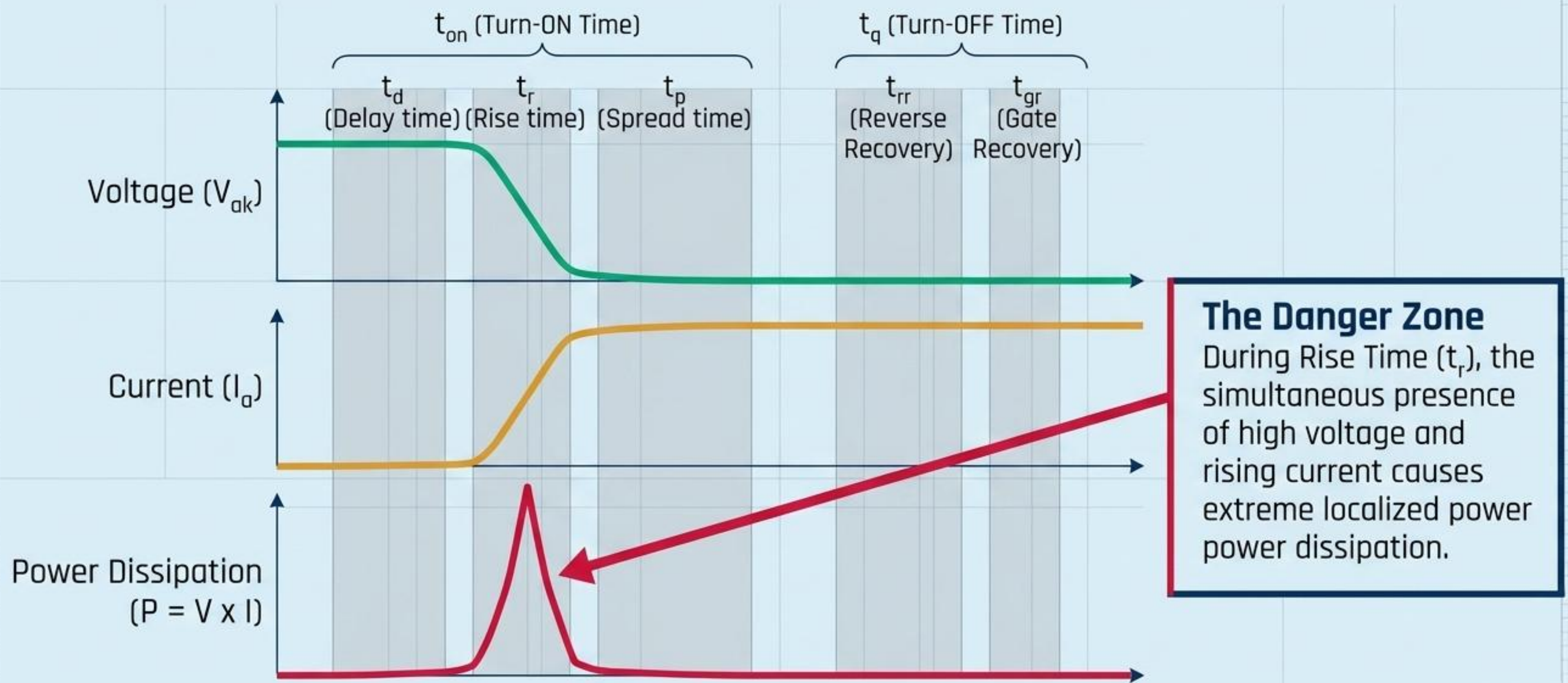
Turn-OFF (Commutation)

Forcing anode current below holding current.



- Natural Commutation: Occurs at AC zero-crossing.
- Forced Commutation: Requires external DC circuitry to reverse-bias the SCR.

Dynamic Characteristics: The Switching Timelines



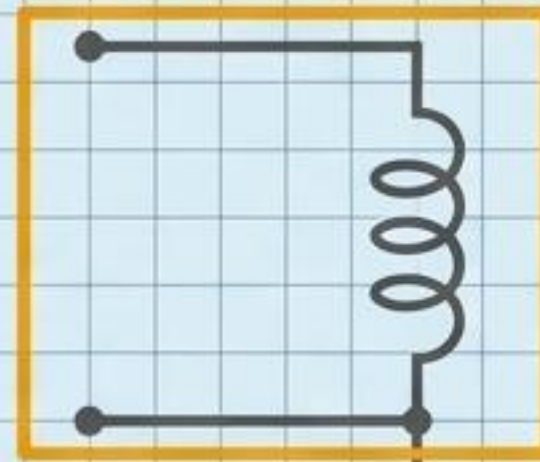
Thyristor Protection: Managing Transients

di/dt Limitation (The Series Inductor)

Rapid current spikes during the spread time create localized hot spots that melt the silicon.

The series inductor chokes these rapid current changes.

