Lecture Notes for SCR and UJT

(Electronics : PHYS4008)

Dr. Pawan Kumar
Assistant Professor
Department of Physics
Mahatma Gandhi central university
Motihari-845401,Bihar

Contents

1. SILICON-CONTROLLED RECTIFIER (SCR)

- It is one of the prominent members of the thyristors family. It was introduced in 1956 by Bell Telephone Laboratories

- It is a three terminal four layer or PNPN device. Basically, **it is a rectifier with a control element.**

- it consists of ***three diodes*** connected back-to-back with a gate connection.

- It is widely used as a switching device in power control applications. It can control loads by switching current OFF and ON up to many thousand times a second.

- It can **switch ON** for variable lengths of time, thereby delivering selected amount of power to the load. Hence, it possesses the advantages of a rheostat and a switch

1.1 Basic symbol and construction of SCR

- The graphic symbol for the SCR is shown in Fig 1 with the corresponding connections to the four-layer semiconductor structure.

- In Fig 2 , if forward conduction is to be established, the anode must be positive with respect to the cathode. This is not, however, a sufficient criterion for turning the device on. A pulse of sufficient magnitude must also be applied to the gate to establish a turn-on gate current, represented symbolically by I_{GT}.

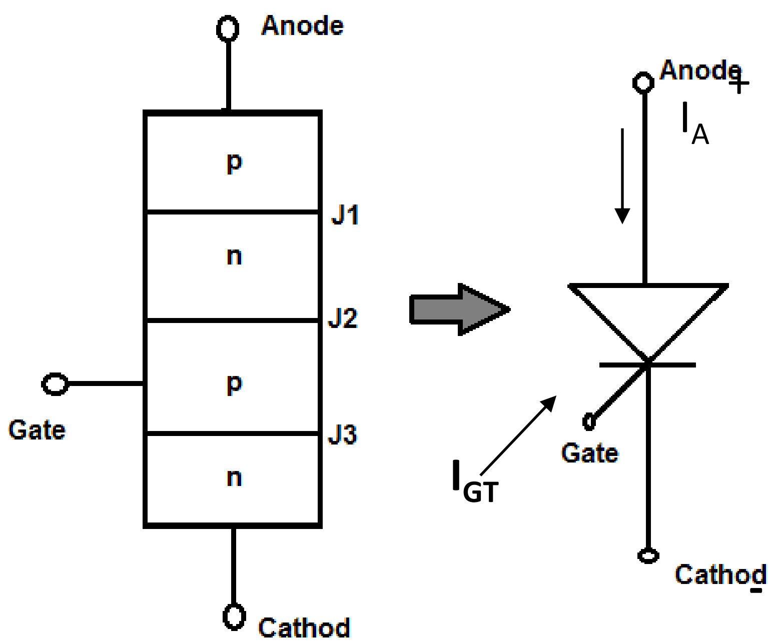
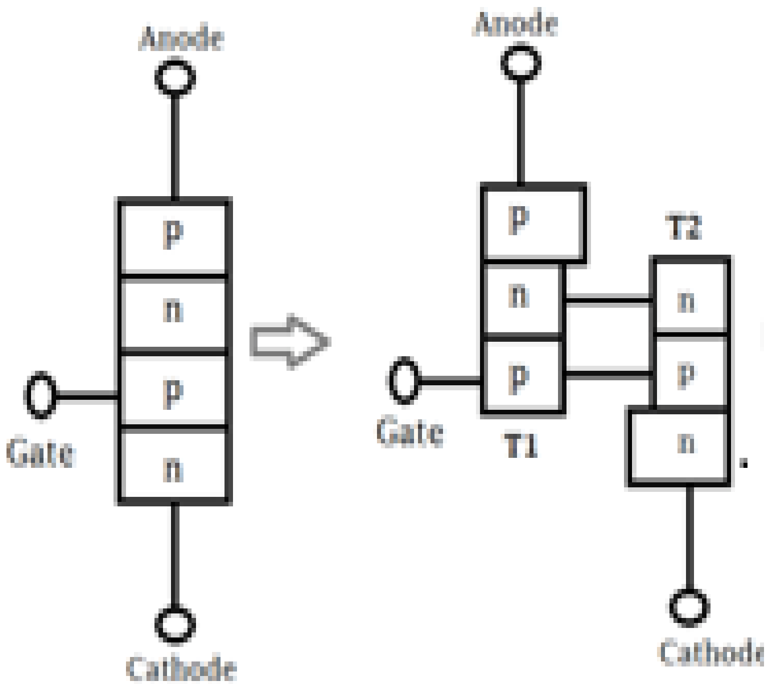


