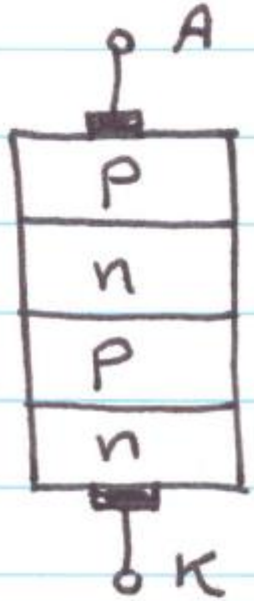
Thyristors and other Devices

Thyristors

- Devices Constructed of four semiconductor Layers
- They act as open Circuits Capable of withstanding a Certain rated voltage untill they are triggered

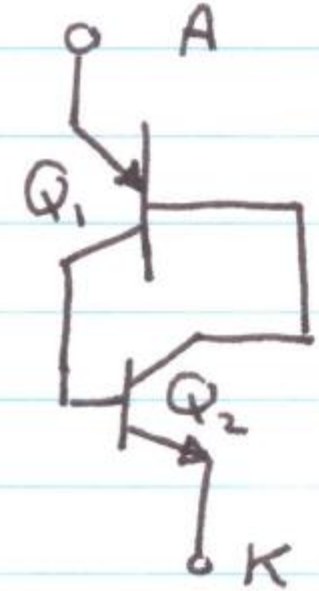
- When triggered, they turn on and become low-resistance current path, and remains on, even after the trigger is removed, untill the current is reduced to a certain level or they are triggered off, depending on the type of the device
- Thyristors can be used to control the amount of ac power to a load
- They are used in Lamp dimmers, motor speed controls and charging circuits.

The Shockley Diode



Basic Construction

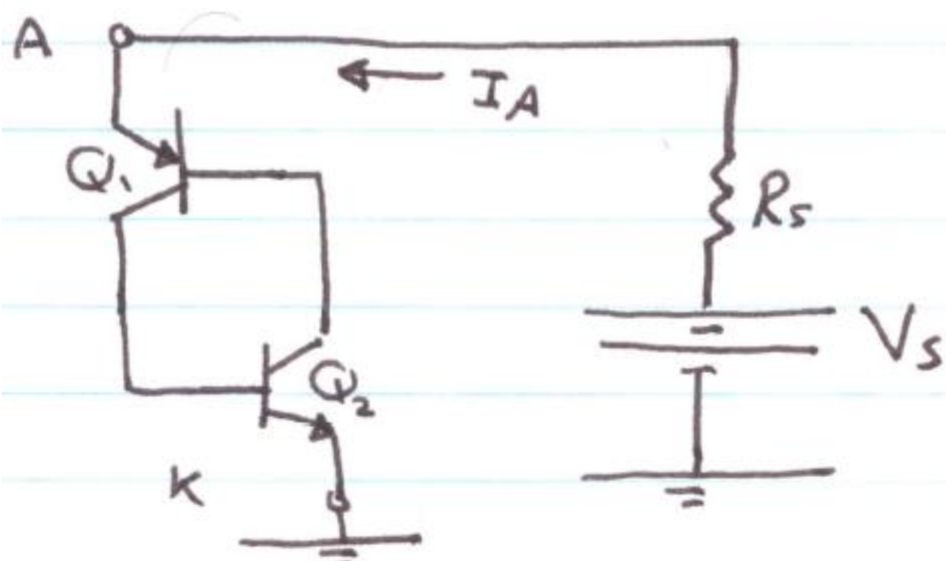
Circuit Symbol



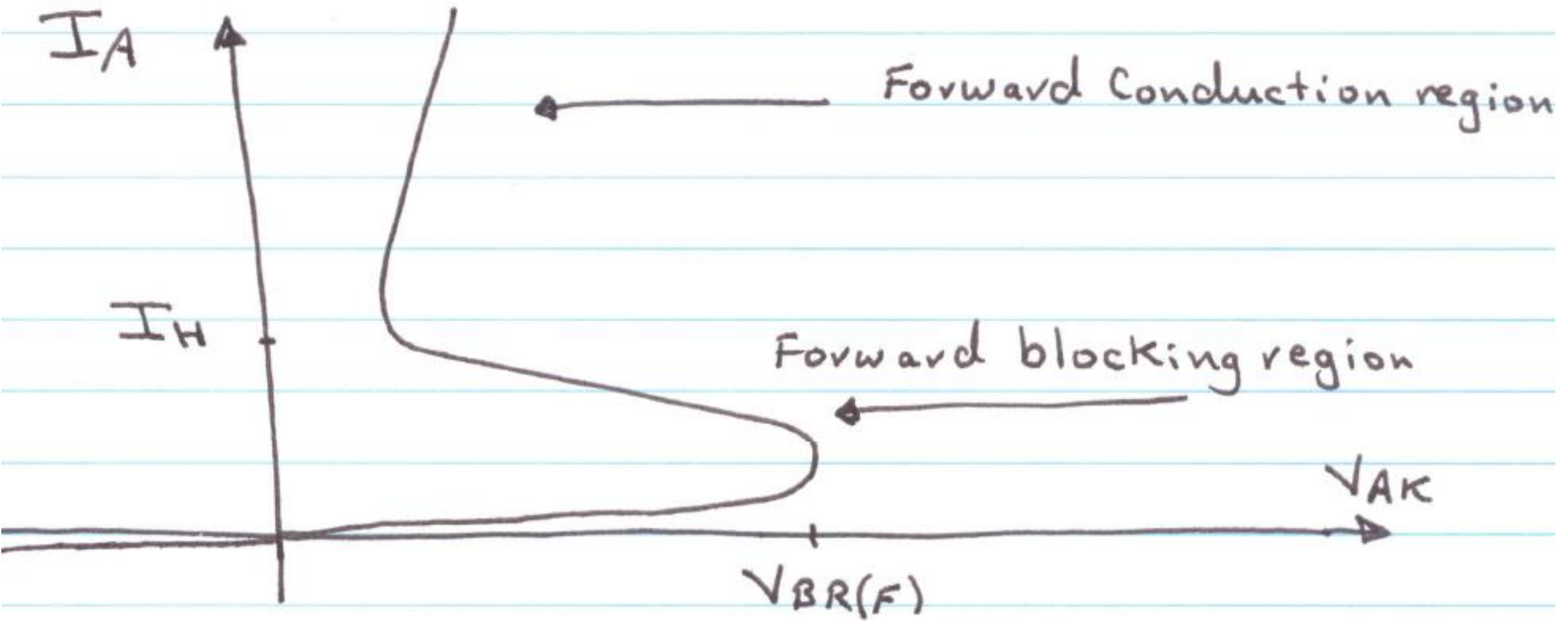
Equivalent Circuit

- The basic 4-lyer device
- It is a two terminal device
- It acts as a Switch

- It remain off until the forward voltage reaches a certain value ; then it turns on and conducts current.
- Conduction continue until the current is reduced below a specified value



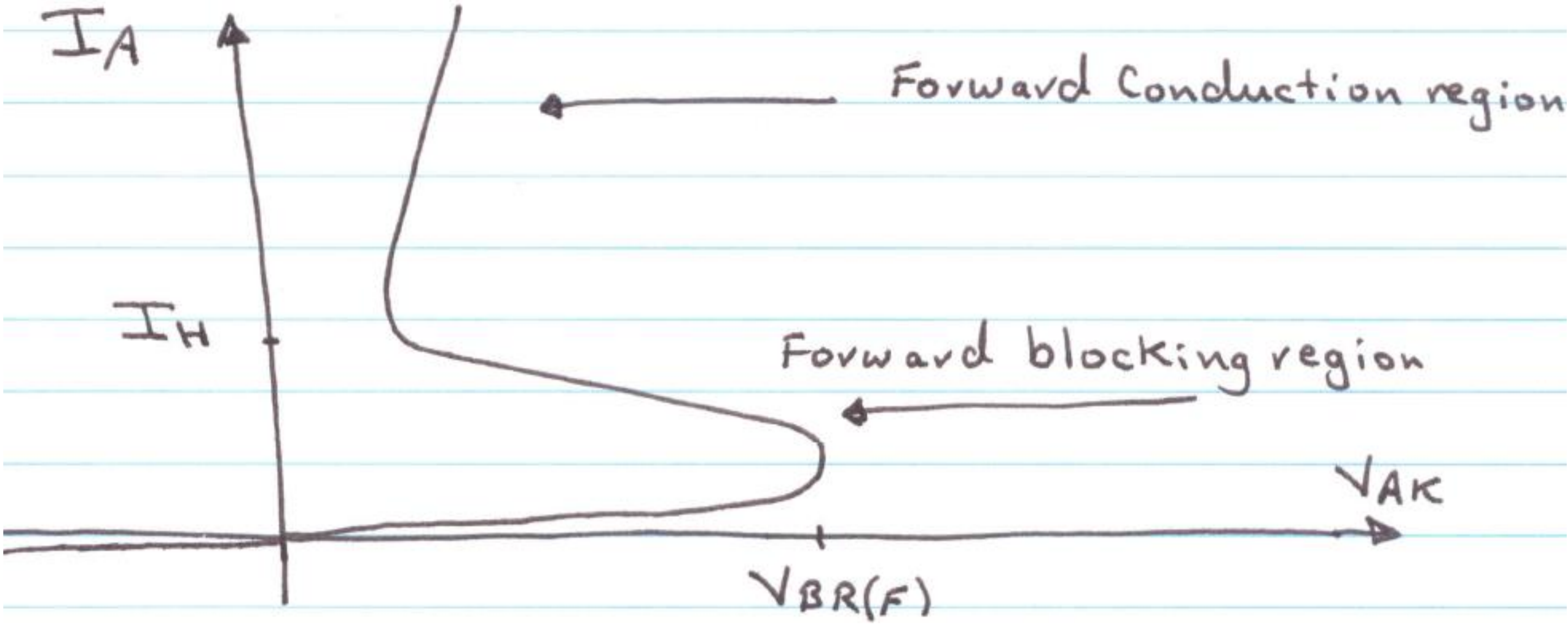
Characteristic Curve



$V_{BR(F)}$ ≡ Forward breakover voltage

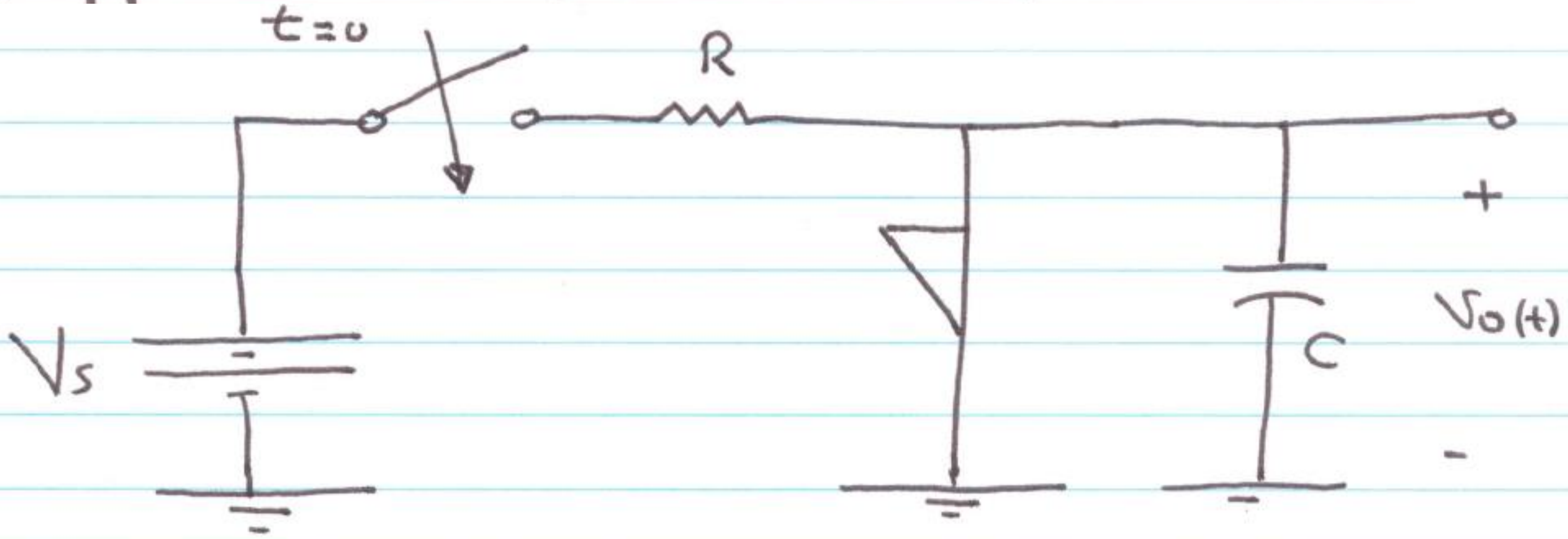
I_H ≡ Holding Current

* when $V_s > V_{BR(F)}$; the device is in the on state and acts as a closed switch