Series Inductor (L_s)



dv/dt Limitation (The Parallel Snubber)

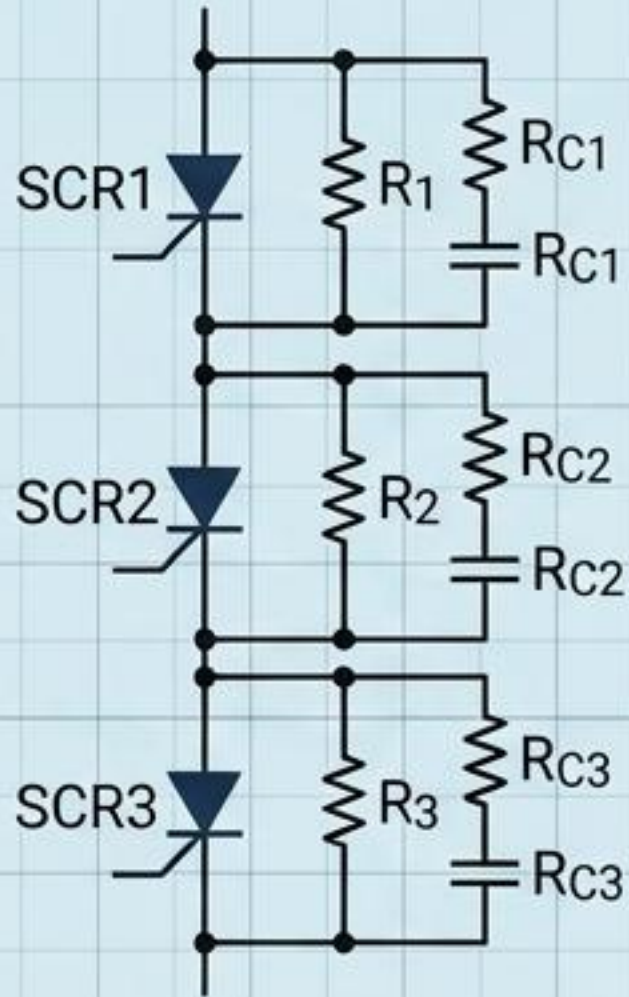
Rapid voltage changes charge the junction capacitance, causing a parasitic gate current and false triggering.

The RC snubber absorbs voltage spikes; the resistor limits capacitor discharge.

RC Snubber Circuit

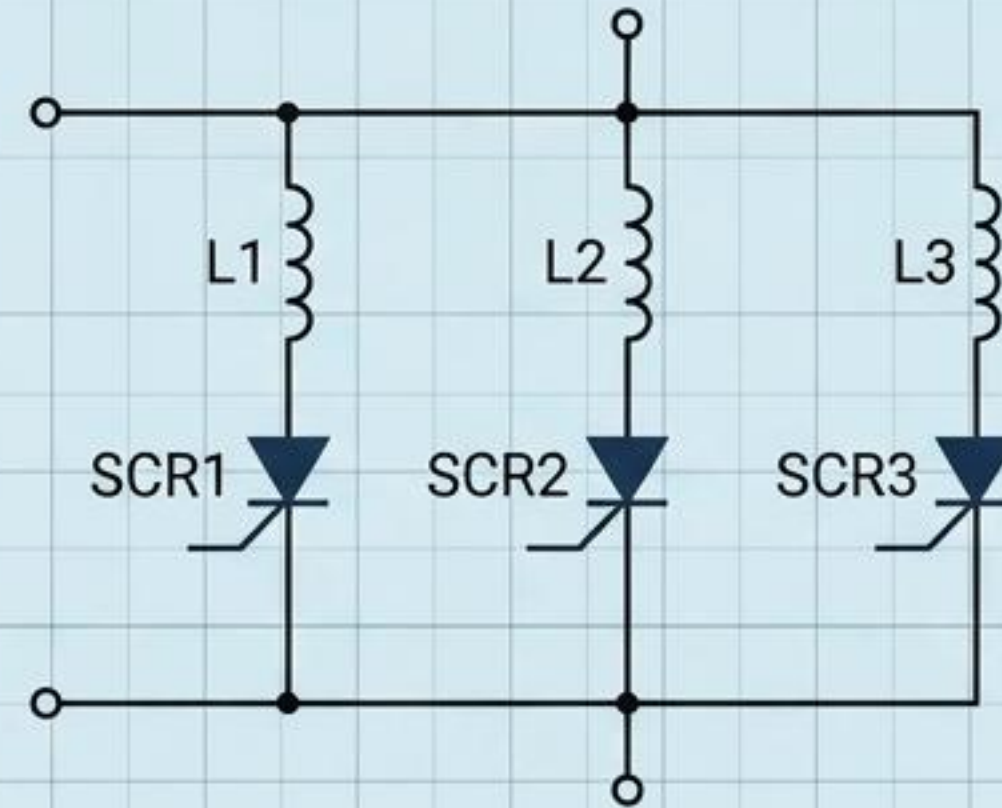


Scaling Capacity: Series and Parallel Operation



Series Operation (Voltage Scaling)

- Required when system voltage exceeds a single SCR's rating.
- The Challenge: Unequal leakage currents cause uneven voltage sharing.
- The Fix: Static (R) and Dynamic (RC) equalization networks.