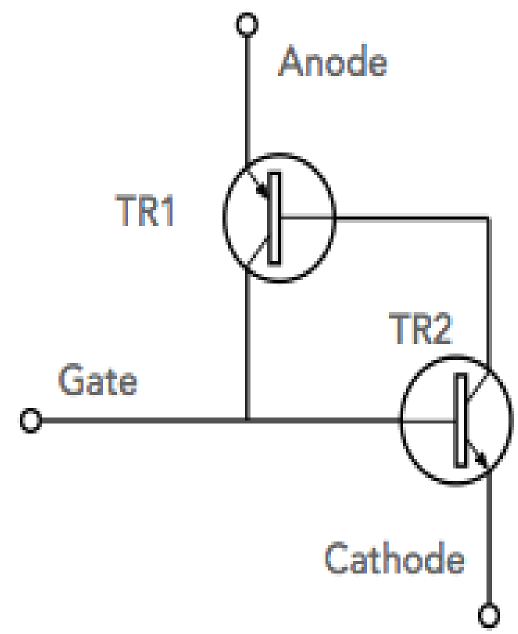
Figure-1

Figure-2

1.1 SCR two state equivalent circuit

- A more detailed examination of the basic operation of an SCR is best effected by splitting the four-layer pnpn structure of Fig1. into two three-layer transistor structures as shown in Fig 2.and then considering the resultant circuit.



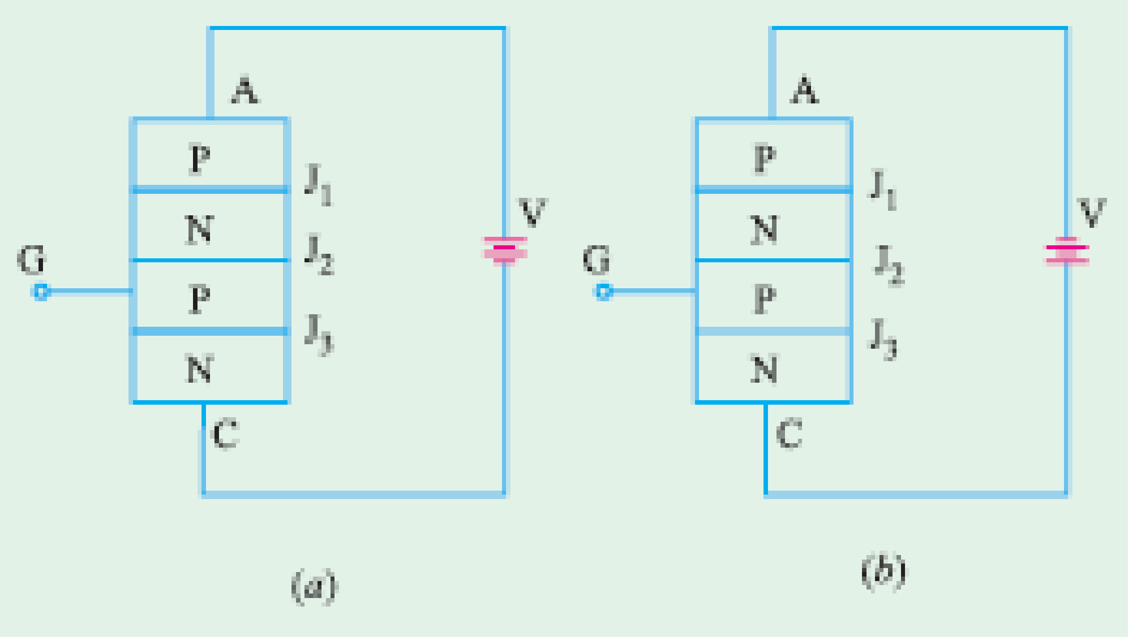


1.2 Biasing

- With the polarity of *V* as shown in Fig.(*a*), the junctions *J*1 and *J*3 become forward biased whereas *J*2 is reverse- biased.

- Hence, no current (except leakage current) can flow through the SCR.

- In Fig. (*b*), polarity of V has been reversed. It is seen that, now, junctions *J*1 and *J*3 become reverse-biased and only *J*2 is forward-biased. Again, there is no flow of current through the SCR.



1.2 Operation

- In above Fig. current flow is blocked due to reverse-biased junction *J*2. However, when anode voltage is increased, a certain critical value called **forward break over voltage (VBO)** is reached, when *J*2 breaks down and SCR switches suddenly to a highly conducting state

- Under this condition, SCR offers very little forward resistance (0.01 Ω –1.0 Ω) so that voltage across it drops to a low value (about 1 V) as shown in Fig. and current is limited only by the power supply and the load resistance. Current keeps flowing indefinitely until the circuit is opened briefly.