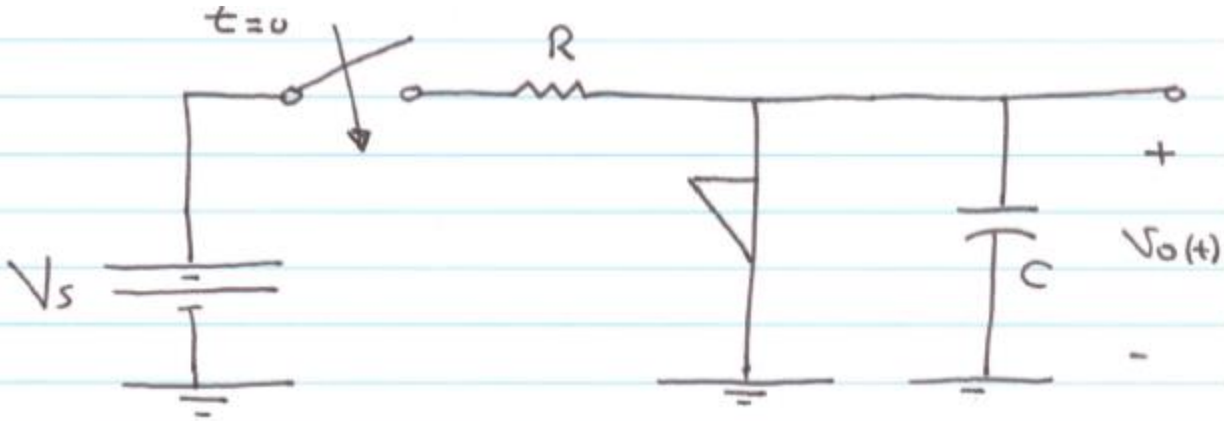
* When the anode Current I_A drops back below the holding value I_H, the device turns OFF (open Circuit)

Application : Relaxation Oscillator

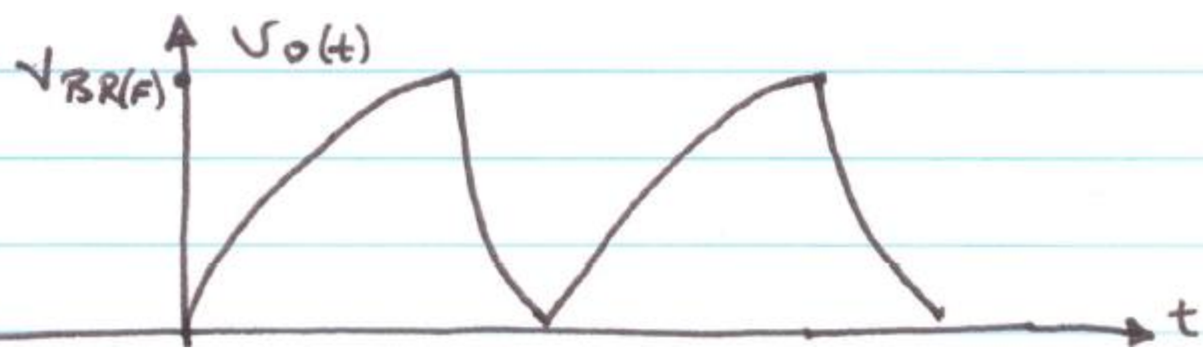


$v_c(0^-) = 0$

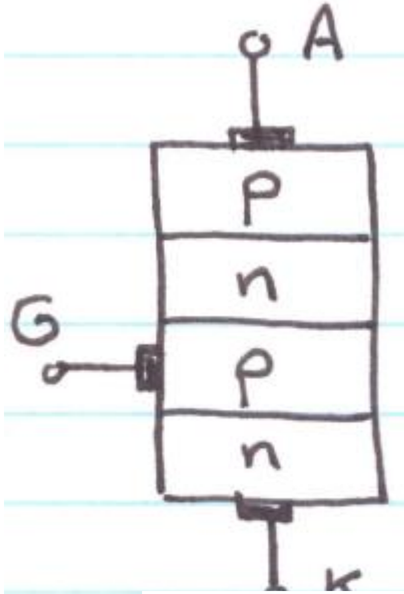
- At $t = 0^+$, $v_c(0^+) = V_{AK}(0^+) = 0$; the device is OFF (open Circuit)
- The device switch into conduction (short circuit)

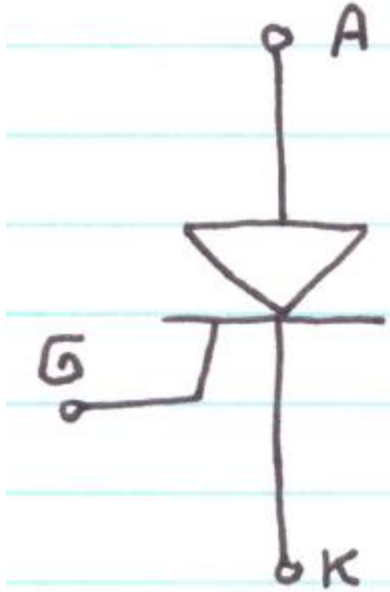


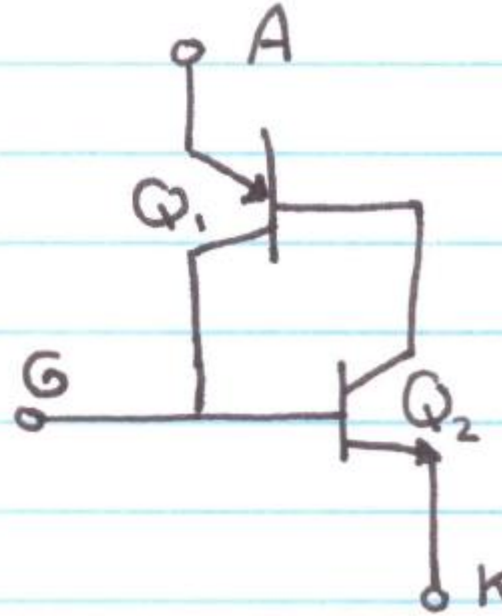
- The Capacitor rapidly discharge through the device until $I_A < I_H$
- The device switch back to the OFF state



The Silicon Controlled Rectifier . SCR

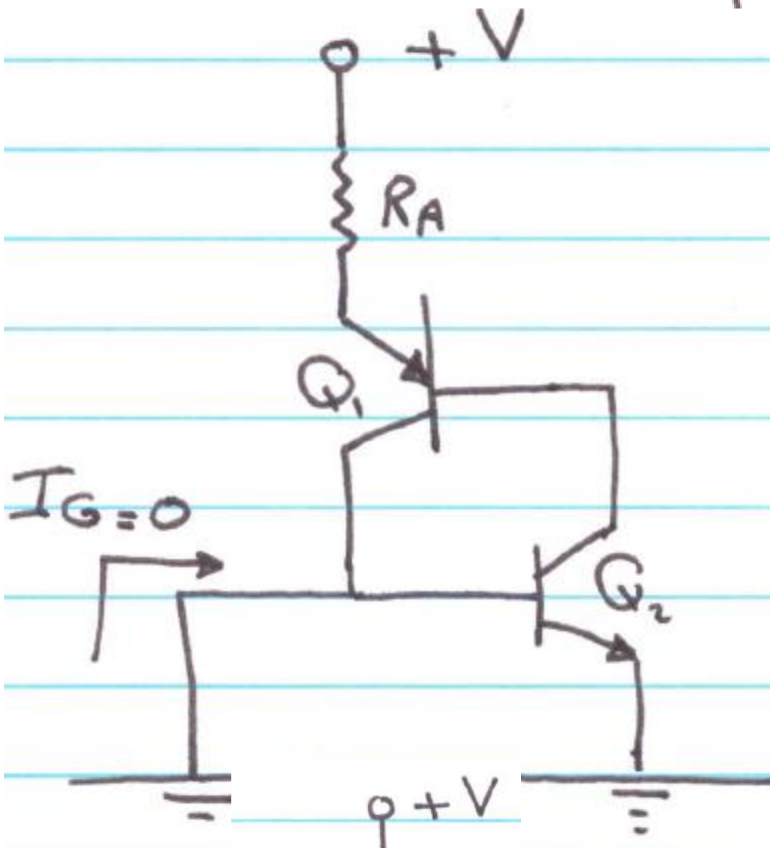




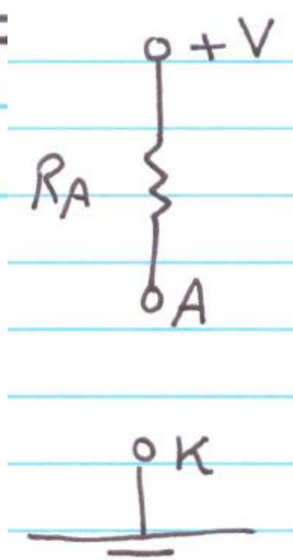


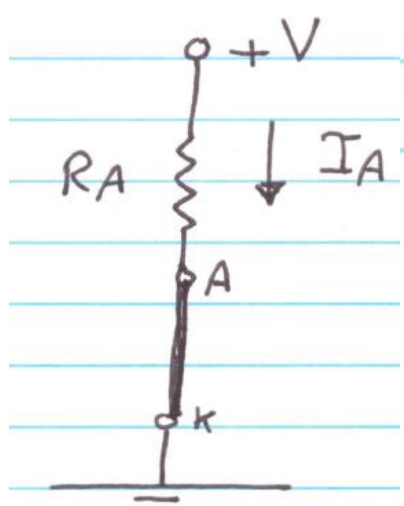
- It is a three terminal device
- It is four Layer pnpn device
- It acts as a switch
- In the off state; it acts as an open circuit between Anode and Cathod

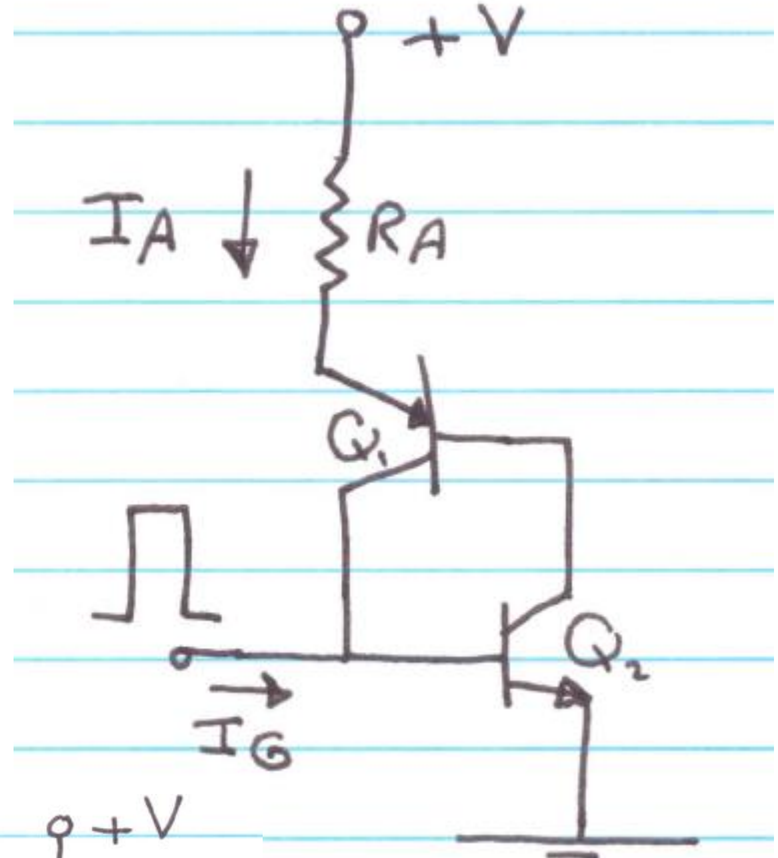
Turning the SCR On



FF







SCR On

- when $I_G = 0$; it act as the schockley diode in the off state (open Circuit)
- When a positive pulse of Current (trigger) is applied to the gate, both transistors turn on
- The SCR stays on (Latches) once it is triggered on
- In this state, SCR can be approximated by close switch.