Parallel Operation (Current Scaling)

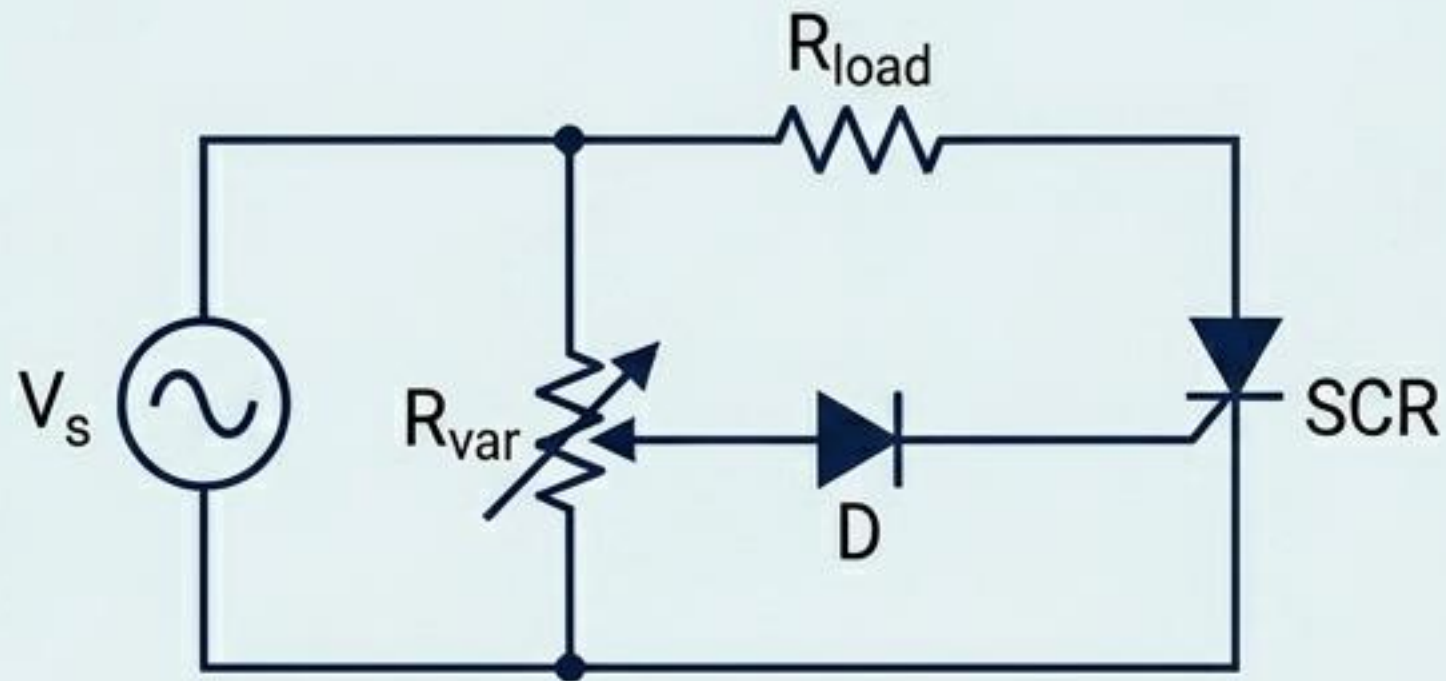
- Required for massive current loads.
- The Challenge: Different ON-state voltage drops cause uneven current sharing.
- The Fix: Current equalizing reactors force balance.

The Thyristor Family: Variations on a Theme

Symbol	Full Name	Core Capability	Primary Application
	GTO (Gate Turn-Off Thyristor)	Can be turned OFF by a negative gate pulse, eliminating bulky commutation circuits.	High-power traction
	TRIAC	Bidirectional thyristor. Equivalent to two anti-parallel SCRs.	Consumer AC phase control, dimmers
	DIAC	Bidirectional trigger without a gate.	Firing TRIACs
	LASCR (Light-Activated SCR)	Triggered by photons for complete electrical isolation.	High-voltage direct current (HVDC)
	MCT (MOS-Controlled Thyristor)	High current density of a thyristor + easy voltage-control of a MOSFET.	Medium-power switching

Firing Circuits: The Brains of the Operation (R-Triggering)