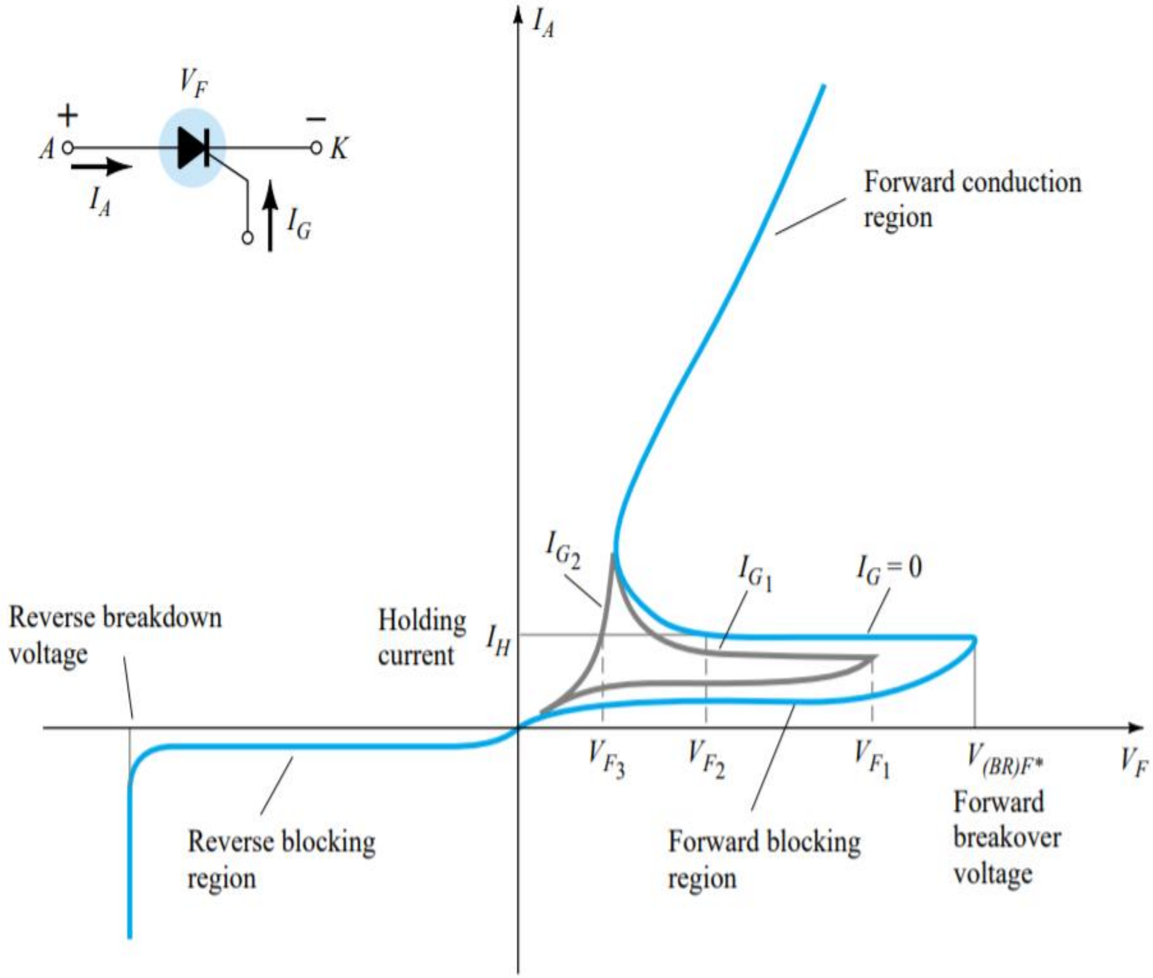
- With supply connection as in Fig.(*b*), the current through the SCR is blocked by the two reverse biased junctions *J*1 and *J*3. When *V* is increased, a stage comes when Zener breakdown occurs which may destroy the SCR .

- Hence, it is seen that SCR is unidirectional device.

1.2 SCR I-V Characteristics

- The characteristics of an SCR are provided in Fig. for various values of gate current. The currents and voltages of usual interest are indicated on the characteristic.

- A brief description of each follows



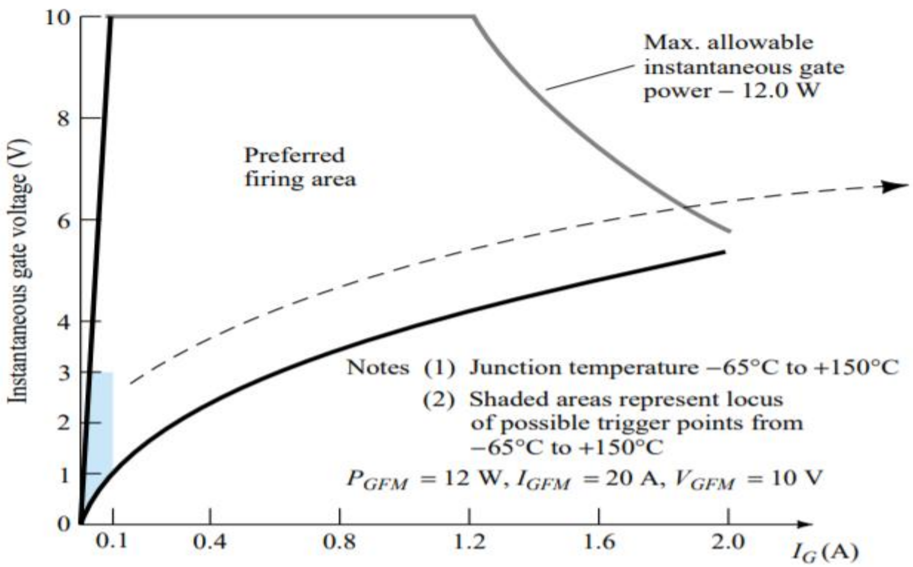
I. **Forward breakover voltage mode** $V_{(BR)\ F*}$: is that voltage above which the SCR enters the conduction region.

