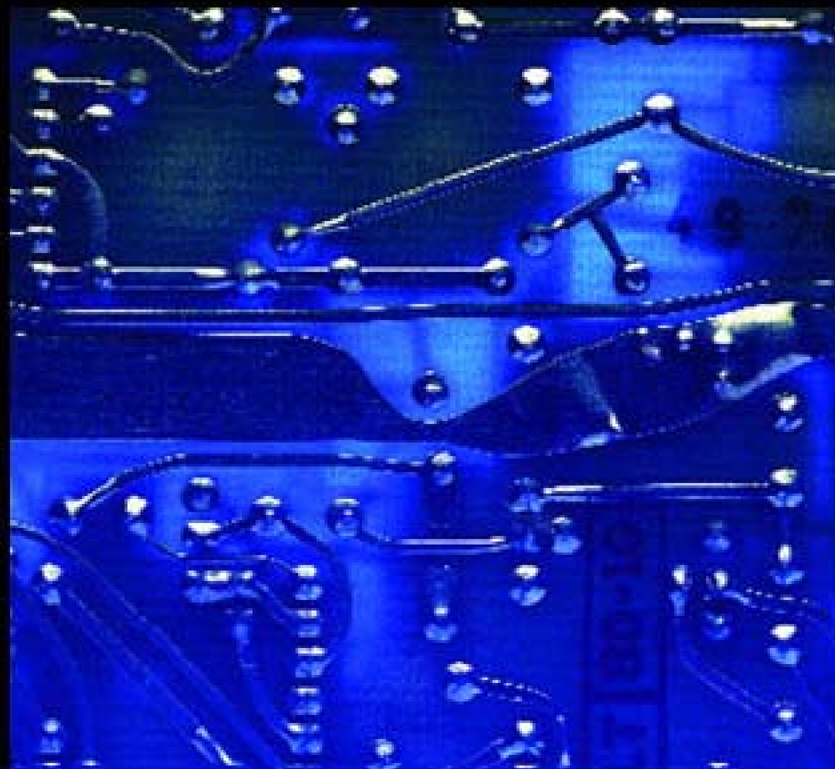
Electronic Devices and Circuit Theory

Tenth Edition



BOYLESTAD

PEARSON

Chapter 17
pnpn and Other Devices

pnpn Devices

SCR—silicon-controlled rectifier
SCS – silicon-controlled switch
GTO – gate turn-off switch
LASCR – light-aActivated SCR
Shockley diode
Diac
Triac

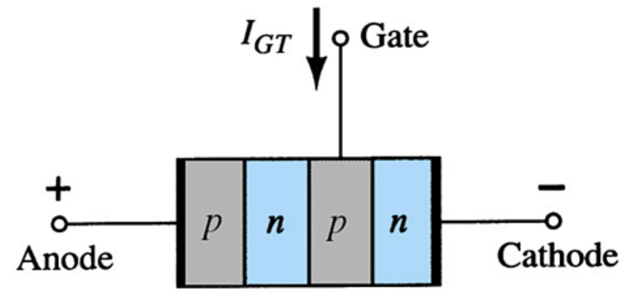
SCR—Silicon-Controlled Rectifier

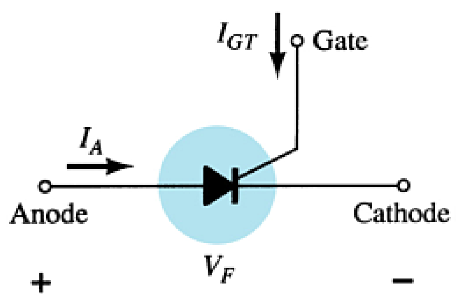
The SCR is a switching device for high-voltage and high-current operations.

Like an ordinary rectifier, an SCR conducts in one direction

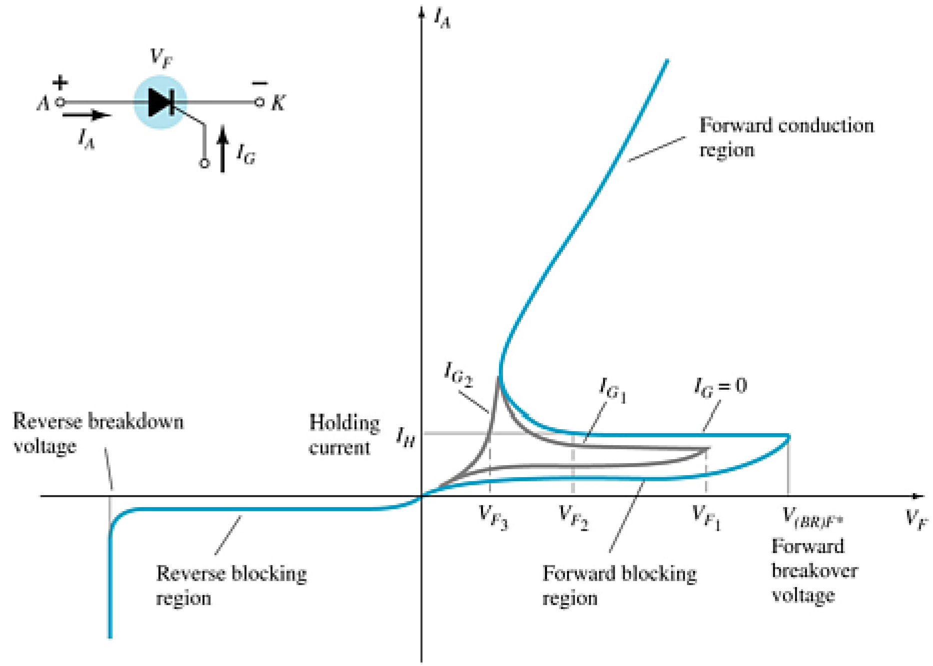
The terminals are:

- Anode
- Cathode
- Gate





SCR Operation



To switch on an SCR:

- **Forward bias the anode-cathode terminals (V_F)**

AND

- **Apply sufficient gate voltage (V_{gate}) and gate current (I_{GT})**

Once an SCR is switched on, it remains latched on, even when the gate signal is removed.