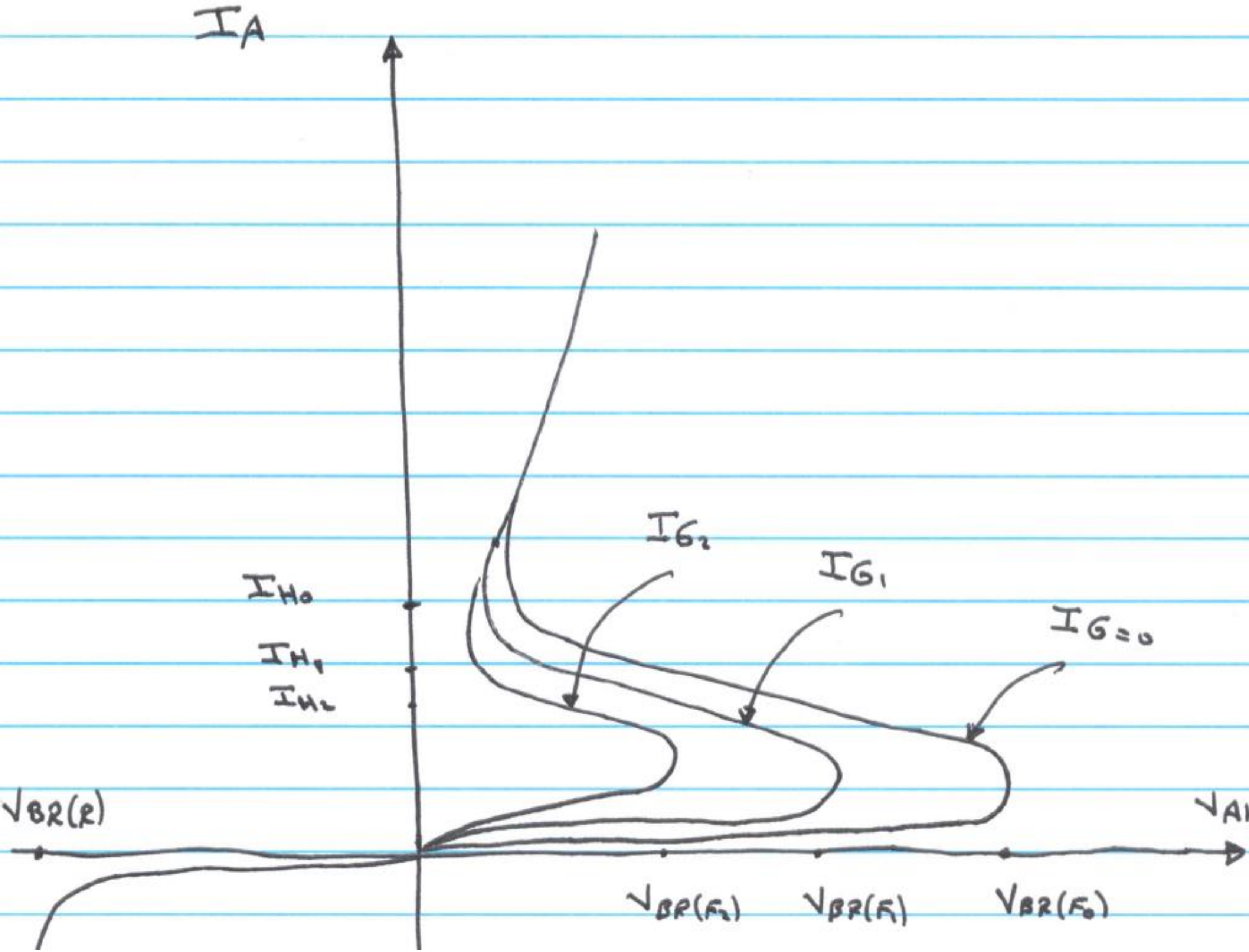
- Like the schockley diode, an SCR can also be turned on without gate triggering by increasing V_{AK} to a value exceeding $V_{BR(F_0)}$

Turning the SCR OFF

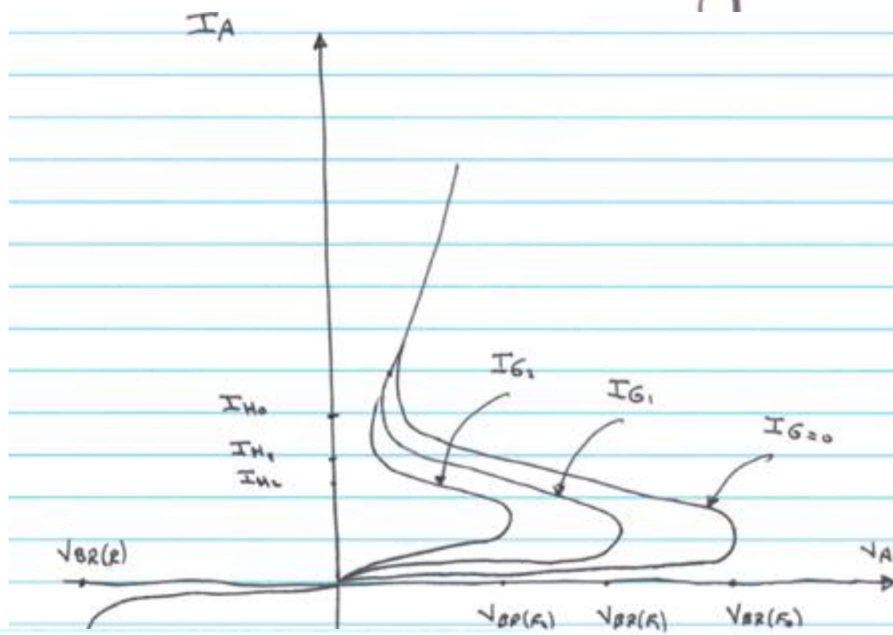
- When the gate returns to 0v, after the trigger pulse is removed, the SCR can not turn off

- It stays in the on state until the anode current I_A drop below I_H

SCR Characteristic Curves



SCR characteristics and ratings

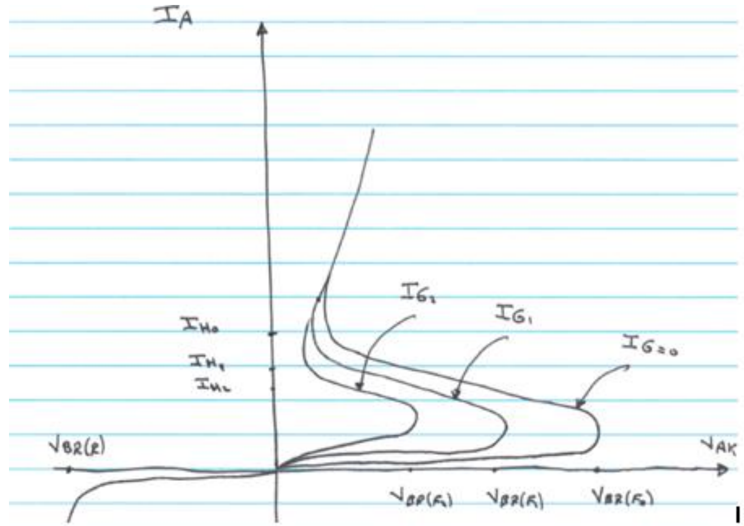


1) Forward breakover voltage : $V_{BR(F)}$

This is the voltage at which the SCR enters the forward conduction region.

$V_{BR(F)}$ is maximum when $I_G = 0$.

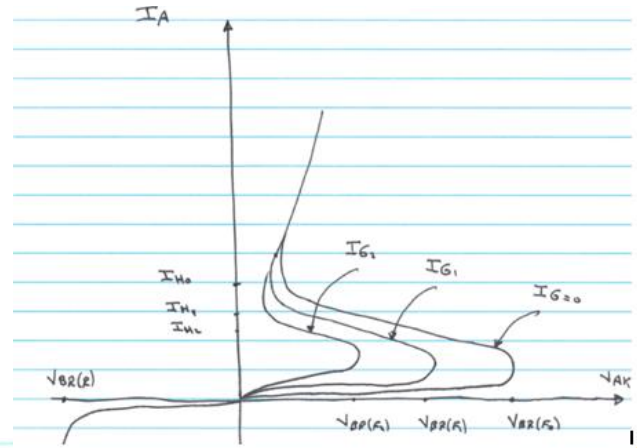
When I_G increases, $V_{BR(F)}$ decreases.



2) Holding Current : I_H

This is the value of anode current below which the SCR switches from the forward conduction region to the forward blocking region

$I_H \downarrow$ as $I_G \uparrow$

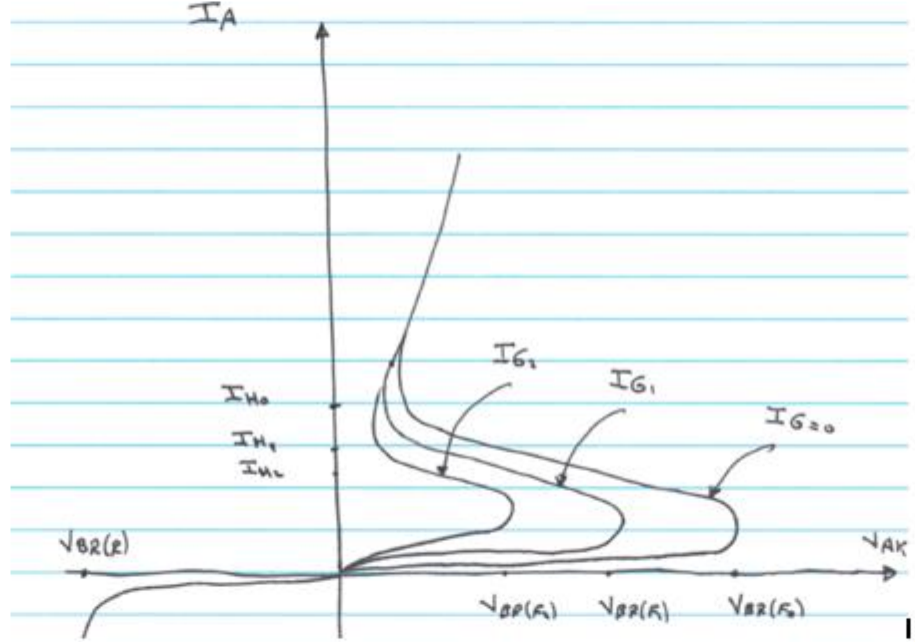


3) Gate triggering Current : I_{GT}

This is the value of gate Current necessary to switch the SCR from the forward blocking region to the forward Conduction region

4) Forward Conduction region :

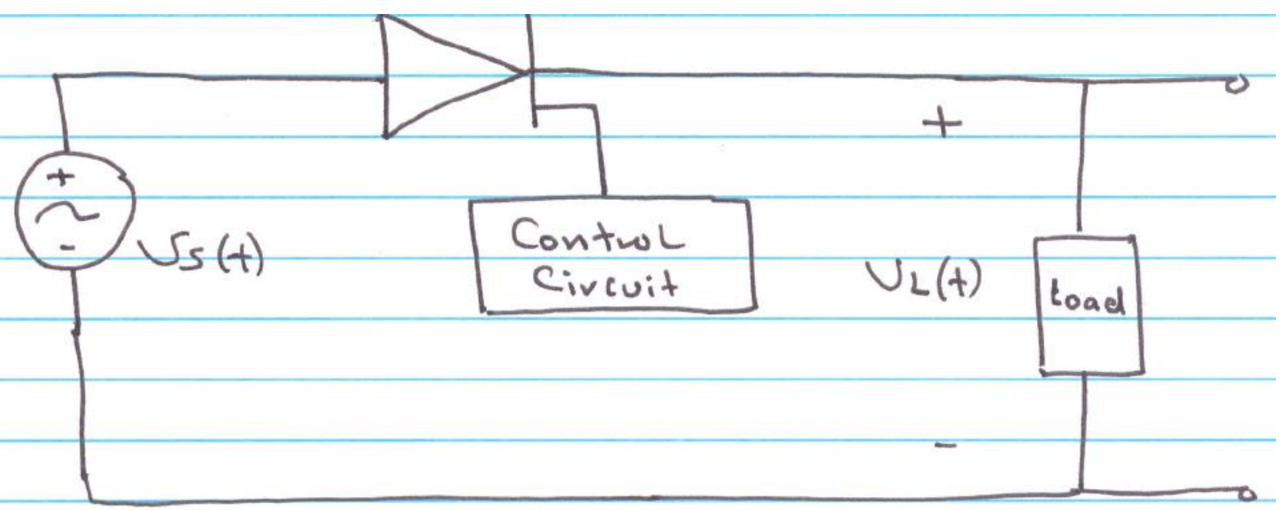
This region Corresponds to the on Condition of the SCR where there is forward current from Anode to Cathod.