II. **Holding current (IH**): is that value of current below which the SCR switches from the conduction state to the forward blocking region under stated conditions.

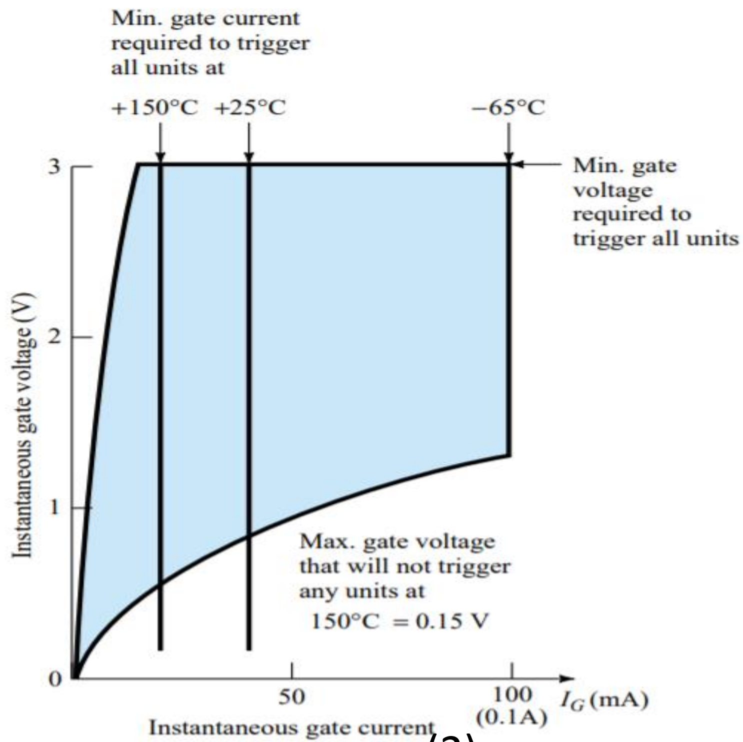
III. **Forward and reverse blocking regions** are the regions corresponding to the open circuit condition for the controlled rectifier which block the flow of charge (current) from anode to cathode.

IV. **Reverse breakdown voltage** is equivalent to the Zener or avalanche region of the fundamental two-layer semiconductor diode.

1.3 Gate characteristics



(1)



(2)

The characteristics of Fig1. are an expanded version of the shaded region of Fig. 2.

- In Fig.1, the three gate ratings of greatest interest, PGFM, IGFM, and VGFM are indicated. Each is included on the characteristics in the same manner employed for the transistor. Except for portions of the shaded region, any combination of gate current and voltage that falls within this region will fire any SCR in the series of components for which these characteristics are provided. Temperature will determine which sections of the shaded region must be avoided..

1.3 Application

- Main application of an SCR is as a ***power control device*.**

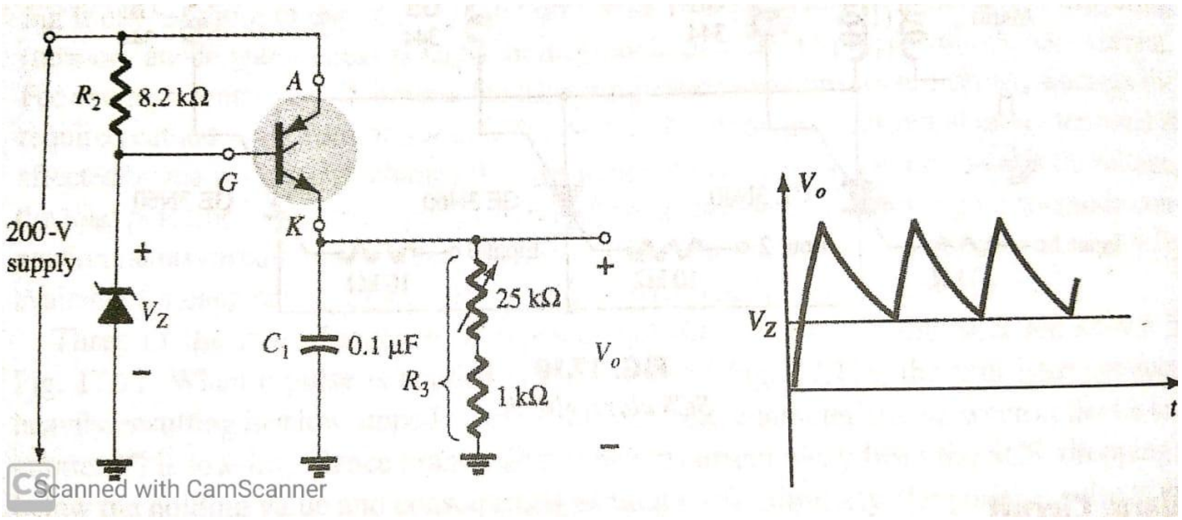
- Consequently, it never dissipates any appreciable amount of power even when controlling substantial amounts of load power. For example, one SCR requires only 150 mA to control a load current of 2500 A.