- **Holding current (I_H) is the minimum required current from anode to cathode**
- **Reverse breakdown voltage is the maximum reverse bias voltage for the SCR**

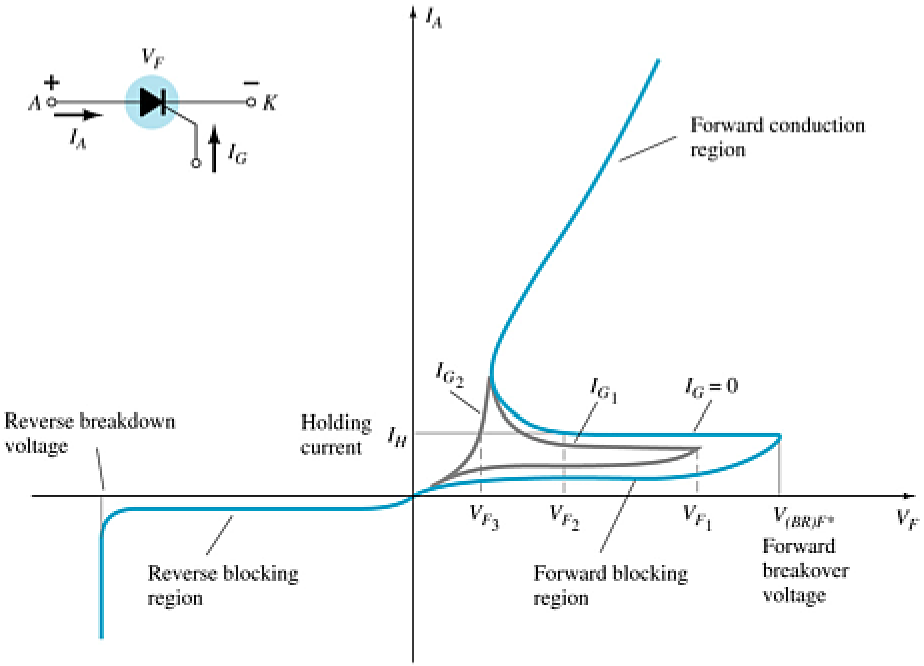
SCR Operation

To switch off an SCR:

- **Remove the power source the anode and cathode terminals**

OR

- **Reverse bias the anode and cathode terminals**



An SCR cannot be switched off by simply removing the gate voltage.

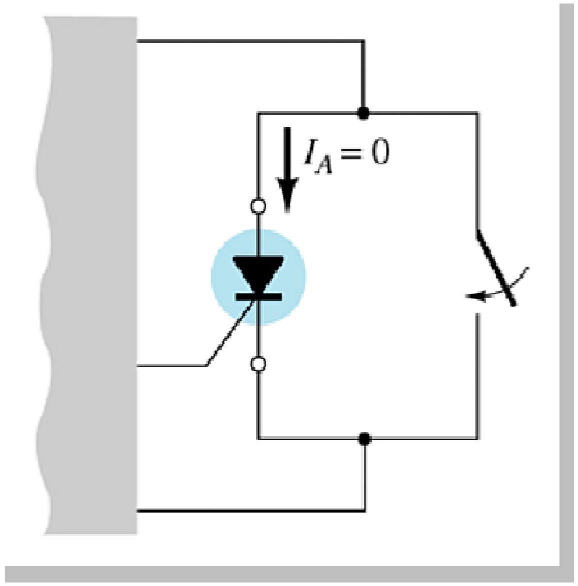
Commutation circuitry can be used for satisfying either of the conditions for switching off an SCR.

SCR Commutation

Commutation circuitry is simply a class of switching devices connected in parallel with the SCR.

A control signal activates the switching circuitry and provides a low impedance bypass for the anode to cathode current. This momentary loss of current through the SCR turns it off.

The switching circuitry can also apply a reverse bias voltage across the SCR, which also will turn off the SCR.



SCR False Triggering

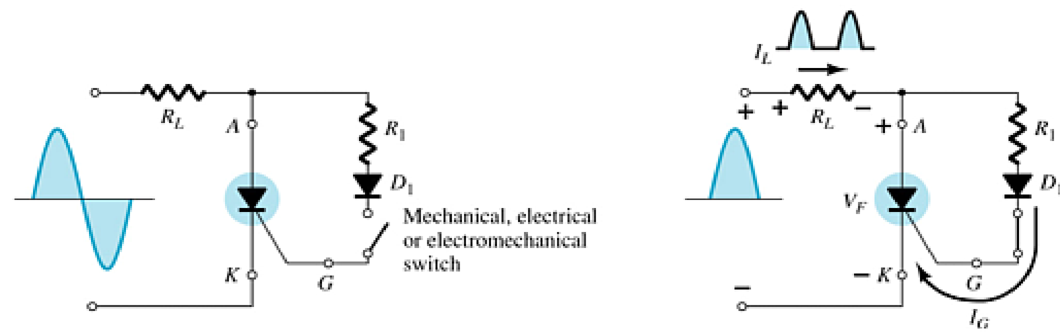
An SCR can be forced to trigger conduction under several conditions that must be avoided:

- **Excessively high voltage from anode to cathode**
- **High frequency signal from gate to cathode**
- **High operating temperature**

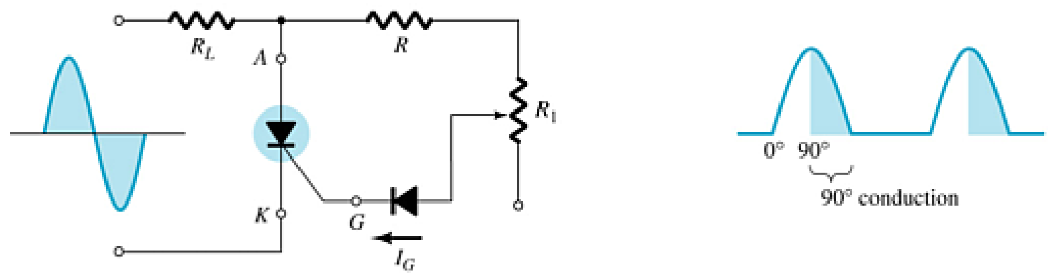
SCR Phase Control

The gate voltage can be set to fire the SCR at any point in the AC cycle.