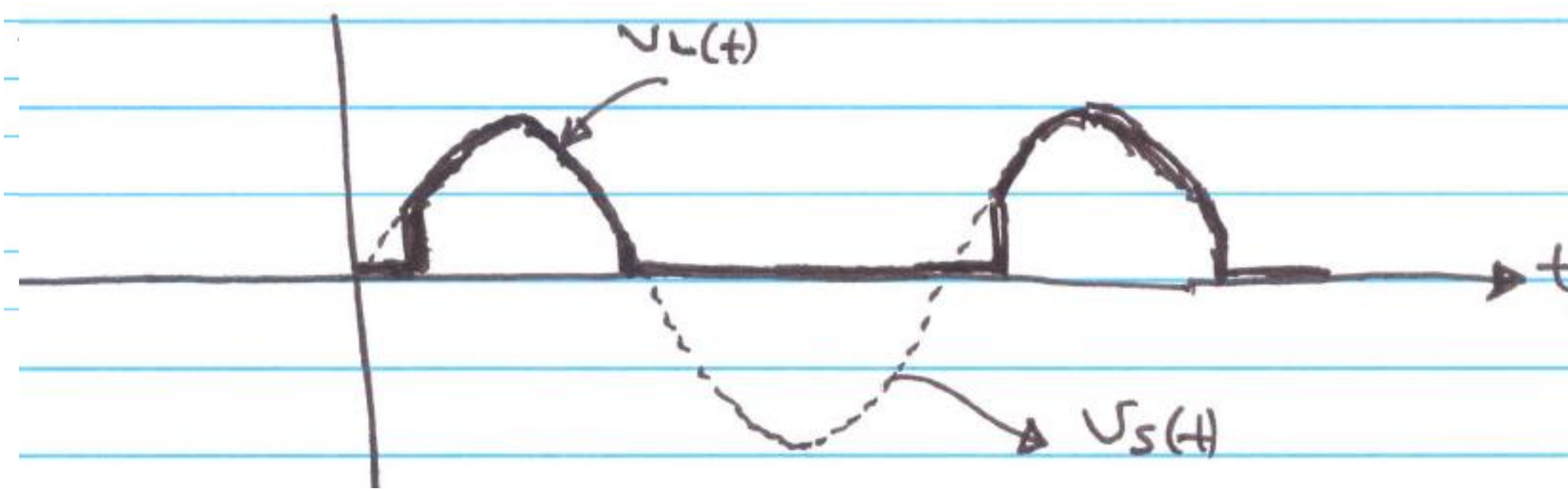


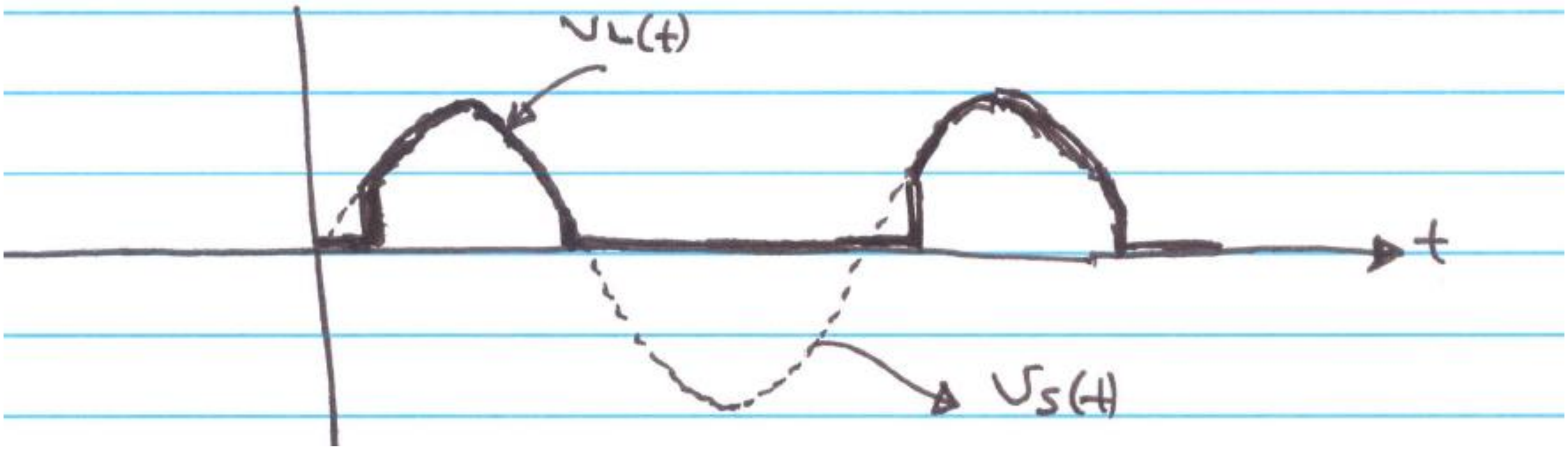
5) Forward blocking region :

This region Correspond to the OFF Condition of the SCR where the forward Current from anode to Cathod is blocked by the open Circuit of the SCR.

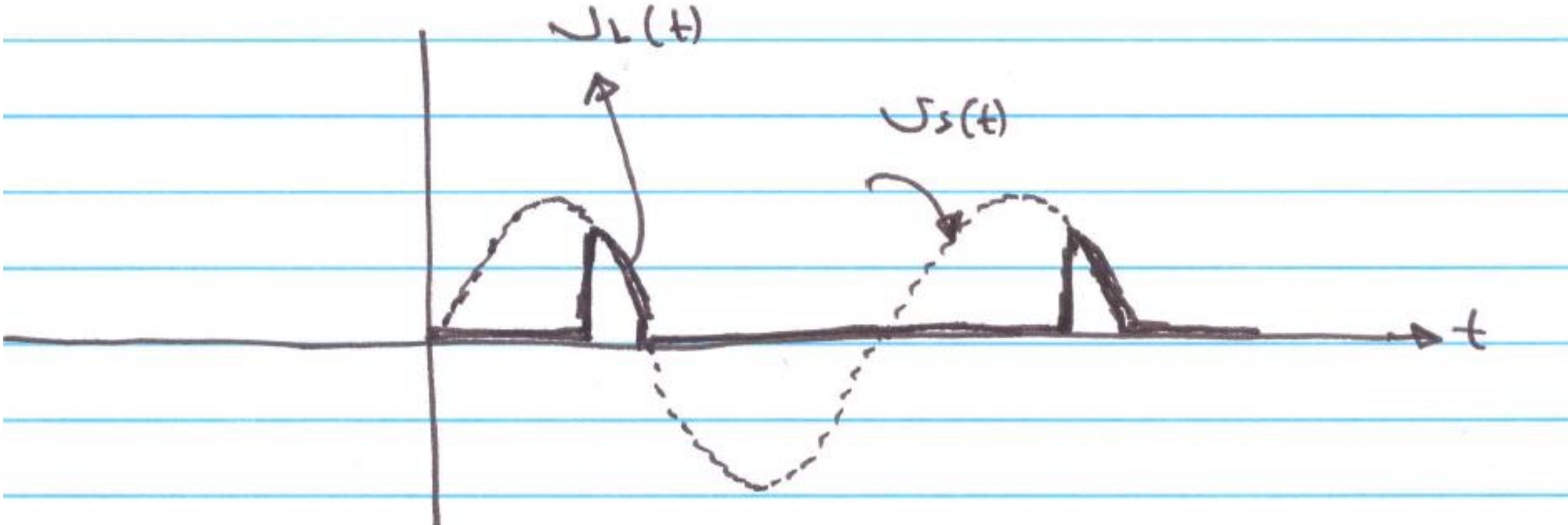
SCR Application



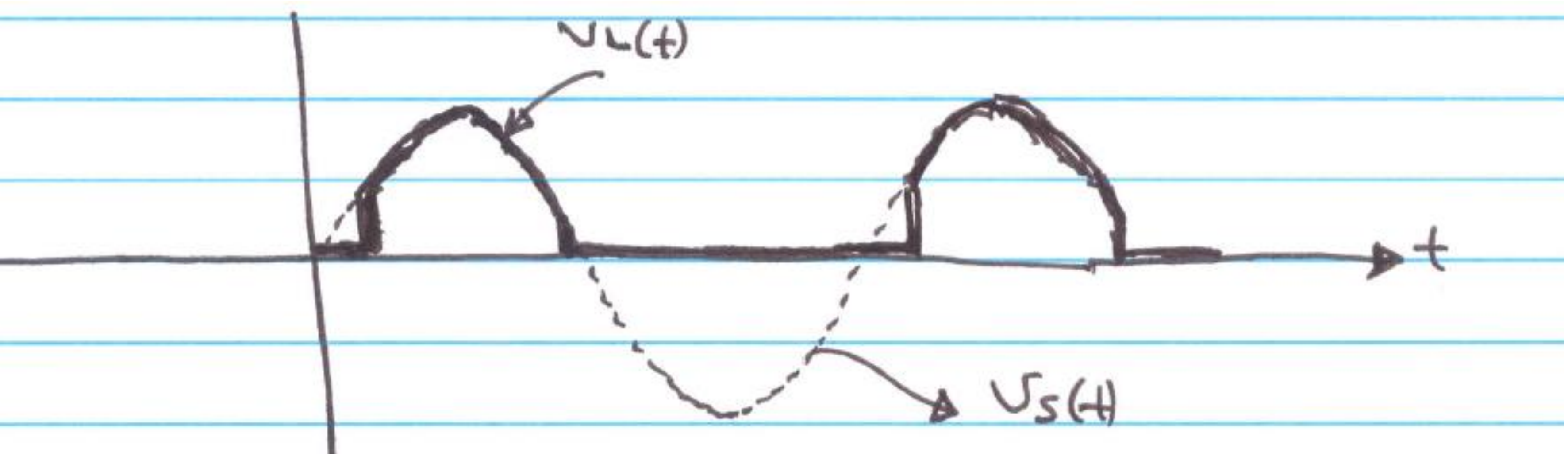




vL(t)
vs(t)
t

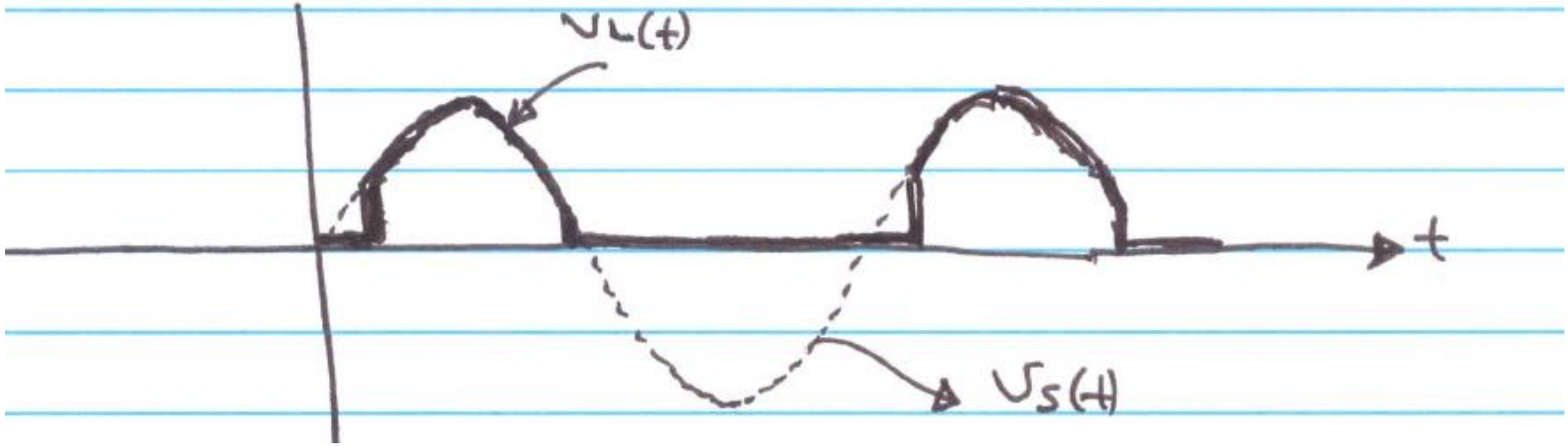


vL(t)
vs(t)
t



Conduction angle : is the number of Degrees of an ac Cycle during which the SCR is turned on

Conduction angle = 135



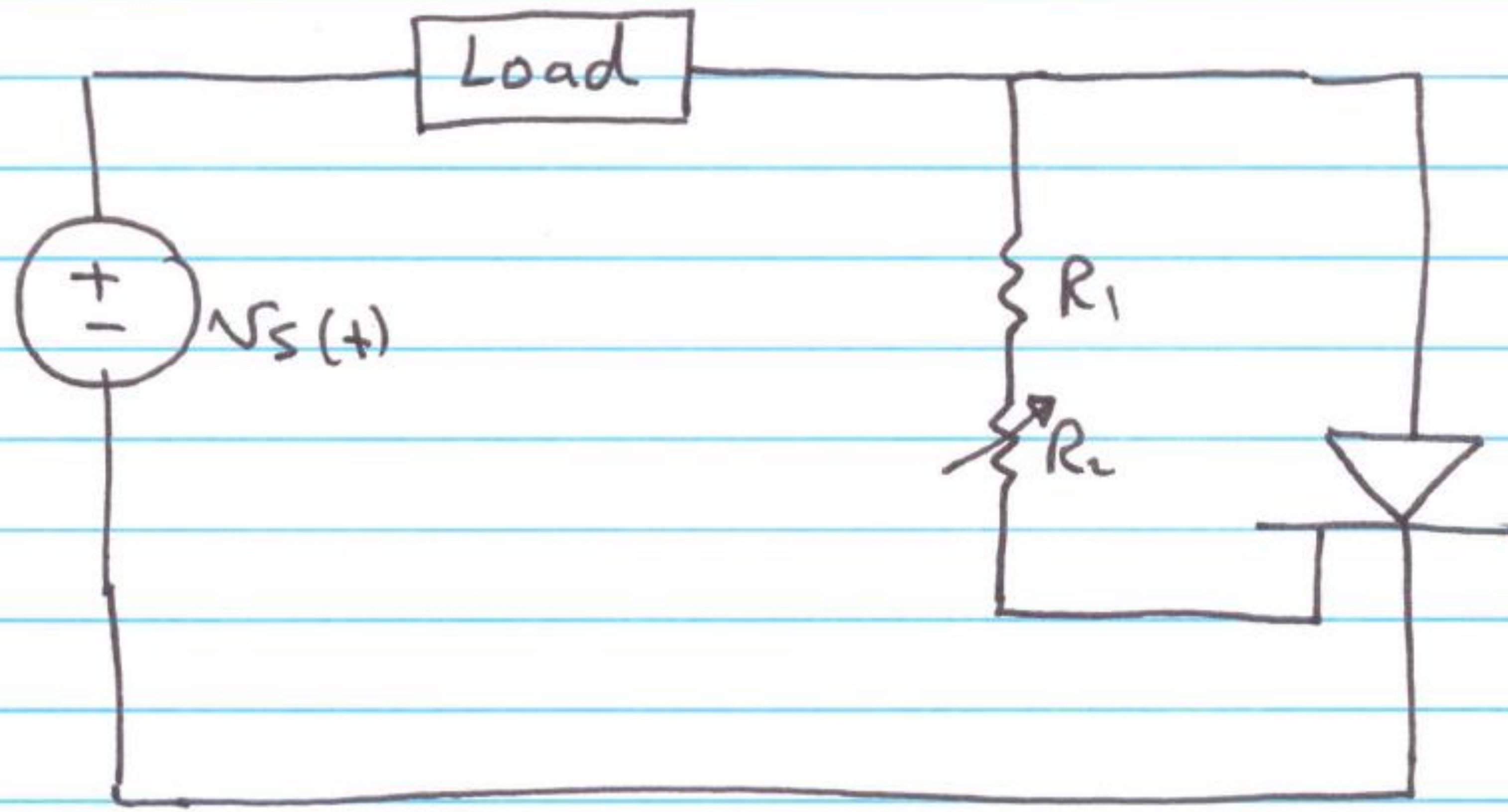
Firing delay angle : is the number of Degrees of an ac Cycle elapes before the SCR is turned on.