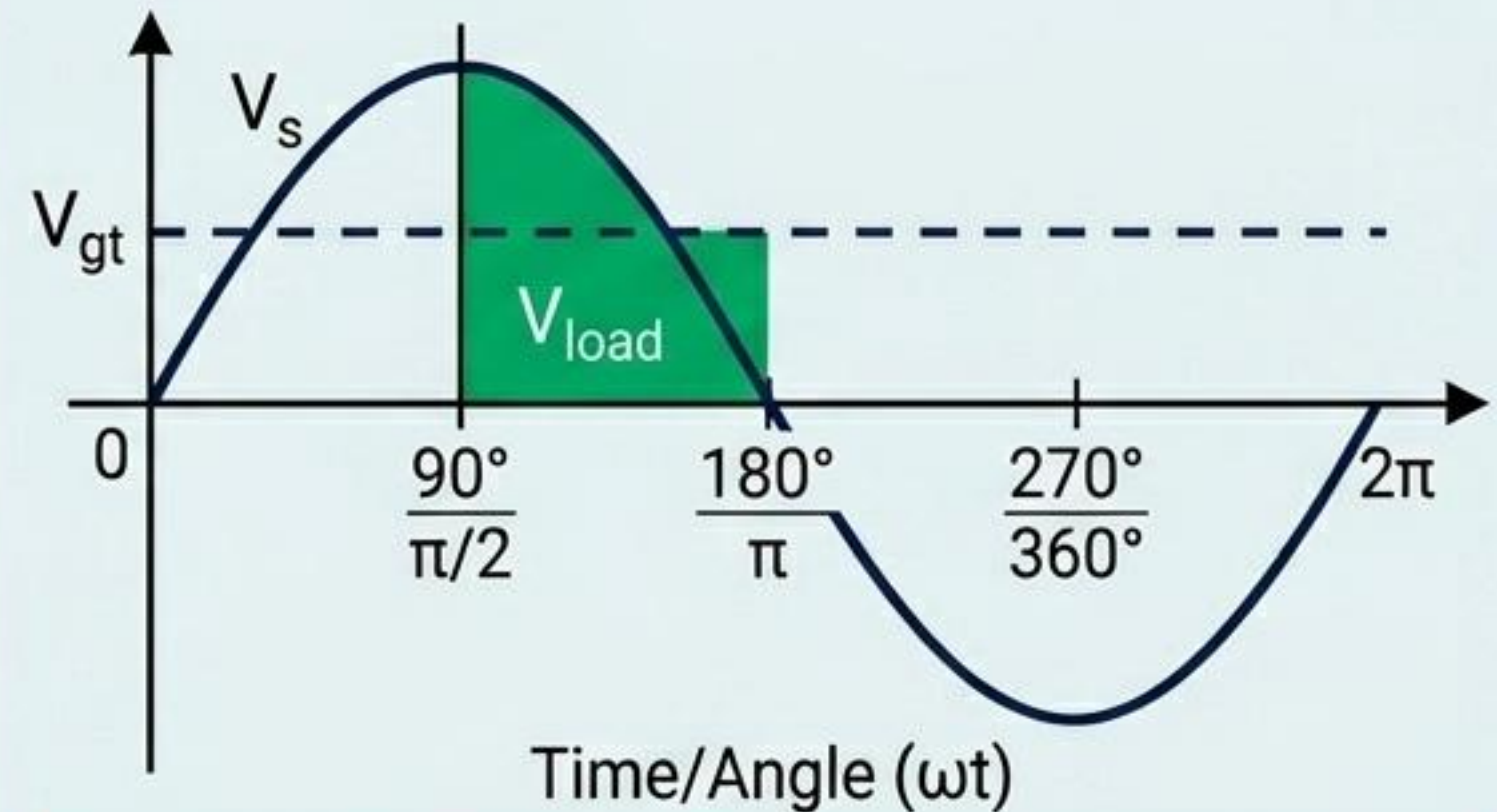
The Circuit



The Brains: Firing circuits generate synchronized pulses to dictate the firing angle (alpha).

R-Triggering: The simplest method. Gate current is directly proportional to the input AC voltage amplitude.