- Other common areas of its application include.

I. regulated power supplies,
II. static switches,
III. motor controls,
IV. inverters,
V. relay controls,
VI. battery chargers,
VII. heater controls,
VIII. phase control.
IX. Half and Full wave rectifier
X. Sawtooth wave generator

1.4 Sawtooth Wave Generator

- Figure illustrate the simple sawtooth generator employing a gate turn-off switch(GTO) and Zener diode.
- When the supply is energized the GTO will turn on, resulting in the short circuit equivalent from anode to cathode.
- The capacitor will then begin to charge toward the supply voltage, the capacitor c1 charges the Zener potential, a revisal in gate to cathode voltage will result, establishing reversal in gate current.
- Eventual the negative gate current will large enough to turn the GTO off
- The proper choice of resistance R3 and c1 will result a sawtooth waveform. Once the output voltage v0 drops below vz the GTO will turn ON and the process will repeat.

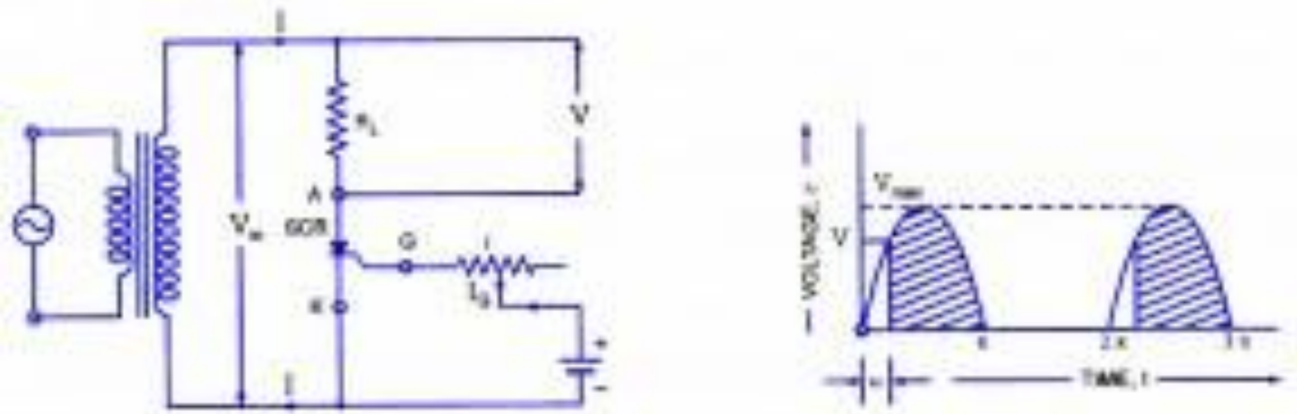


1.5 SCR as Half Wave Rectifier

- SCRs are very useful as **rectifiers** whose output current can be controlled by controlling the gate current.

- The ac supply to be rectified is applied to the primary of the transformer ensuring that the negative voltage appearing at the secondary of the transformer is less than reverse breakdown voltage of the SCR.

- The load resistance R_L is connected in series with anode. A variable resistance r is inserted in the gate circuit for control of gate current.



Circuit Diagram　　Output Waveform

SCR As Half-Wave Rectifier

- The worth noting point is that in an ordinary half-wave rectifier using a P-N diode, conduction current flows during the whole of the positive cycle whereas in SCR half-wave rectifier the current can be made to flow during the part or full of the positive half cycle by adjustment of gate current. Hence SCR operates as a controlled rectifier and hence the name silicon controlled rectifier.

- The output voltage from the SCR rectifier is not a purely dc voltage but also consists of some ac components, called the ripples, along it. The ripple components are undesirable and need to be removed or filtered out. This is accomplished by placing a filter circuit between the rectifier and load, as shown in figures.

- During the negative half cycles of ac voltage appearing across the secondary, the SCR does not conduct regardless of the gate voltage, because anode is negative with respect to cathode and also peak inverse voltage is less than the reverse breakdown voltage. The SCR will conduct during the positive half cycles provided appropriate gate current is made to flow. The gate current can be varied with the help of variable resistance *r* inserted in the gate circuit for this purpose. The greater the gate current, the lesser will be the supply voltage at which SCR will start conducting.