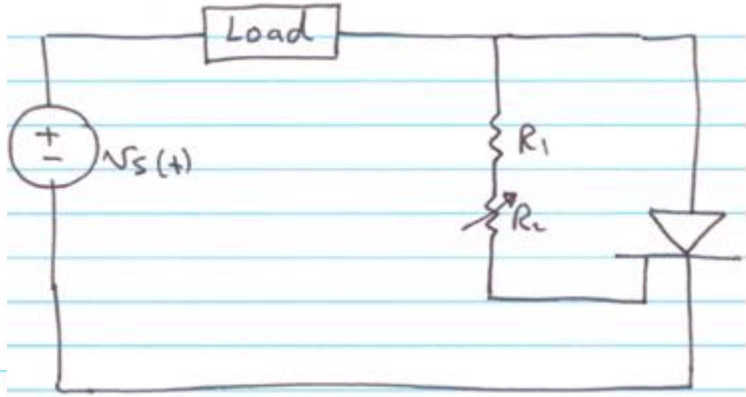
Firing delay angle = 45

The SCR spends a certain portion of the ac cycle time in the on state, and the remainder of the time is in the off state. The amount of time spent in each state is Controlled by the gate.

The SCR Can not be turned on more than half the time.

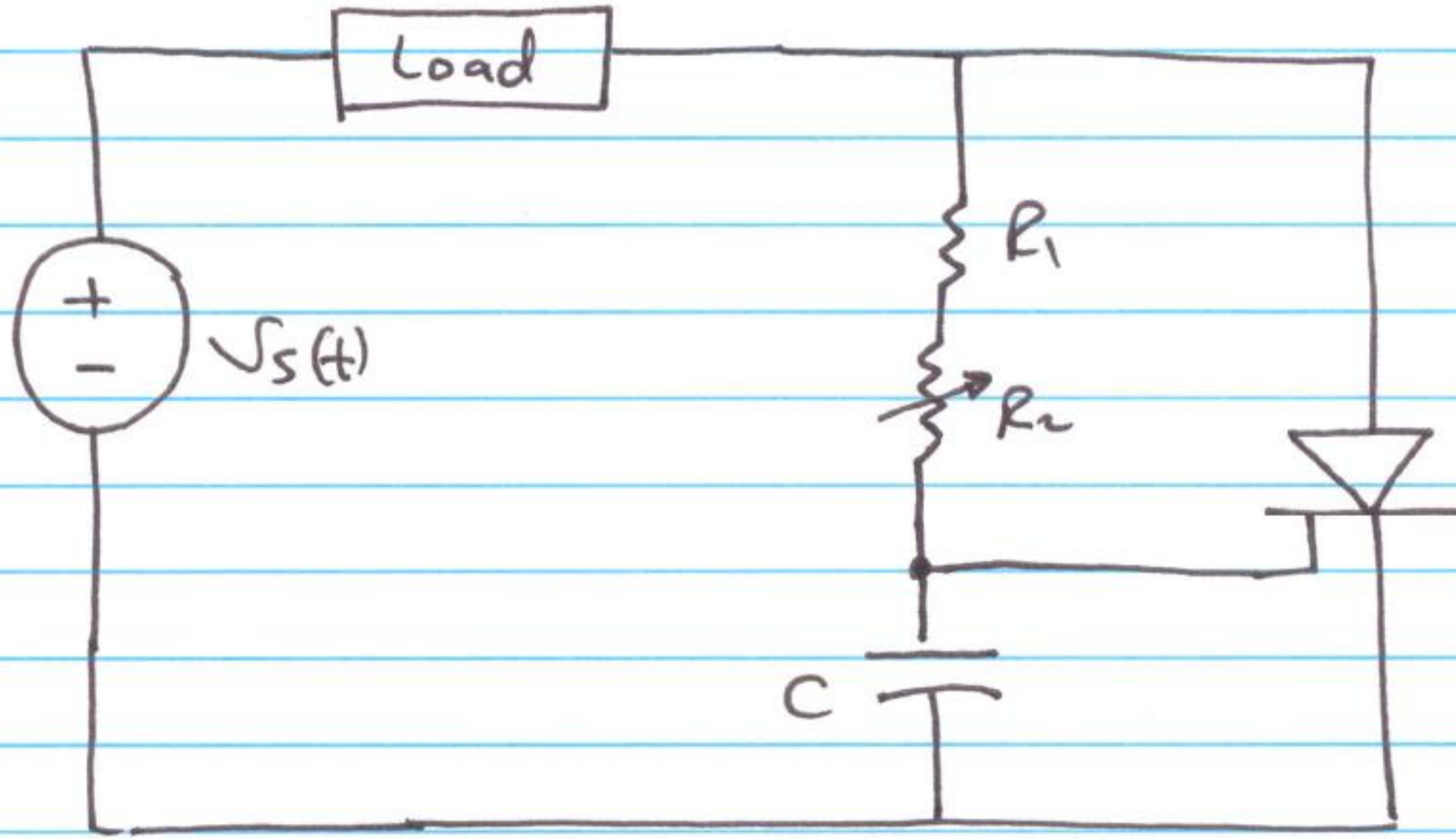
Typical Gate Control Circuits





- The Same voltage supply $v_s(t)$ is used to power both the gate Control and the load
- when the supply voltage $v_s(t)$ is positive and Large enough so that $I_G > I_{GT}$; the SCR turns on
- The firing angle is determined by the setting of R_2
- $90 > \theta > 0$

Other Gate Control Circuit

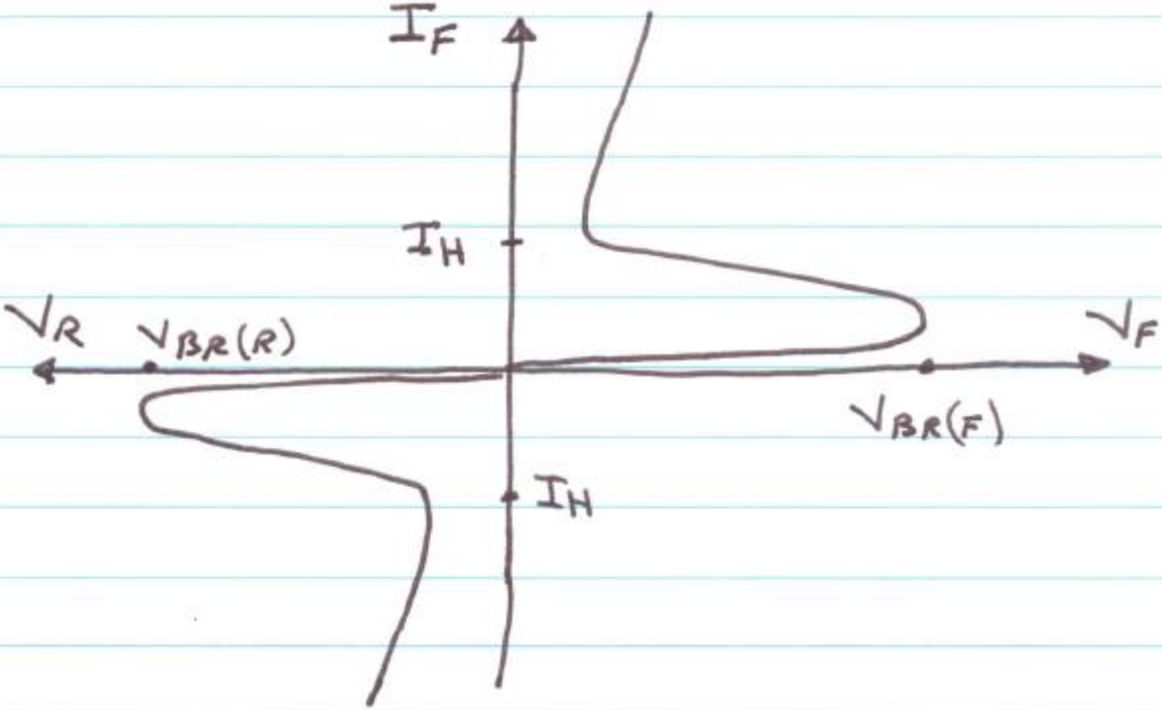


Firing delay angle could be greater than 90°

$R_2 \uparrow$, $\tau \uparrow$, $\theta \uparrow$

The Diac

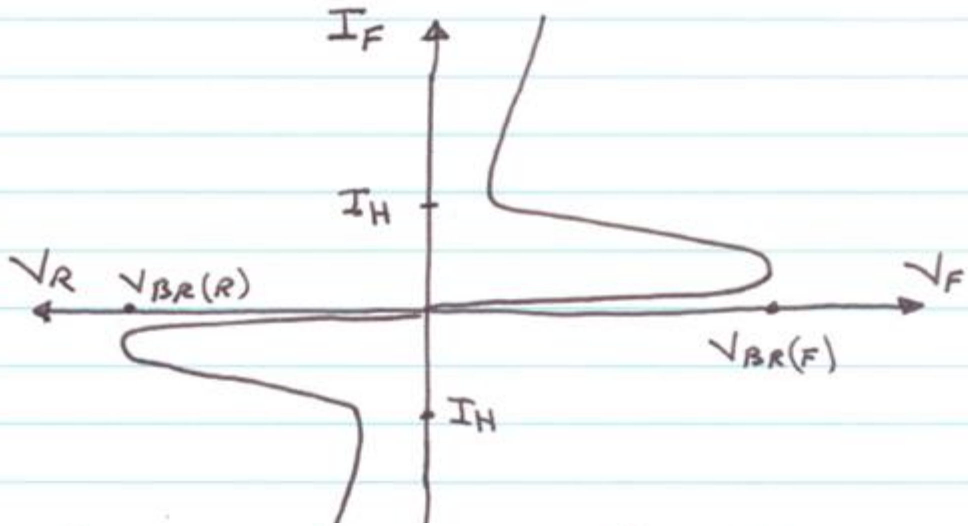
Circuit symbol



Characteristic Curve

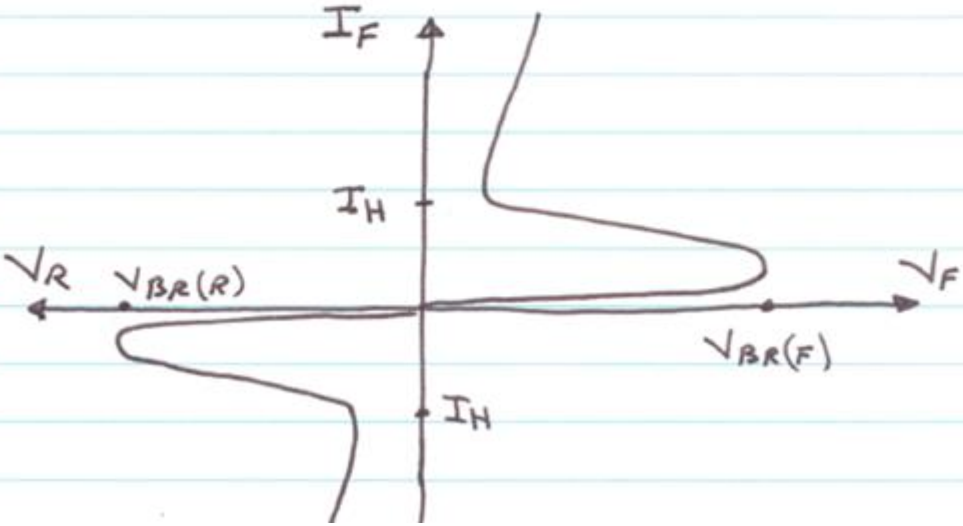
- It is a two terminal device
- It can conduct current in either direction when properly activated
- Conduction occurs when the breakover voltage is reached with either polarity