The Waveform

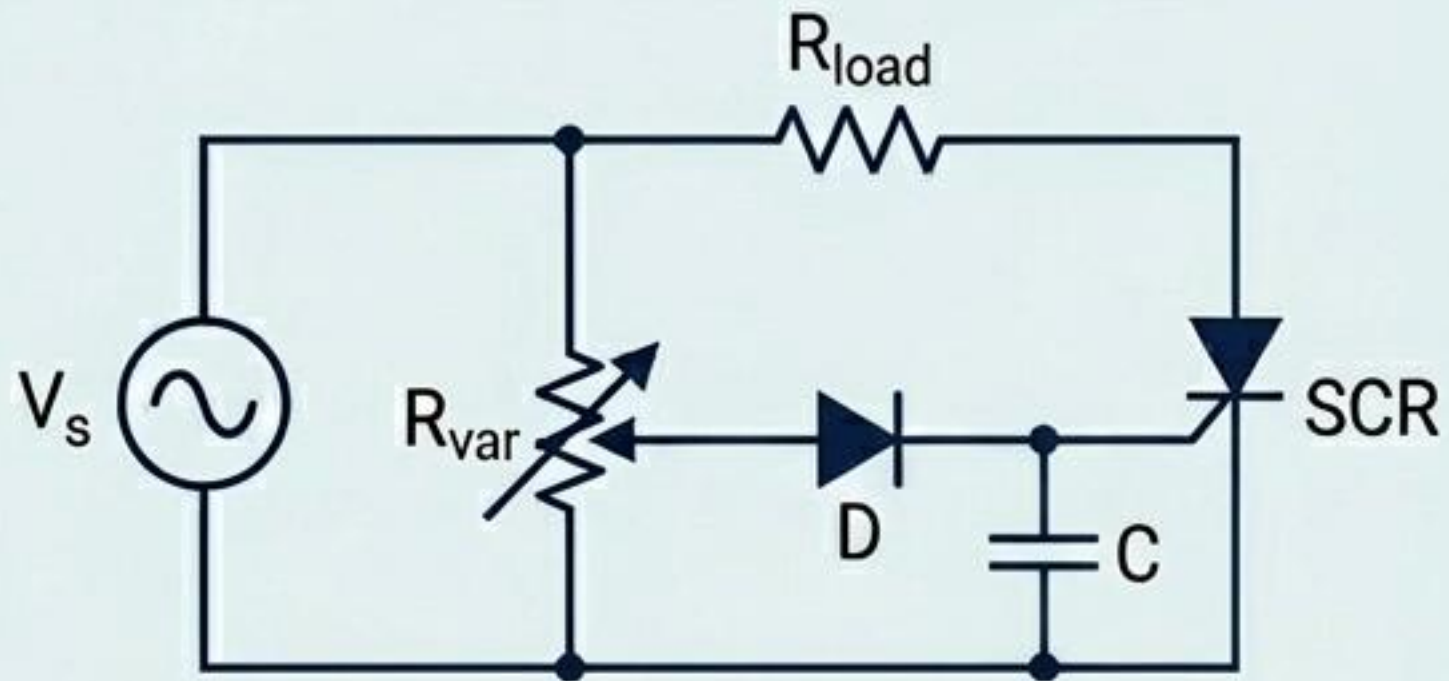


The Limitation

Because it relies purely on amplitude, the maximum control angle is strictly limited to 90 degrees (exactly half of the positive half-cycle).

RC Firing Circuits: Expanding the Control Range

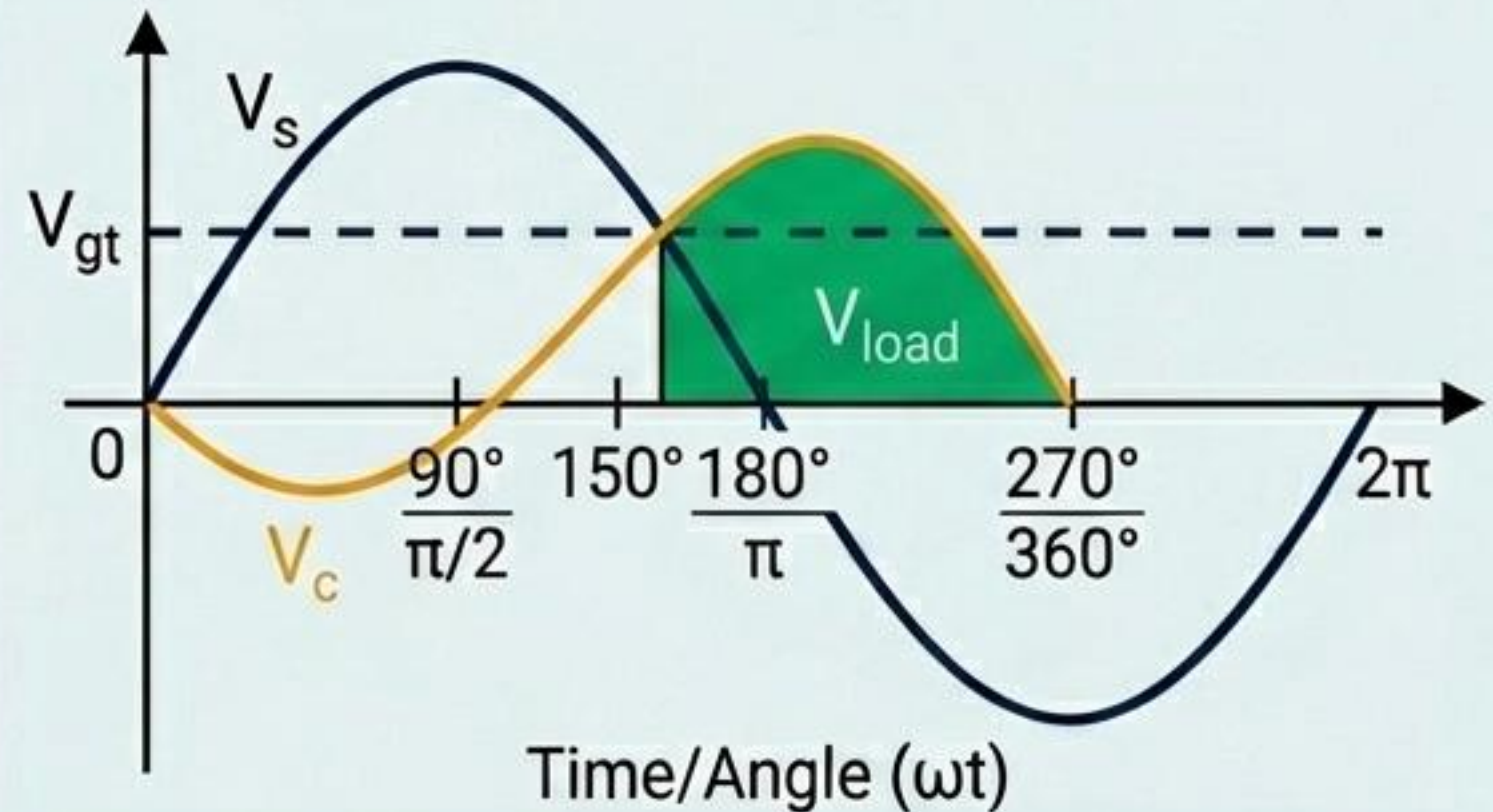
The Circuit



The RC Advantage: Adding a capacitor creates a temporal phase shift between the supply voltage and the gate voltage.

Phase-Angle Control: Adjusting the variable resistor alters the capacitor's charging time constant.