In this example, the SCR fires as soon as the AC cycle crosses 0V. Therefore it acts like a half-wave rectifier.



In this example, the SCR fires later—at the 90° point—on the positive half-cycle.



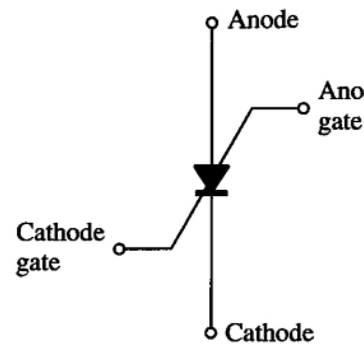
SCR Applications

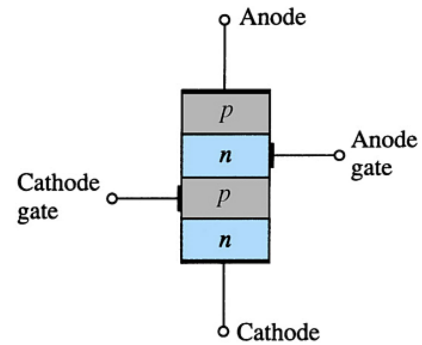
In these applications the SCR gate circuit is used to monitor a situation and trigger the SCR to turn on a portion of the circuit.

- **Battery-charging regulator**
- **Temperature controller circuit**
- **Emergency-lighting system**

SCS—Silicon-Controlled Switch

An SCS is like an SCR, except that it has two gates: a cathode gate and an anode gate.



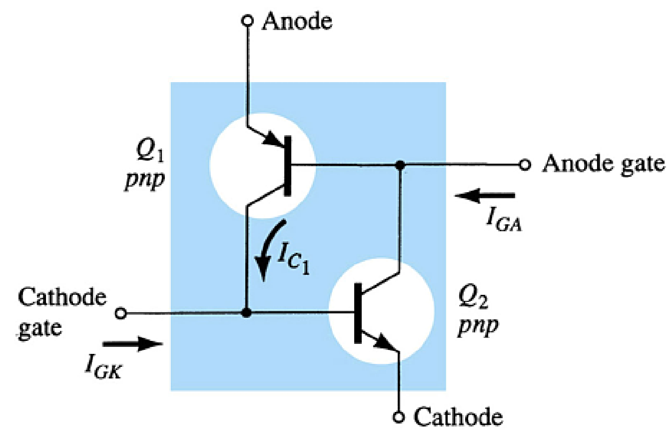


Either gate can fire the SCS

- **A positive pulse or voltage on the cathode gate**
- **A negative pulse or voltage on the anode gate**

Either gate can switch off the SCS

- **A negative pulse or voltage on the Cathode gate**
- **A positive pulse or voltage on the anode gate**

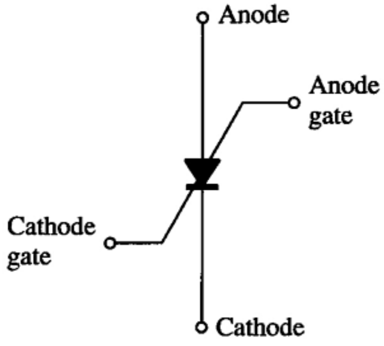


Note: The anode gate requires higher voltages than the cathode gate.

SCS

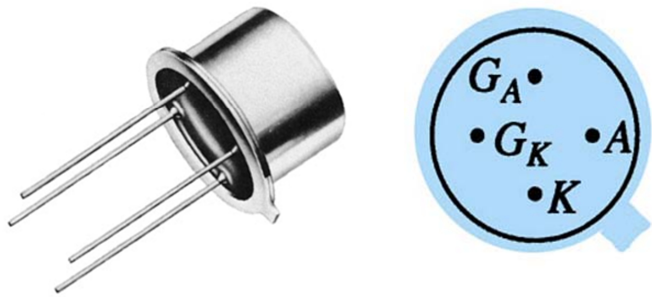
Comparison of the SCR and SCS:

- **The SCS has a much lower power capability compared to the SCR**
- **The SCS has faster switching times than the SCR**
- **The SCS can be switched off by gate control**



Applications

- **Pulse generator**
- **Voltage sensor**
- **Alarm circuits**

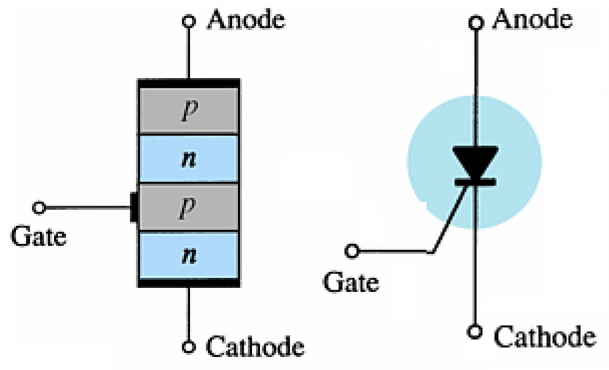


Pin Identification

GTO—Gate Turn-Off Switch

GTOs are similar to SCRs, except that the gate can turn the GTO on *and* off.

It conducts only in one direction.