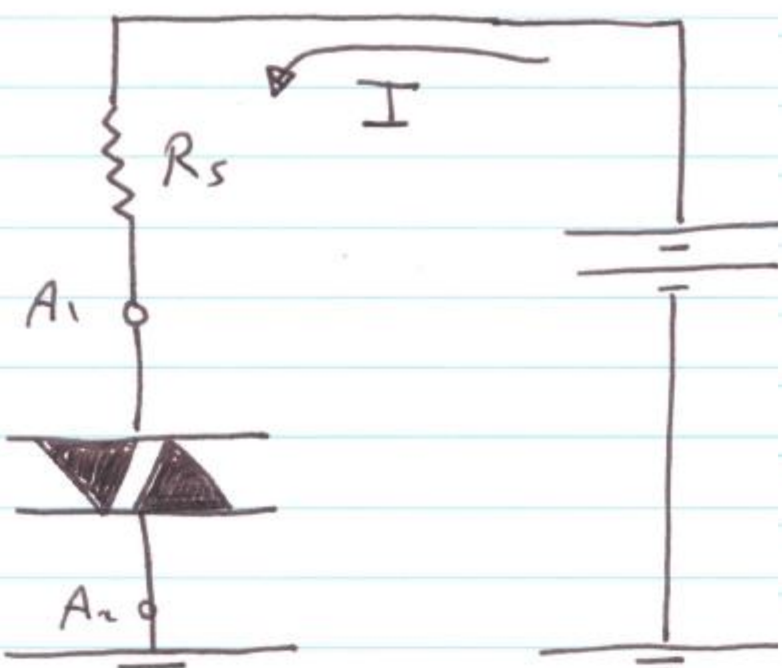
The Diac

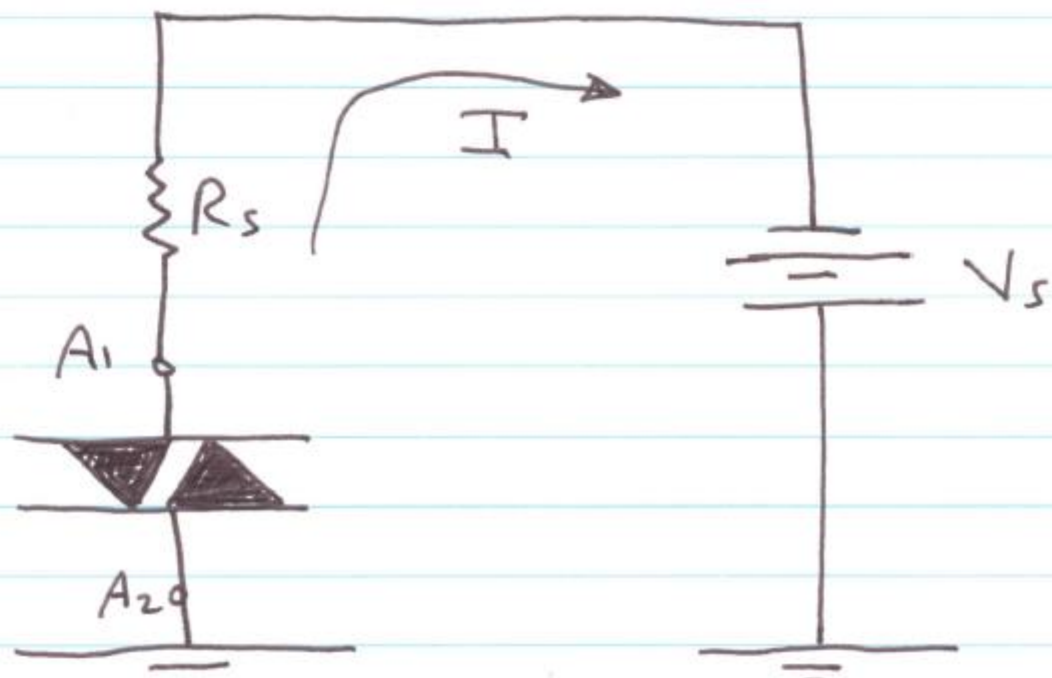


- The device turns off when the current drops below the holding value (I_H)
- The device functions like two parallel shockley diodes turned in opposite direction

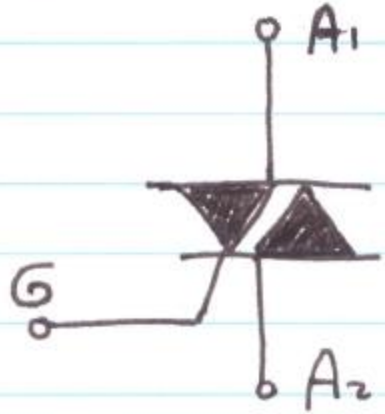
The Diac



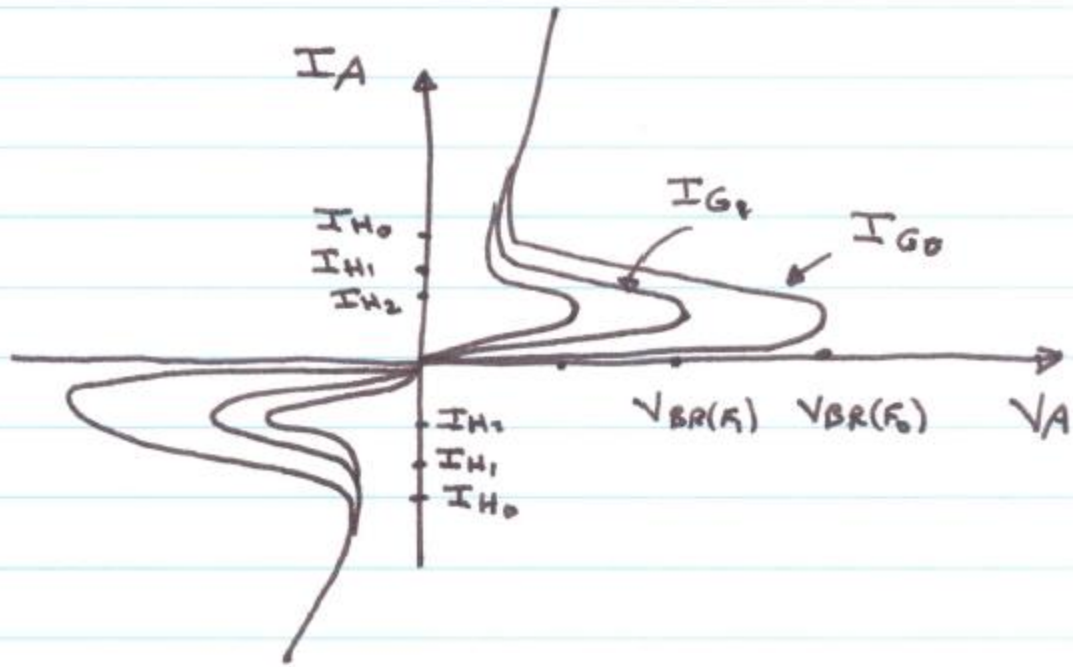




The Triac

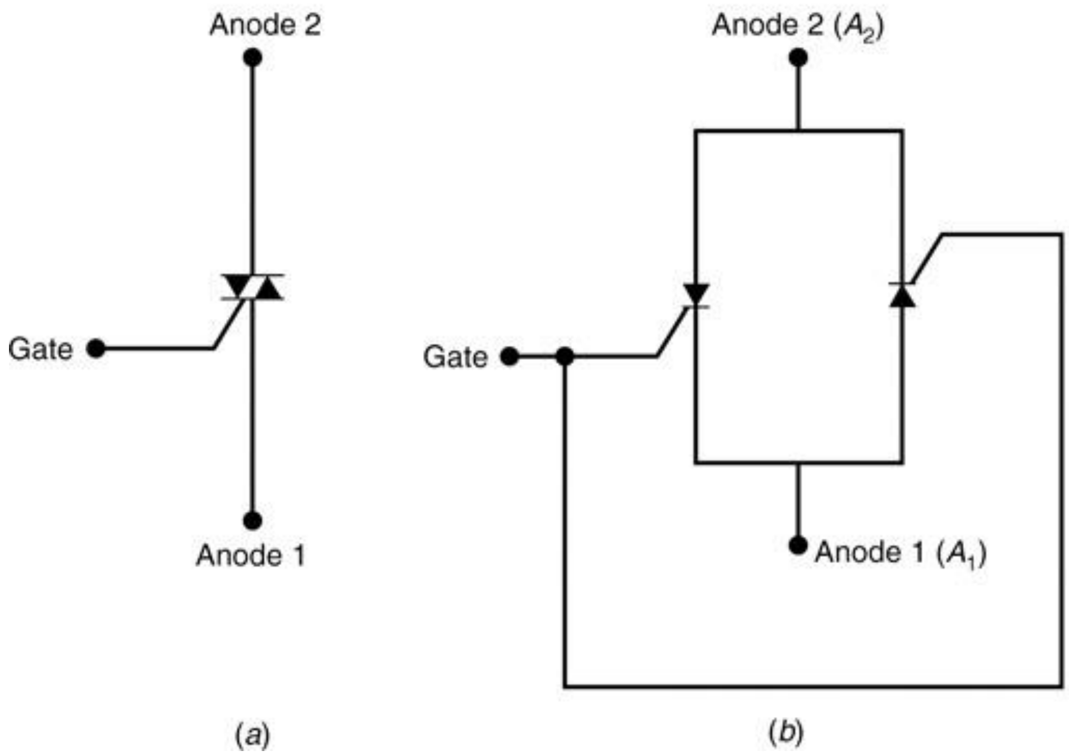


Circuit symbol



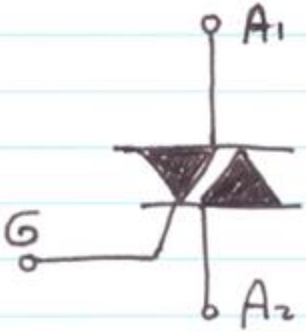
characteristic Curves

- A triac is like a diac with a gate
- The triac functions like two SCR connected in parallel and in opposite direction with a common gate terminal.

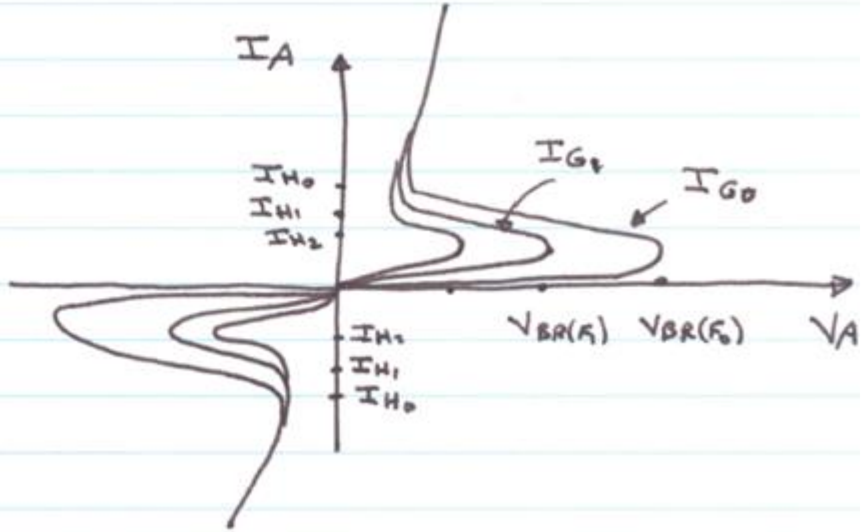


Anode 2
Gate
Anode 1
(a)
Anode 2 (A_2)
Gate
Anode 1 (A_1)
(b)

The Triac



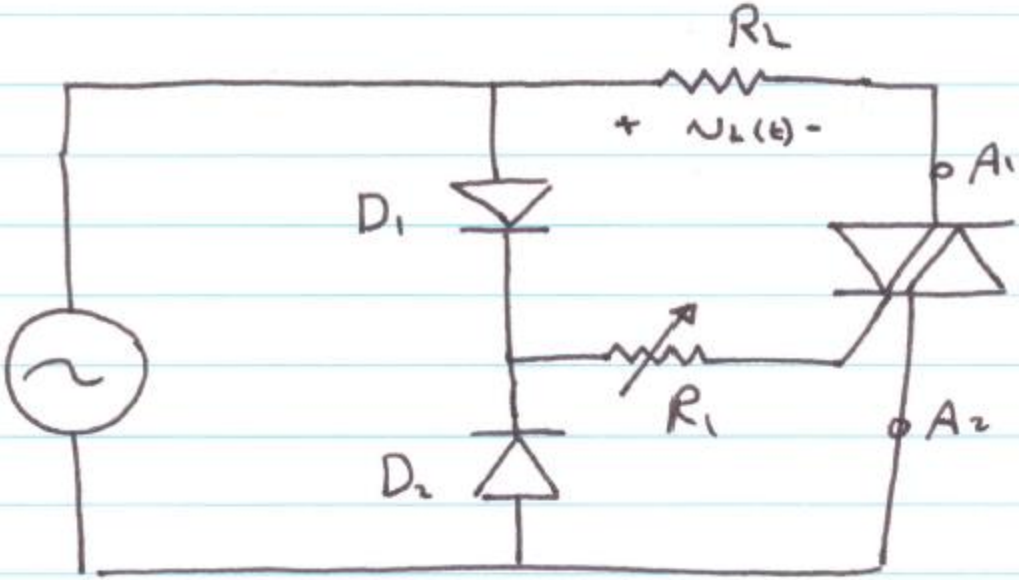
circuit symbol



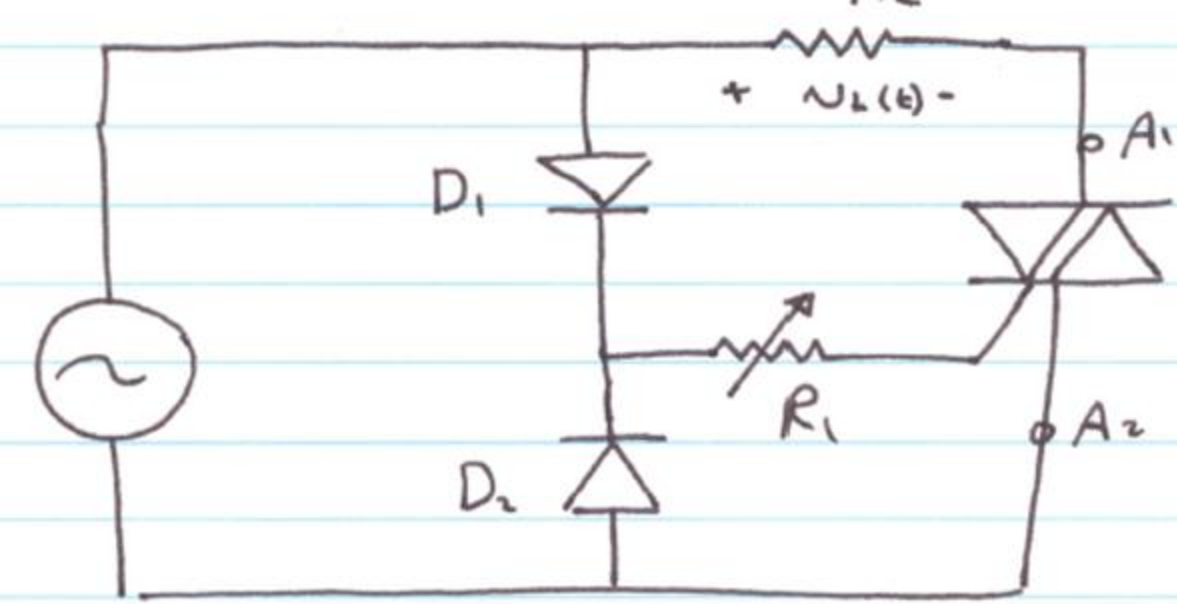
characteristic Curves

- The triac can conduct current in either direction when it is triggered on, depending on the polarity of the voltage across its A_1 and A_2 terminals.
- The triac turns off when the current drops below the holding value (I_H).