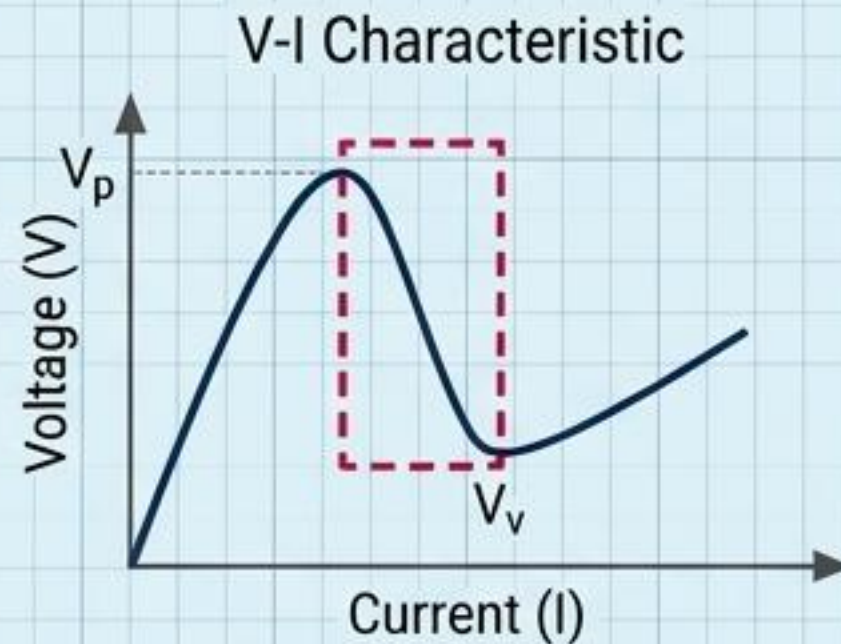
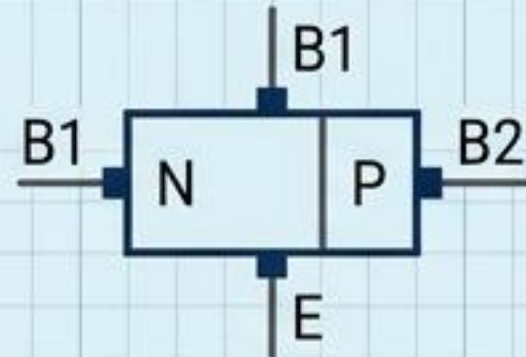
The Waveform