Applications

- **Counters**
- **Pulse generators**
- **Oscillators**
- **Voltage regulators**

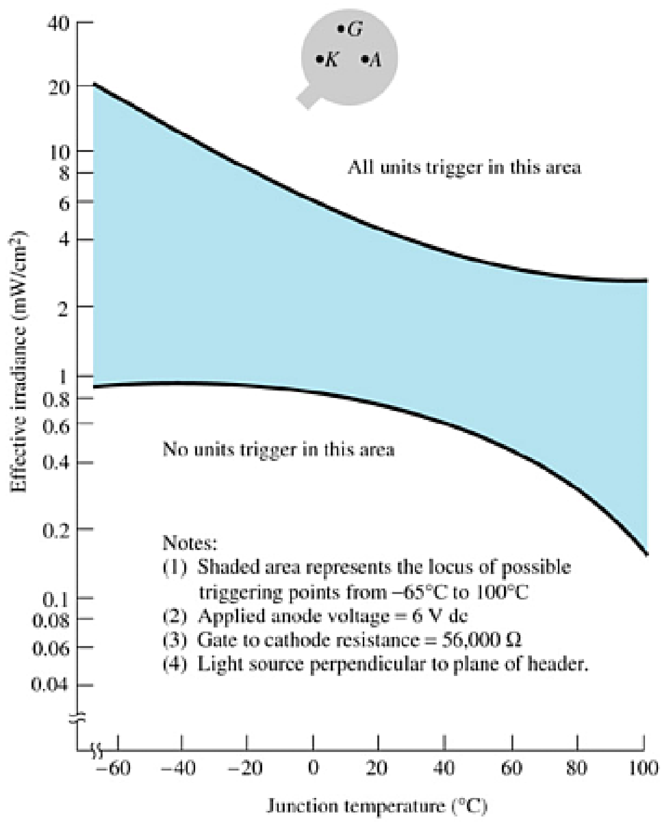
GTO

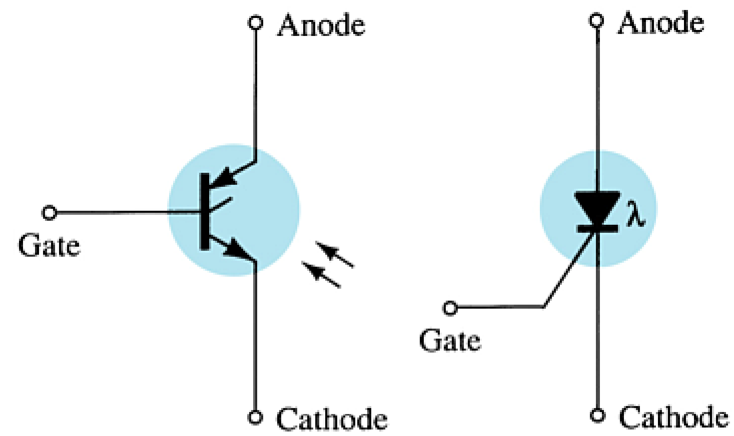
Comparison of the GTO and SCS:

- **GTO is a low power device**
- **The gate signal necessary to fire the GTO is larger than the SCR gate signal.**
- **The gate signal necessary to turn the GTO off is similar to that of SCS**
- **The switching rate for turning the GTO off is much faster than the SCR**

LASCR—Light-Activated SCR

The LASCR is an SCR that is fired by a light beam striking the gate-cathode junction or by applying a gate voltage.

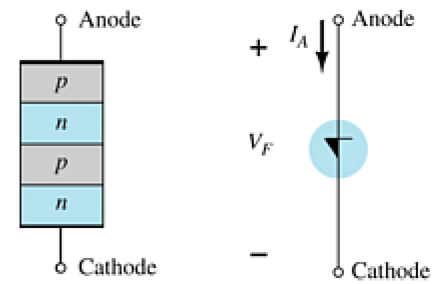




Applications

- **Optical light controls**
- **Relays**
- **Phase control**
- **Motor control**
- **Computer applications**

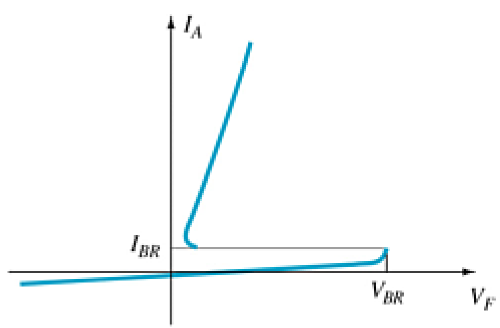
Shockley Diode



The Shockley diode conducts once the breakover voltage is reached. It only conducts in one direction.

Operation

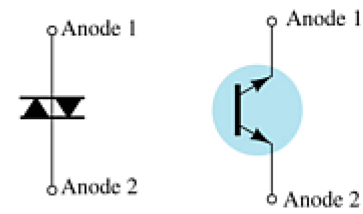
The Shockley diode must be forward biased, and then once the voltage reaches the breakover level it will conduct. Like an SCR it only conducts in one direction.



Application

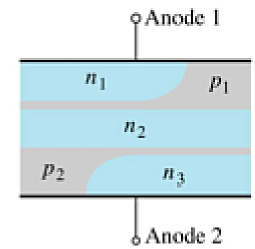
- Trigger switch for an SCR

Diac



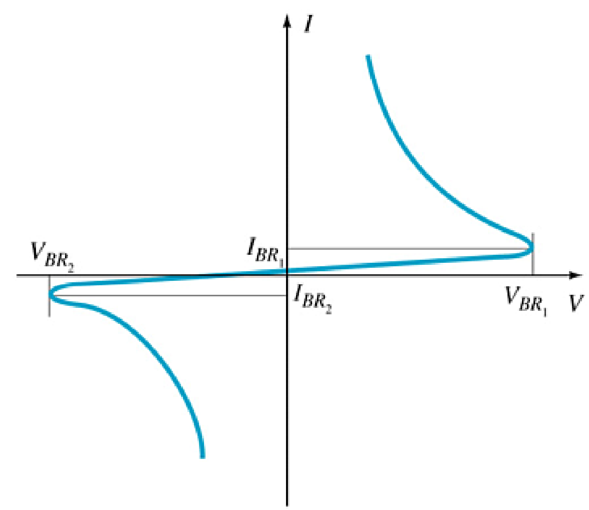
The Diac is a breakover type device.