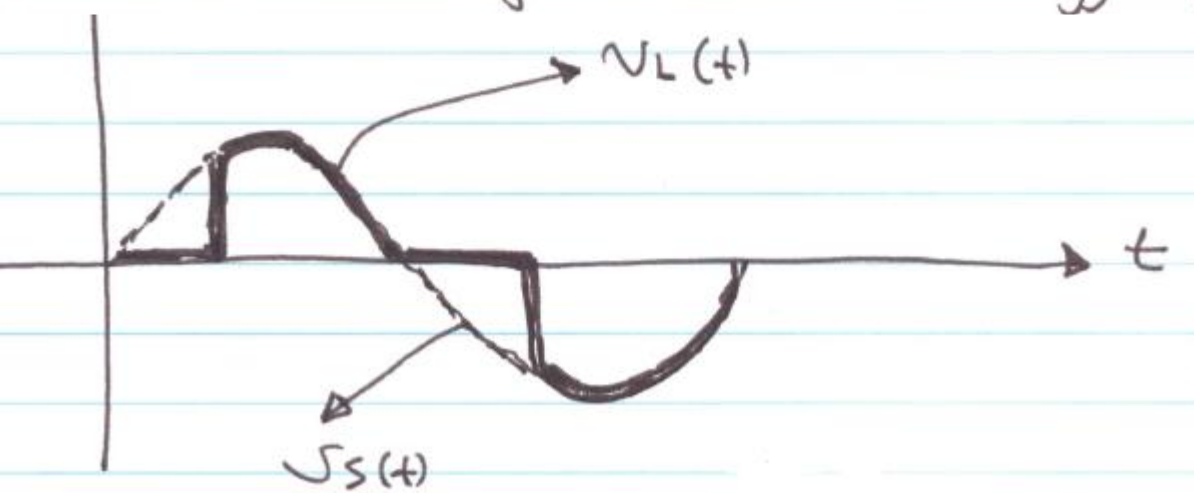
Triac Application



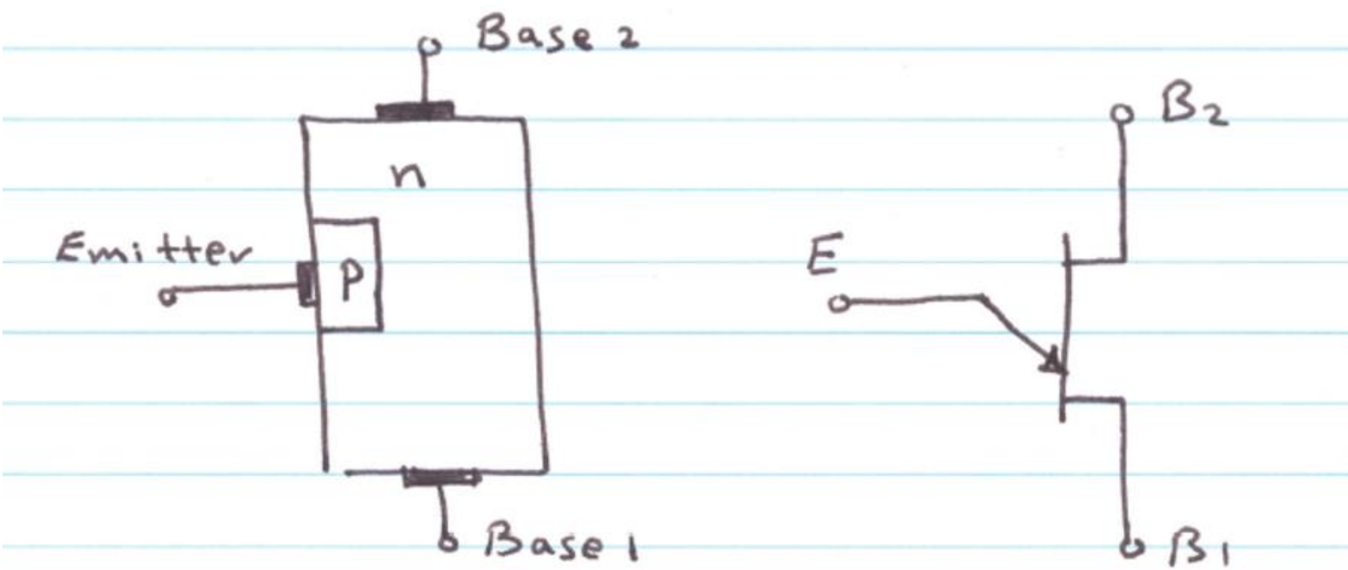
- Diode D_1 Conducts during the positive half-cycle
- The value of R_1 sets the point on the positive half cycle at which the triac triggers

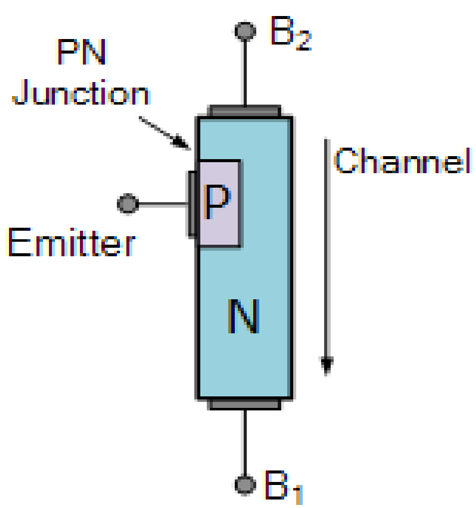


- Diode D_2 Conducts during the negative half cycle
- The value of R_1 sets the trigger point

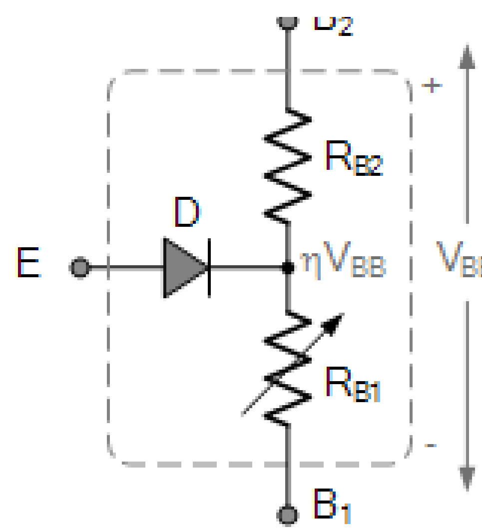


Unijunction Transistor (UJT)





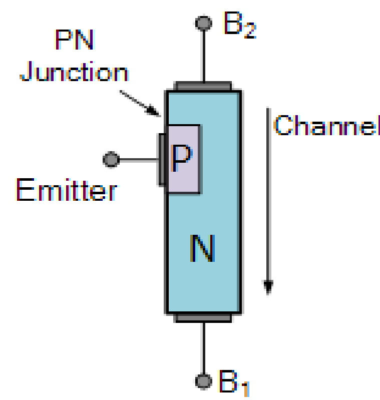
Construction



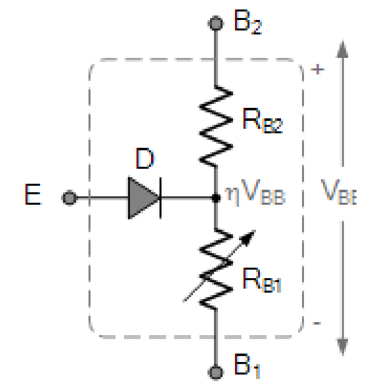
Simplified Equivalent Circuit

Unijunction Transistors

- The **unijunction transistor** (UJT) is a three-terminal semiconductor device that has only one p-n junction.
- The unijunction transistor (UJT) has two base leads, B_1 and B_2 and an emitter (E) lead.
- The interbase resistance, R_{BB} of a UJT is the resistance of its n-type silicon bar.
- The ratio $R_{B1}/(R_{B1} + R_{B2})$ is called the intrinsic standoff ratio, designated η.



Construction



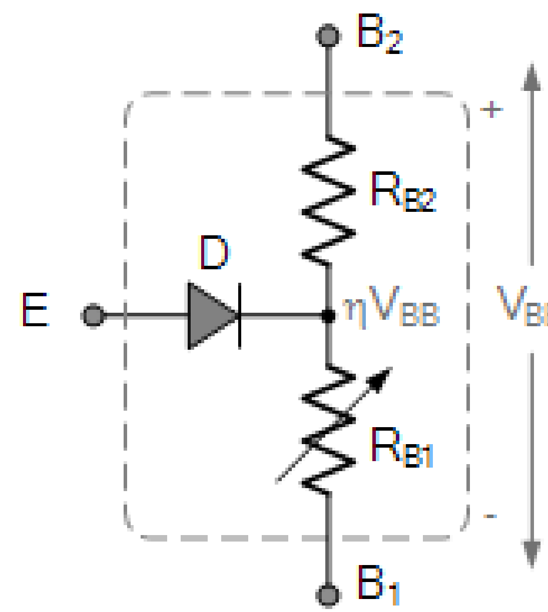
Simplified
Equivalent Circuit

Unijunction Transistor (UJT)

- For a Unijunction transistor, the resistive ratio of R_{B1} to R_{BB} is called the **intrinsic stand-off ratio (**η).

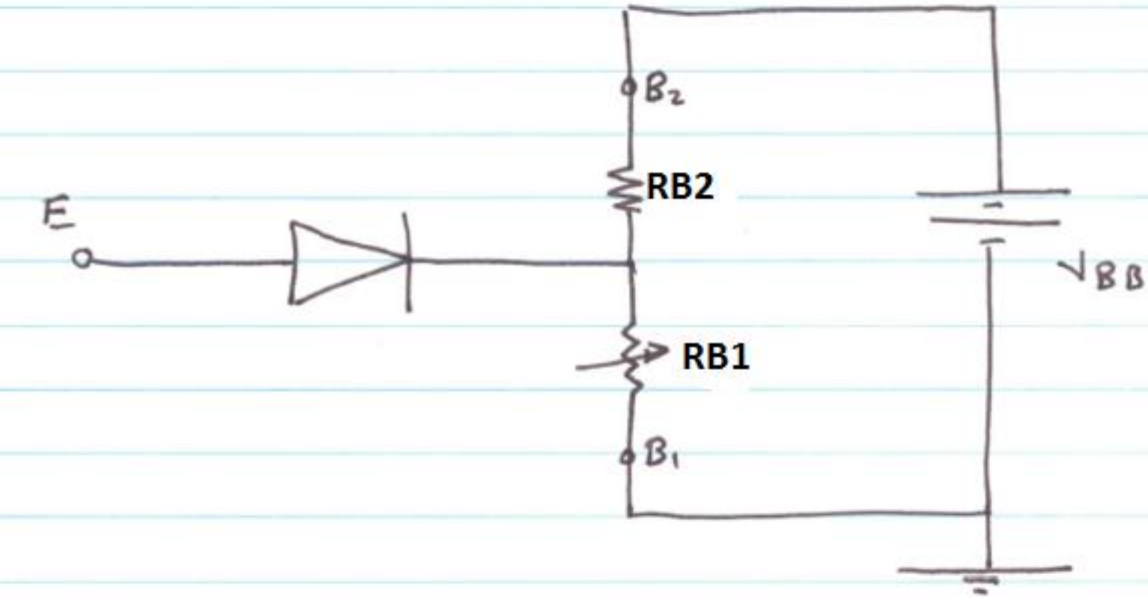
$$\eta = \frac{R_{B1}}{R_{B1} + R_{B2}}$$

- **Typical standard values of η range from 0.5 to 0.8 for most common UJT's.**



Simplified Equivalent Circuit

UJTs are used in conjunction with SCRs and Triacs to control their conduction angle