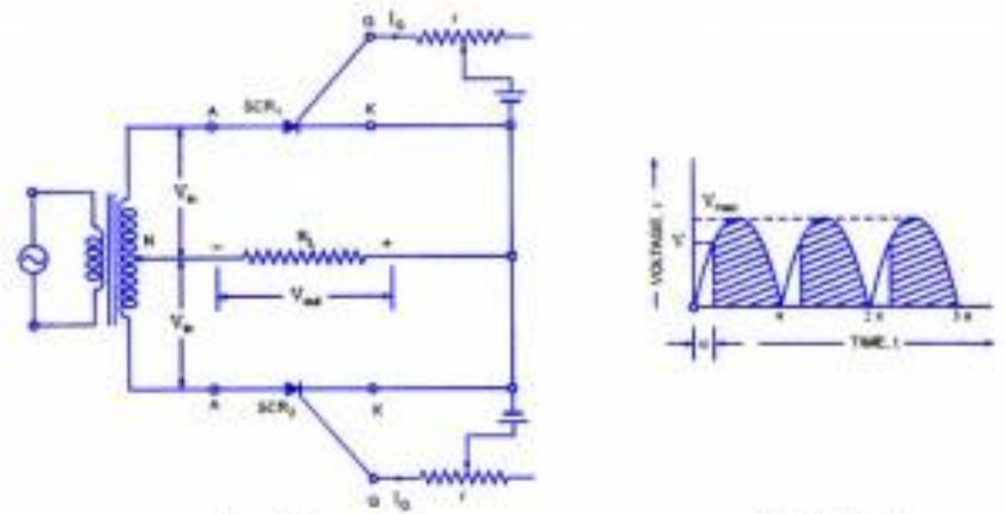
- Assume that gate current is such that SCR starts conducting at a positive voltage V, being less than peak value of ac voltage, V_{max}. From fig.b, it is clear that SCR will start conducting, as soon as the secondary ac voltage becomes V in the positive half cycle, and will continue conducting till ac voltage becomes zero when it will turn-off. Again in next positive half cycle, SCR will start conducting when ac secondary voltage becomes V volts.

1.5 SCR as full Wave Rectifier

- Two SCRs are connected across the center taped secondary, as shown in figure.

- The gates of both SCRs are supplied from two gate control supply circuits. One SCR conducts during the positive half cycle and the other during the negative half cycle and thus unidirectional current flows in the load circuit.

- The main advantage of this circuit over ordinary full-wave rectifier circuit is that the output voltage can be controlled by adjusting the gate current.



Circuit Diagram

Output Waveform

Full-Wave Rectifier Circuit Using Two SCRs

2. UNIJUNUCTION TRANSISTOR(UJT)

- It is a three-terminal silicon diode. As its name indicates, it has only one *P-N* junction .

- It differs from an ordinary diode in that it has three leads and it differs from a FET in that it has no ability to amplify.

- However, it has the ability to control a large ac power with a small signal. It is a three-terminal silicon diode. As its name indicates, it has only one *P-N* junction.

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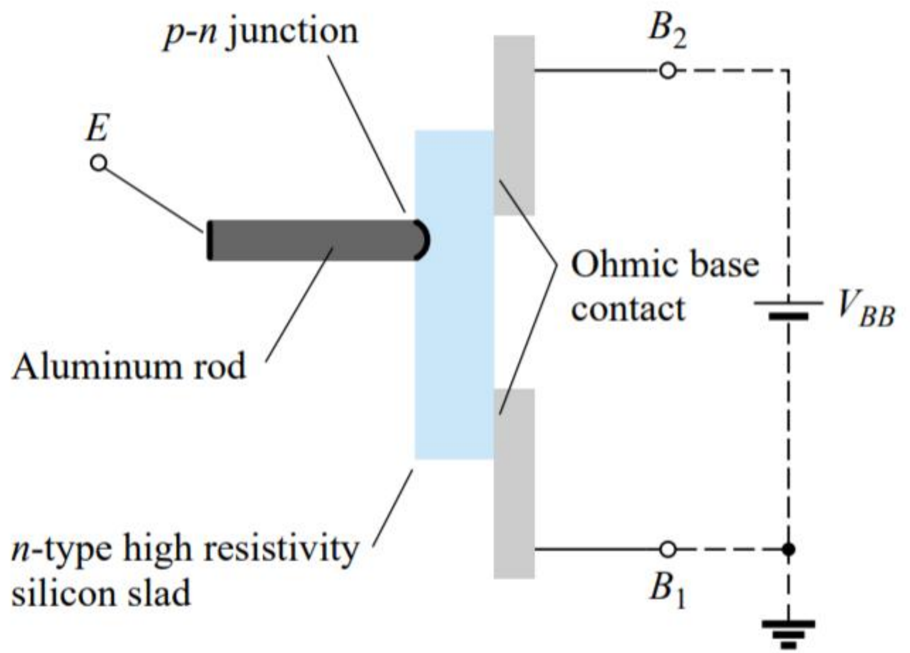
2.1 Construction

- A slab of lightly doped (increased resistance characteristic) n-type silicon material has two base contacts attached to both ends of one surface and an aluminum rod alloyed to the opposite surface.