Operation



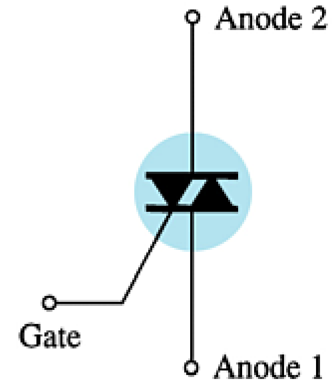
Once the breakover voltage is reached the Diac conducts. The Diac, though, can conduct in both directions. The breakover voltage is approximately symmetrical for a positive and a negative breakover voltage.

Applications



- **Trigger circuit for the Triac**
- **Proximity sensor circuit**

Triac



A triac is like a diac with a gate terminal.

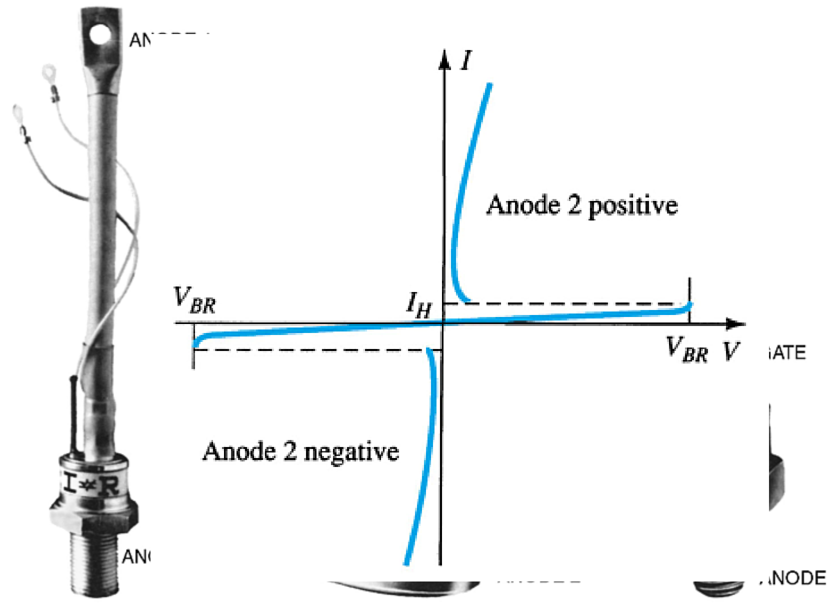
Operation

When fired by the gate or by exceeding the breakover voltage, a triac conducts in both directions.

Applications

- **AC power control circuits**

Terminal Identification



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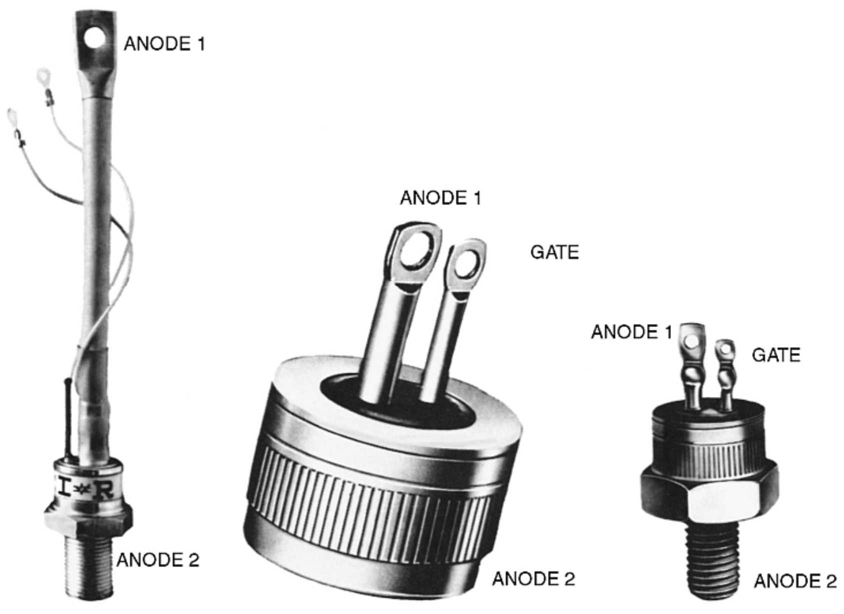
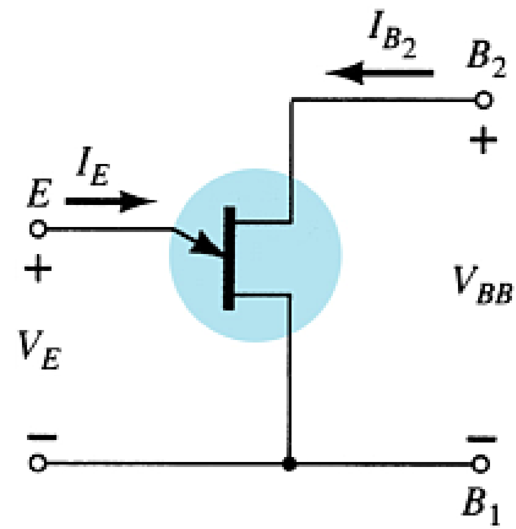
Triac Terminal Identification



The Unijunction Transistor (UJT)

The unijunction transistor (UJT) has two base terminals (B_1 and B_2) and an emitter terminal (E).

The UJT symbol resembles the FET symbol. The emitter terminal is angled as shown.