To fire the UJT

$$V_{EB_1} \geq V_D + \frac{RB1}{RB1+RB2} V_{BB} = V_P$$

$$V_{EB_1} \geq V_D + \frac{RB1}{RBB} V_{BB} = V_P$$

$$V_{EB_1} \geqslant V_D + \eta V_{BB} = V_P$$

$$\eta = \frac{RB1}{RBB} \equiv \text{standoff ratio}$$

$V_P \equiv$ peak point voltage

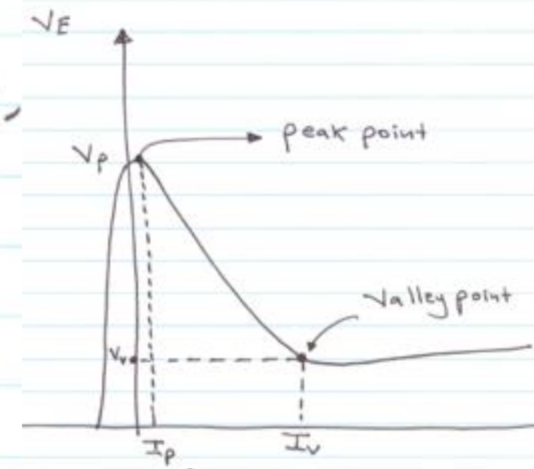
As long as the applied emitter voltage V_{EB_1} is less than V_P; there is no emitter current because the pn junction is not forward biased

- When V_{EB_1} reaches V_P, the pn junction becomes forward biased and I_E begins.
- Holes are injected into the n-type bar from the p-type emitter

r_{B1} decreases

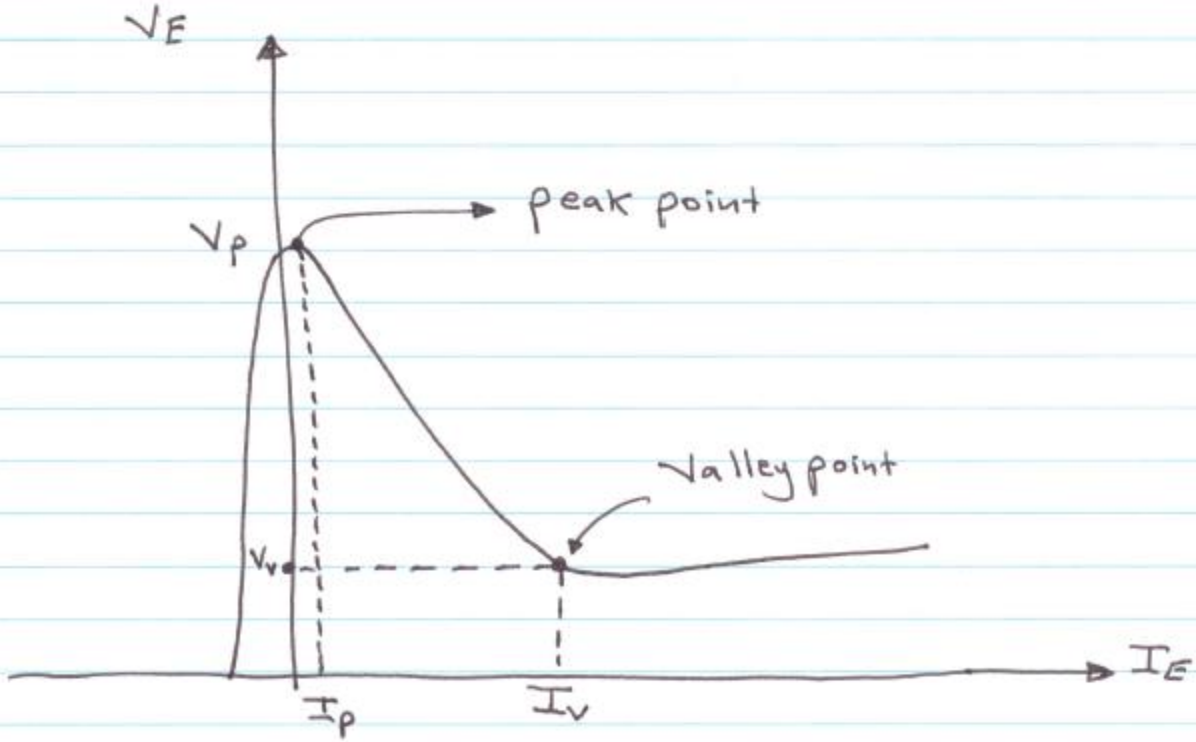
After turn on, the UJT operates in a negative resistance region up to a certain value of I_E.

After the peak point ($V_E = V_p$ and $I_E = I_p$) V_E decreases as I_E continues to increase, thus producing the negative resistance characteristic.



Beyond the valley point ($V_E = V_v$ and $I_E = I_v$), the device is in saturation

UJT Characteristic Curve

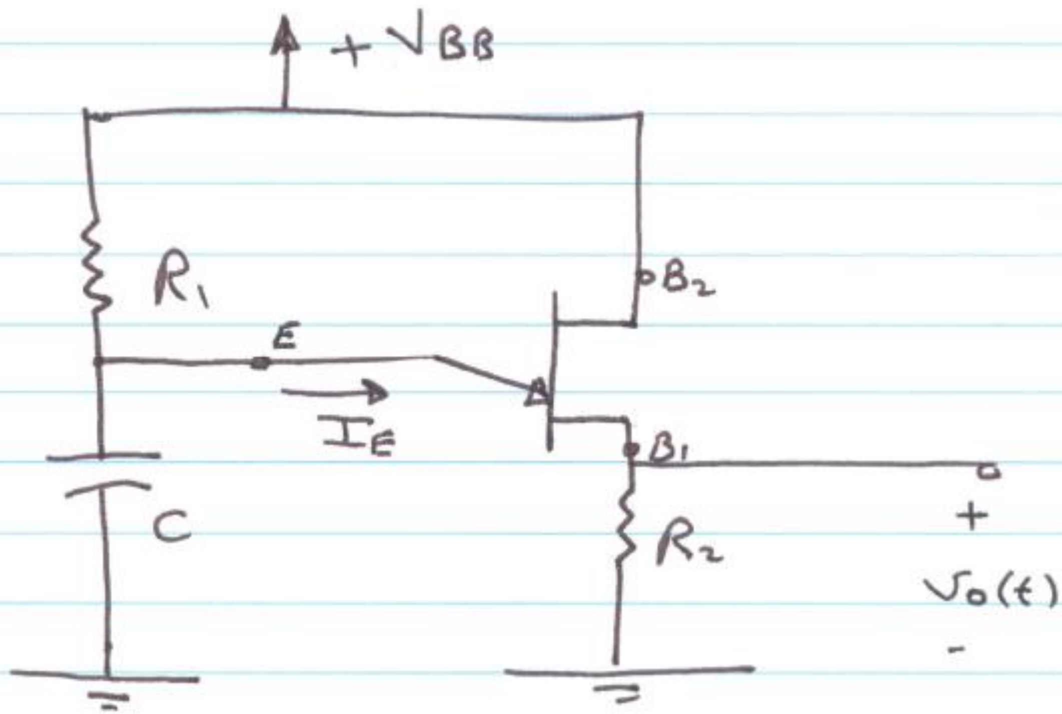


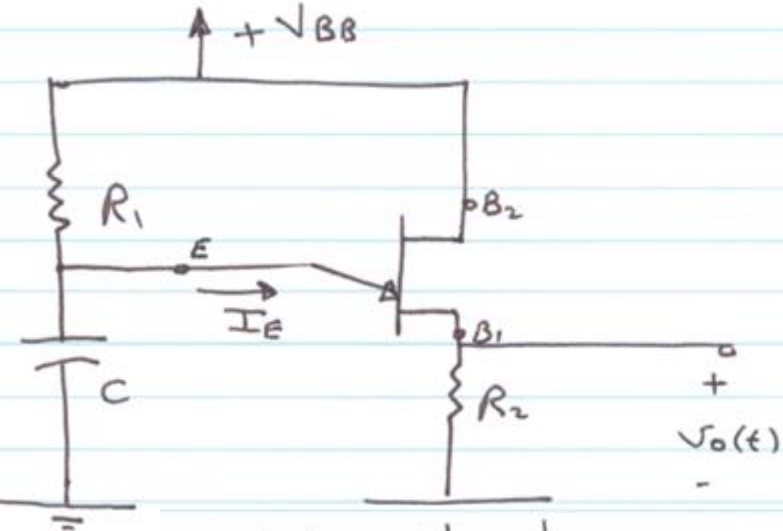
$V_V \equiv$ Valley Voltage

$I_V \equiv$ Valley Current

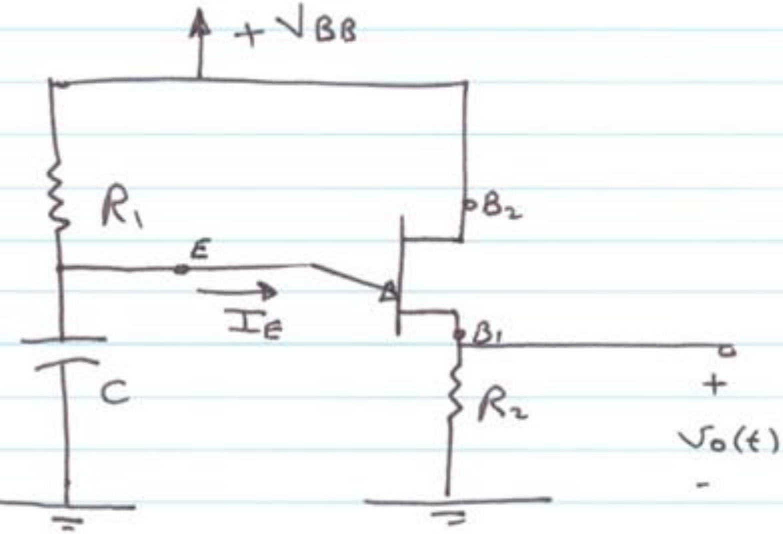
A UJT Application

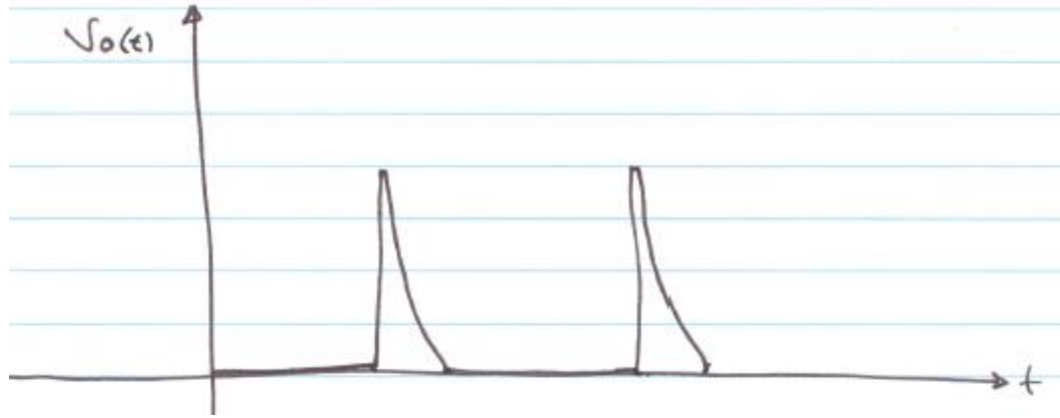
Relaxation Oscillator



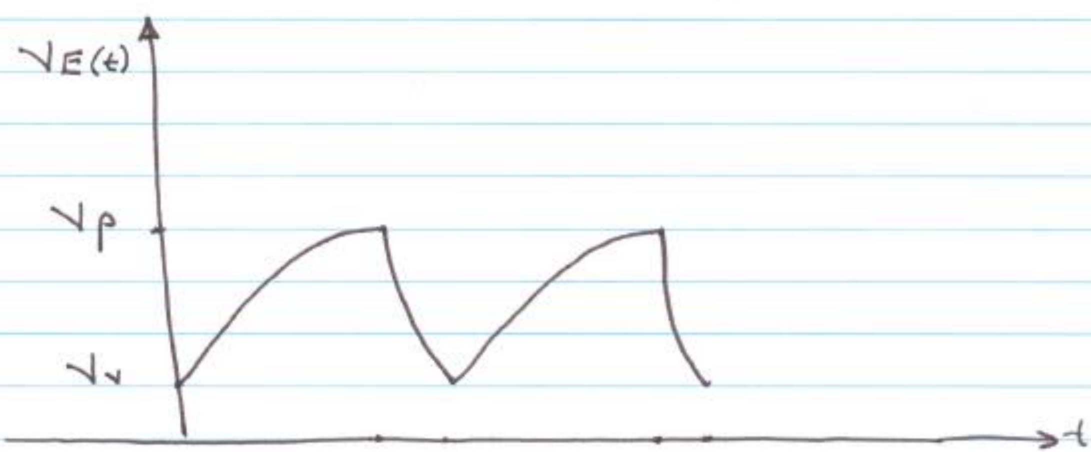


- When the dc power supply is applied, the Capacitor C charges through R_1 until it reaches V_P
- At this point, the pn junction becomes forward biased and I_E Conducts. and r_{B_1} decreases
- The Capacitor then quickly discharge through R_2 and r_{B_1}
- When the Capacitor voltage decreases to the Valley voltage, the UJT turns OFF





- The capacitor begins to charge again and the cycle is repeated.



UJT Relaxation Oscillator