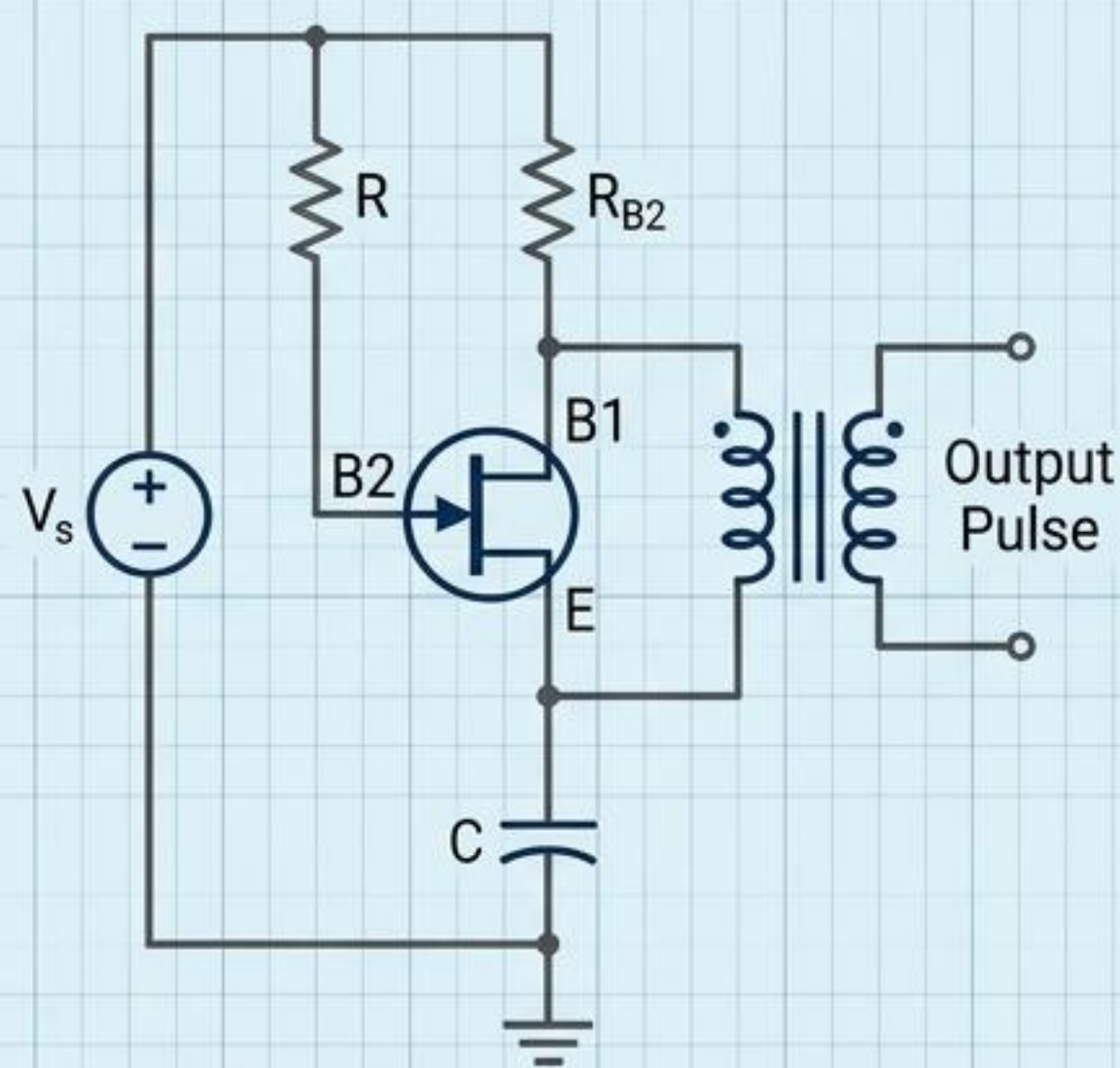
The Result

Firing angle (alpha) control smoothly expands from 0 degrees to nearly 180 degrees, enabling precise industrial heating and lighting control.

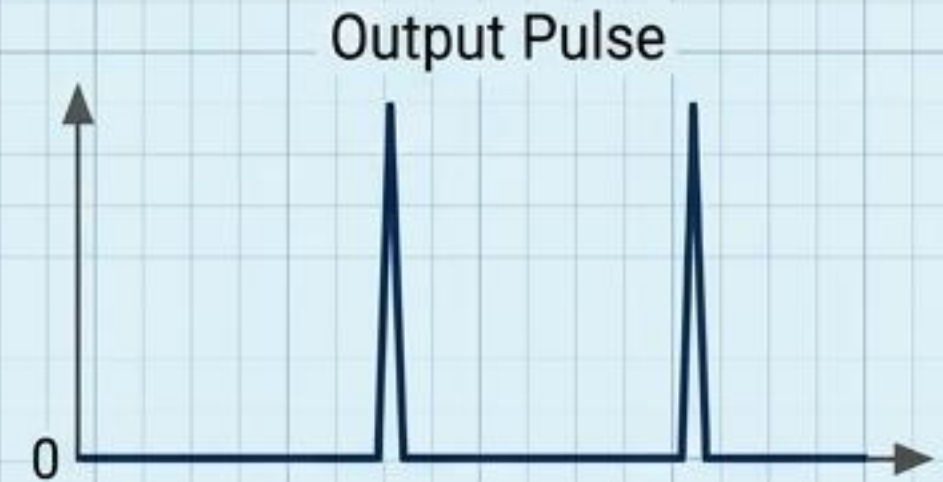
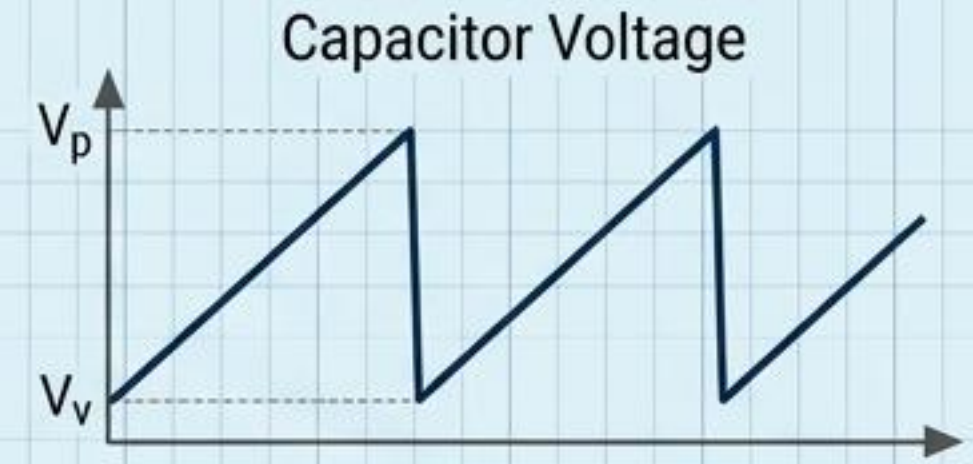
Precision Triggering: The UJT Relaxation Oscillator



Negative Resistance Region: Allows the UJT to act as an incredibly stable voltage-controlled switch.



The Mechanism: Capacitor charges slowly. Upon reaching the peak voltage threshold, the UJT fires rapidly, dumping energy through the pulse transformer.



The Industry Standard: Generates sharp, high-energy, electrically isolated pulses completely independent of AC supply fluctuations.

Power Switch Selection: A Comparative Synthesis

	SCR	GTO	MOSFET	IGBT
Control Type	Current Controlled	Current Controlled	Voltage Controlled	Voltage Controlled
Switching Speed	Slow	Medium	Ultra-Fast	Fast
Power Capability	Ultra-High Power	High Power	Low/Medium Power	High Power
Commutation Complexity	Complex (Forced)	Negative Gate Pulse	Natural	Natural

Synthesis Insight: Device selection dictates efficiency. The IGBT dominates medium power (motor drives), but for raw, grid-scale power transmission, the SCR remains unmatched.