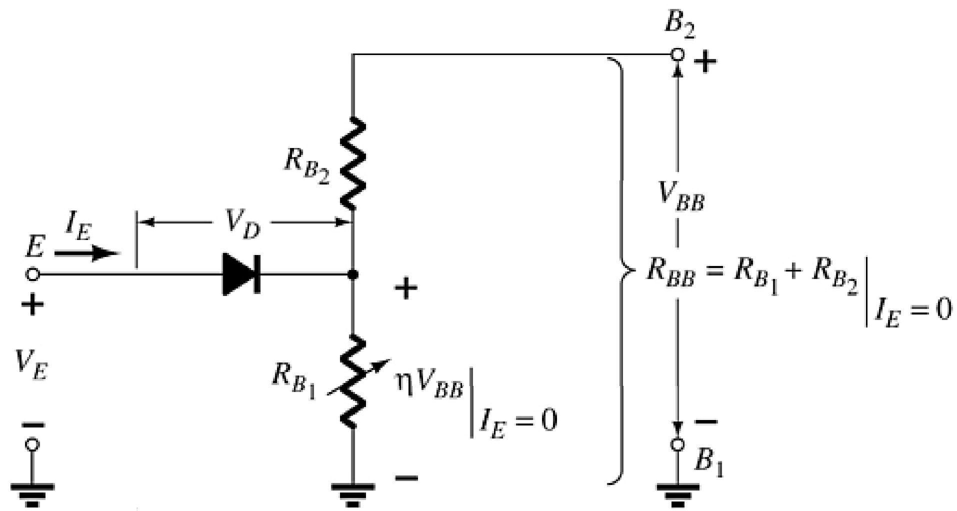
UJT Equivalent Circuit

The **interbase resistance** (R_{BB}) is the total resistance between the two base terminals when $I_E = 0$ A.

The **intrinsic standoff ratio** (η) is the ratio of R_{B1} to R_{BB} when $I_E = 0$ A.

Conduction through the emitter terminal begins when the emitter voltage reaches the firing potential, given as

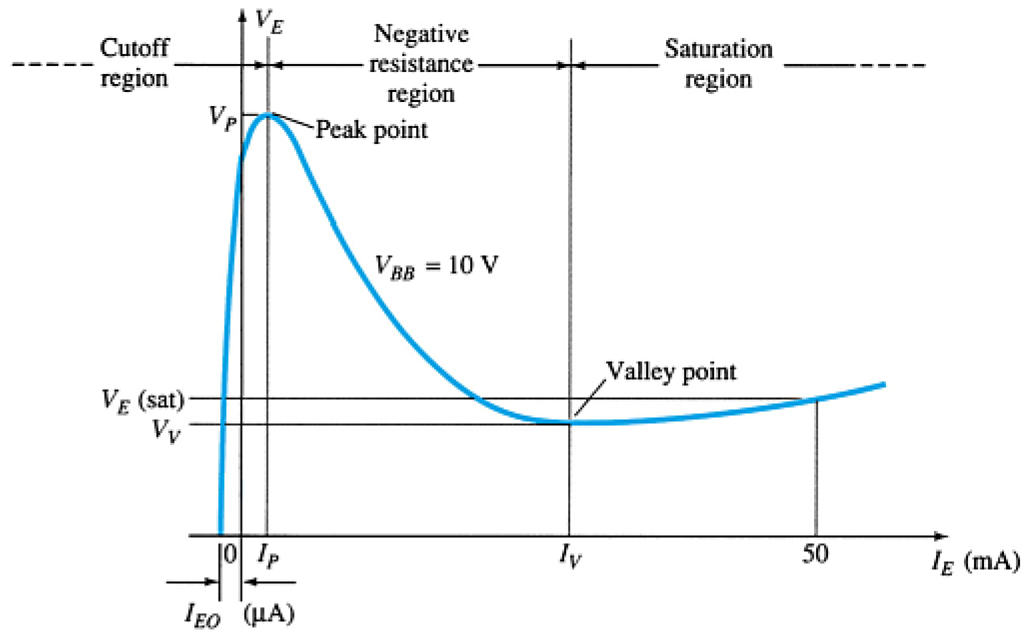
$$V_P = \eta V_{BB} + V_D$$



UJT Negative Resistance Region

After a UJT fires, emitter voltage decreases as emitter current increases.

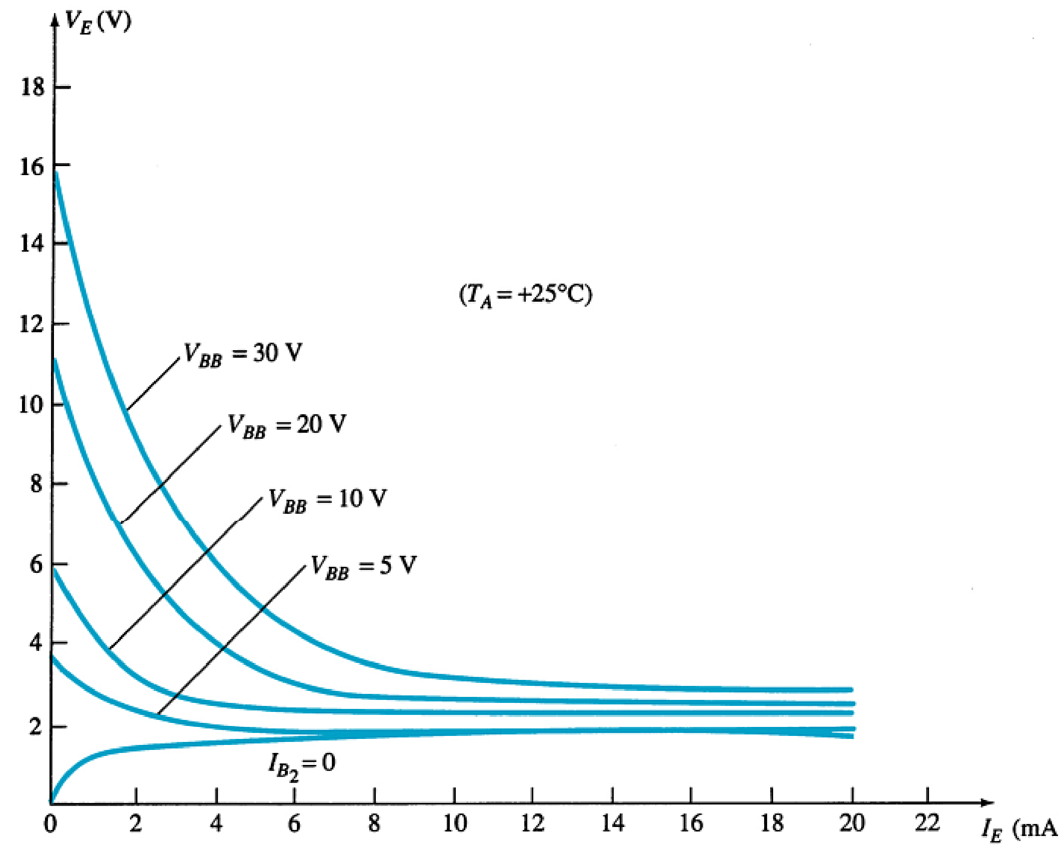
The negative resistance region of operation is definced by the peak point (V_P) and the valley point (V_V).