- The p-n junction of the device is formed at the boundary of the aluminum rod and the n-type silicon slab. The single p-n junction accounts for the terminology unijunction. It was originally called a duo (double) base diode due to the presence of two base

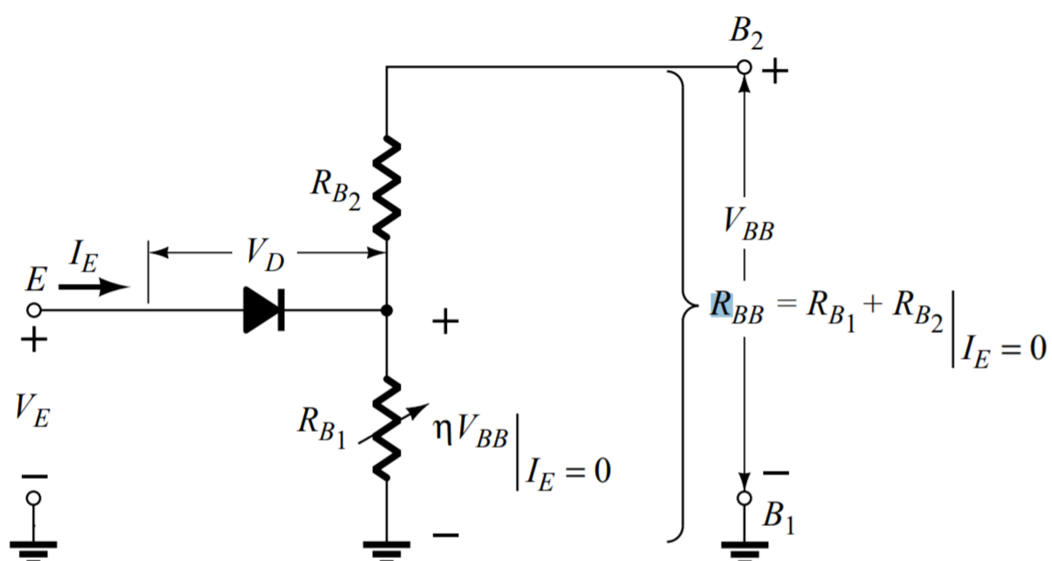


2.2 INTER-BASE RESISTANCE (R_{BB})

- It is the resistance between $B_2$and B_1 *i.e.* it is the total resistance of the silicon bar from one end to the other with emitter terminal open.

- It should also be noted that point
A is such that $R_{B1} > R_{B2}$. Usually, R_{B1} = 60% of $_{RB1}$

- The resistance R_{B1} has been shown as a variable resistor because its value varies
inversely as *i*



2.3 INTRINSIC STAND-OFF RATIO

- As seen from Fig, when a battery of 30 V is applied across $B_2 B_1$, there is a progressive fall of voltage over R_{BB} provided *E* is open.

- It is obvious from Fig. that emitter acts as a voltage-divider tap on fixed resistance*RBB*.

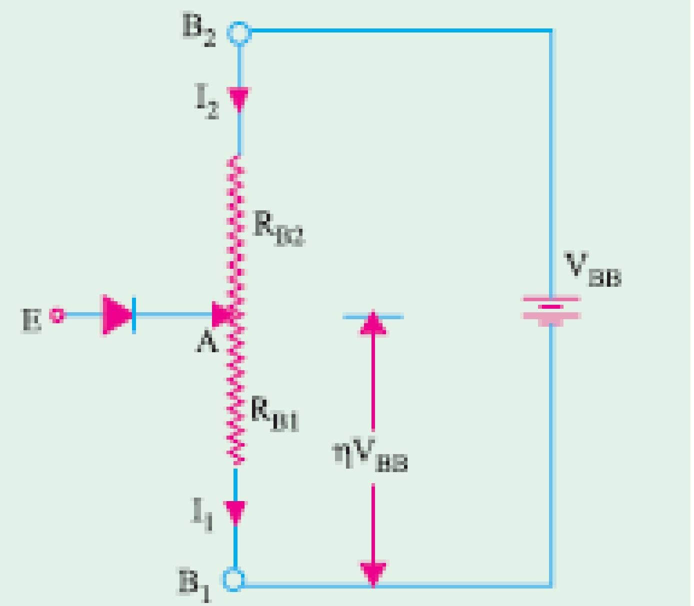
- With emitter open, $I_1 = I_2$, the interbase current is given by Ohm's Law.

$$I_1 = I_2 = V_{BB} / R_{BB}$$

- It may be noted that part of *VBB* is dropped over R_{B2} and part on R_{B1}. Let us call the voltage drop across R_{B1} as V_A.
- Using simple voltage divider relationship, The voltage division factor is given a special symbol (η) and the name of '**intrinsic standoff ratio**'

$$V_{R_{B_1}} = \frac{R_{B_1}}{R_{B_1} + R_{B_2}} \cdot V_{BB} = \eta V_{BB} \bigg|_{I_E=0}$$

$$\eta = \frac{R_{B_1}}{R_{B_1} + R_{B_2}} \bigg|_{I_E=0} = \frac{R_{B_1}}{R_{BB}}$$