Power in Action: Industrial Applications



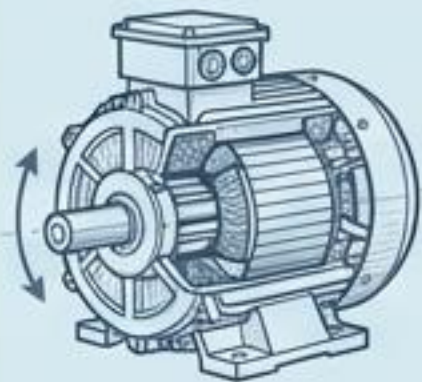
HVDC Transmission

Transmitting gigawatts of power across continents with minimal loss using massive series/parallel SCR valves.



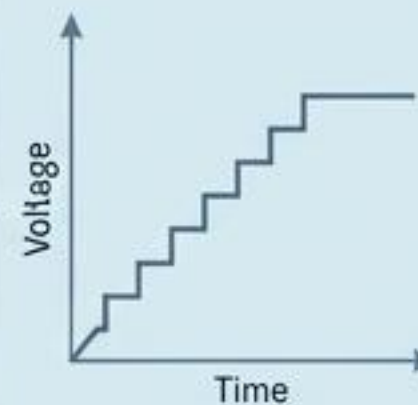
Static VAR Compensators

Providing dynamic reactive power control to stabilize volatile electrical grid infrastructure.



Industrial Motor Drives

Controlled rectifiers converting AC to variable DC for precise heavy-duty traction control.



Soft Starters

Gradually increasing motor voltage to prevent catastrophic inrush currents during heavy machinery startup.

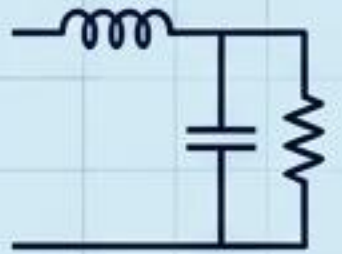
Module 3: Essential Takeaways



State Control

Latching Current (I_L) triggers the ON state. Holding Current (I_H) is the absolute threshold for turn-OFF.

Remember: $I_L > I_H$.



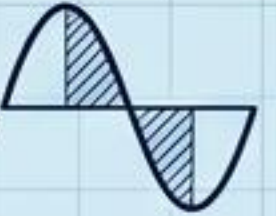
Mandatory Protection

A Series Inductor (L_s) stops fatal di/dt melting.

A Parallel RC Snubber stops dv/dt false triggering.

Core Architecture

Firing Range Limits



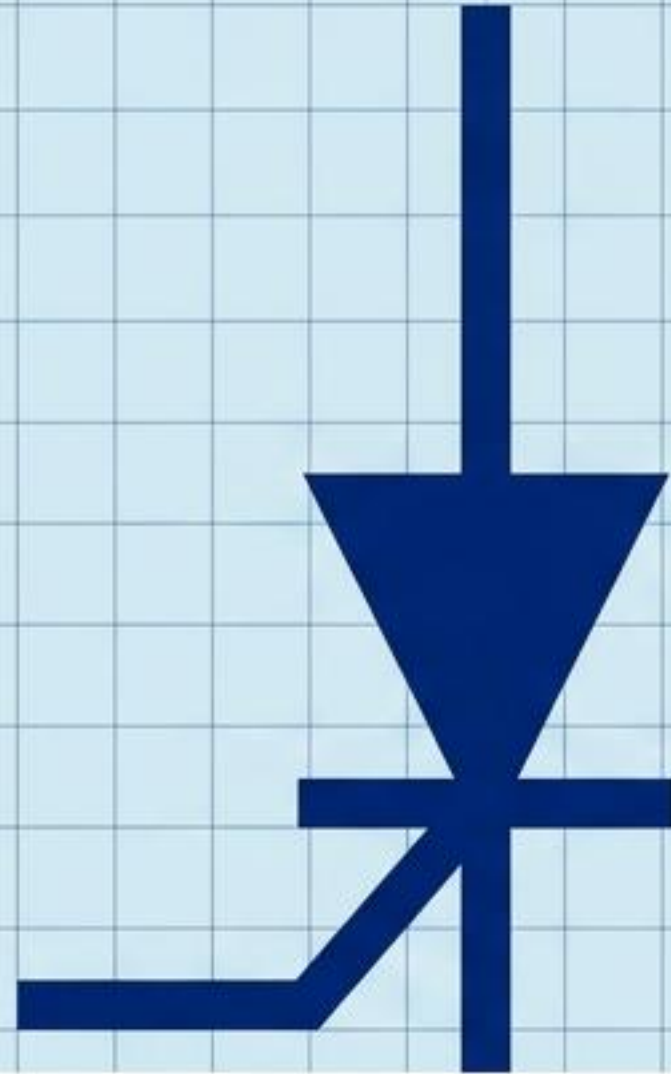
Simple R-Circuit = 90 degree maximum control.

RC-Circuit = 180 degree maximum control via temporal phase shifting.

Pulse Generation



The UJT Relaxation Oscillator guarantees sharp, electrically isolated gate pulses via its negative resistance region.



The Backbone of Power Electronics

The thyristor fundamentally revolutionized electrical engineering, replacing fragile mechanical switches with robust, solid-state silicon capable of harnessing megawatts of power.

While high-speed devices like the IGBT now dominate consumer applications, the immense scaling capacity of the SCR keeps it at the center of the global energy transition—powering HVDC grids and renewable infrastructure worldwide.