UJT Emitter Curves

The UJT emitter curves show the effect of V_{BB} on UJT firing voltage (V_P).

The higher the value of V_{BB}, the higher the value of (V_P) required to fire the component.

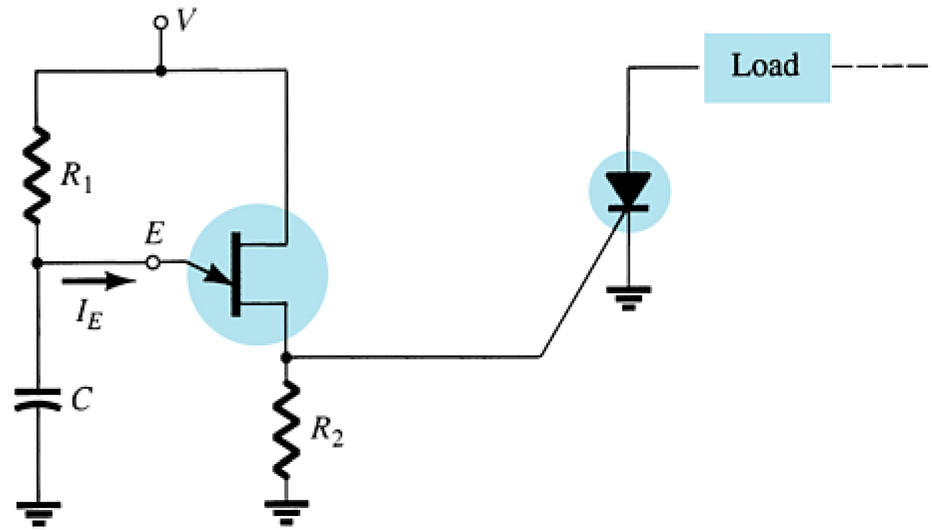


Using a UJT to trigger an SCR

The UJT is commonly used as a triggering device for other breakover devices, like the SCR.

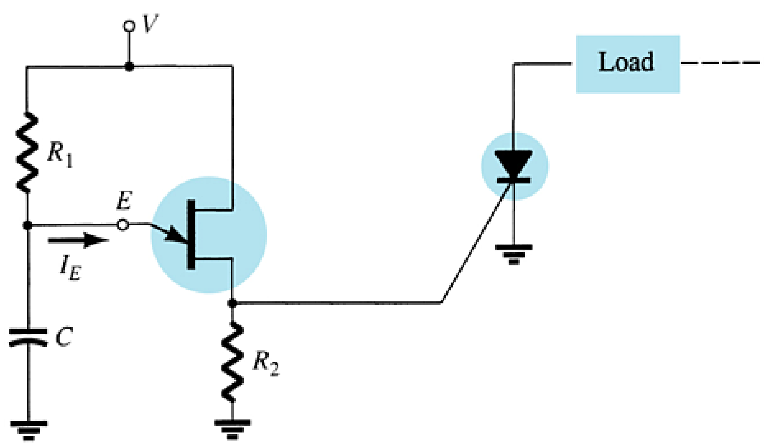
The SCR shown is triggered when the UJT emitter circuit conducts.

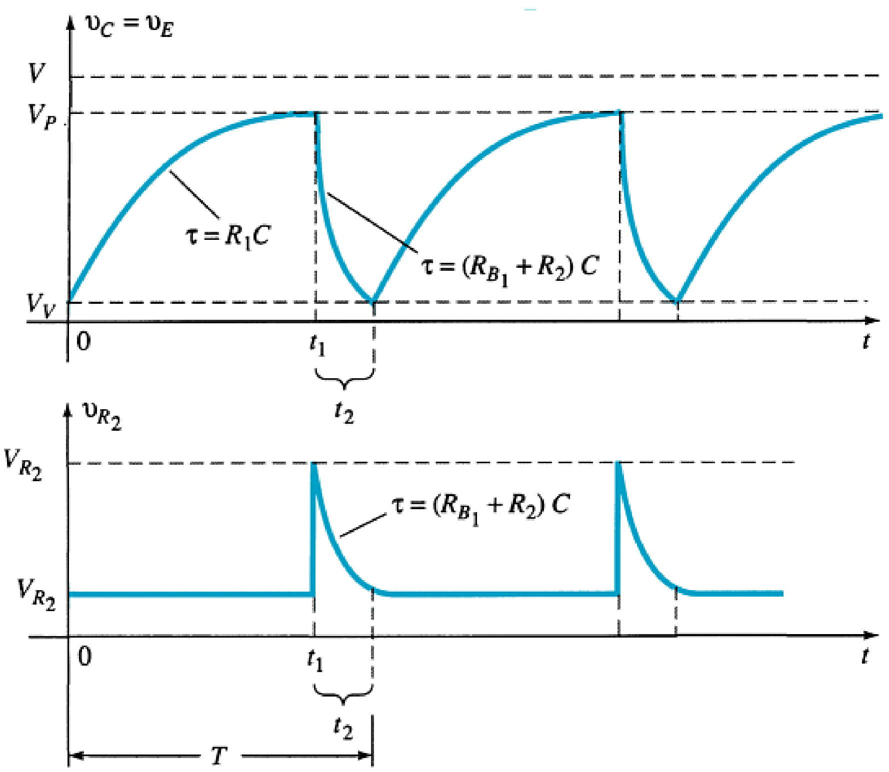
As the capacitor charges, V_E increases. When it reaches V_P, the UJT fires. The voltage developed across R_2 triggers the SCR.



Using a UJT to trigger an SCR

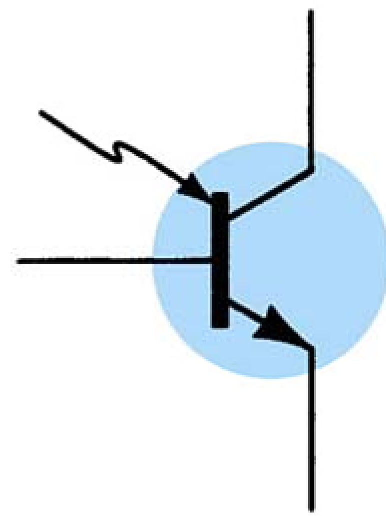
The V_E and V_{R2} waveforms for the SCR triggering circuit (below) are shown.





The Phototransistor

The phototransistor is a light-controlled transistor. The current through the collector and emitter circuits is controlled by the light input at the base.



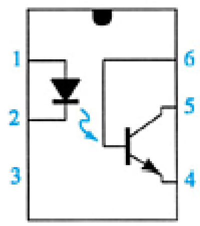
The collector current is the product of the transistor current gain (h_{fe}) and the light induced base current (I_λ).

$$I_C = h_{fe} I_\lambda$$

Phototransistor IC Package

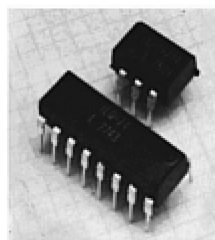
ISO-LIT 1

(Top view)



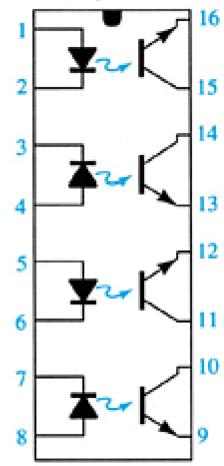
LED chip on Pin 2
PT chip on Pin 5

Pin No.	*Function*
1	anode
2	cathode
3	nc
4	emitter
5	collector
6	base



ISO-LIT Q1

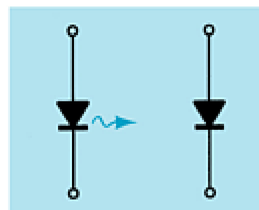
(Top view)

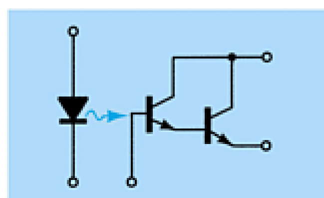


Pin No.	*Function*
1	anode
2	cathode
3	cathode
4	anode
5	anode
6	cathode
7	cathode
8	anode
9	emitter
10	collector
11	collector
12	emitter
13	emitter
14	collector
15	collector
16	emitter

Opto-Isolators

Photodiode





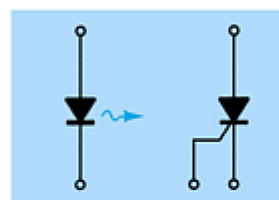


Photo-Darlington

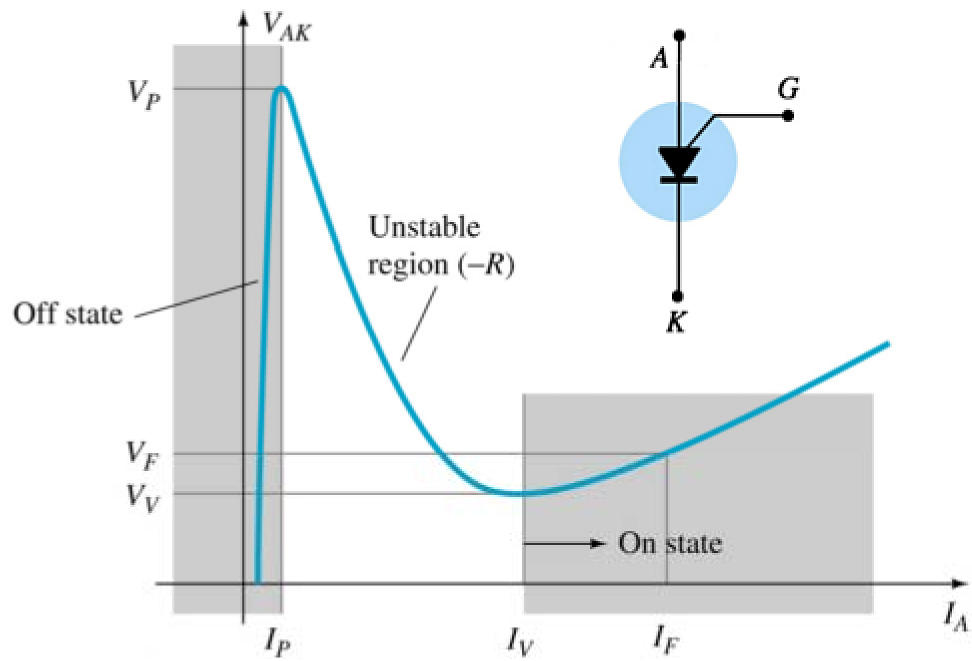
Photo-SCR

PUT—Programmable UJT

Characteristics

In some of its operating characteristics, a PUT is more like an SCR.

Like the UJT, the PUT has a negative resistance region. But this region is unstable in the PUT. The PUT is operated between the on and off states.



PUT Firing

Reducing or removing the gate voltage dies not turn off the PUT. Instead, like an SCR, the Anode to Cathode voltage must drop sufficiently to reduce the current below a holding level.

The gate voltage required to turn the PUT on is determined by external components, and not by specifications of the device as in the η value for the UJT.

$$V_G = \frac{R_{B1}}{R_{B1} + R_{B2}} V_{BB} = \eta V_{BB}$$