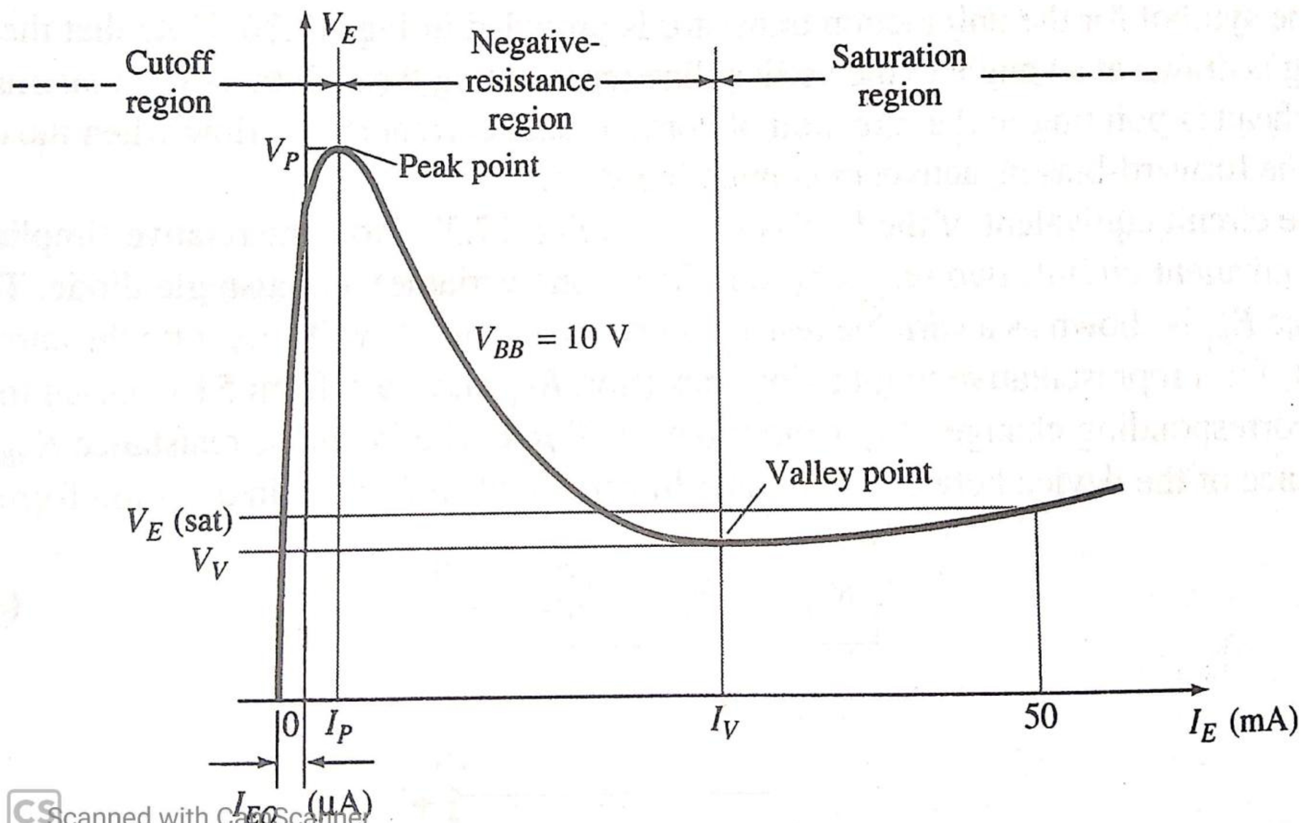


Therefore, $V_{RB1} = \eta V_{BB}$

2.3 UJT Static Emitter Characteristics

- The decrease in resistance in the active region is due to the holes injected into the n-type slab from the aluminum p-type rod when conduction is established.

- The increased hole content in the n-type material will result in an increase in the number of free electrons in the slab, producing an increase in conductivity (G) and a corresponding drop in resistance (R ↓ 1/G ↑). Three other important parameters for the unijunction transistor are IP, VV, and IV. Each is indicated on Fig.



• When *VBB* is switched on, *VA* is developed and ***reverse-biases the junction*.** If V_B is the barrier voltage of the *P-N* junction, then total reverse bias voltage is = V_{RB1} + *VB* = ηV_{BB} + V*B* Value of *VB* for Si is 0.7 V.

• It is obvious that emitter junction will not become forward-biased unless its applied voltage *V*E exceeds (ηV_{BB}+ *VB*). This value of *VE* is **called peakpoint voltage VP** .

• When *VE* = *VP,* emitter (peak current), *IP* starts to flow through *RB1* to ground (*i.e*. *B1*). The UJT is then said to have been ***fired*** or turned ON. Beyond the valley point, UJT is in
saturation and *V*E increases very little with an increasing *IE*.

• It is seen that only terminals *E* and *B*1 are the active terminals whereas *B*2 is the bias terminal *i.e*. it is meant only for applying external voltage across the UJT.

• Generally, UJT is triggered into conduction by applying a suitable positive pulse at its emitter.

• It can be brought back to OFF state by applying a negative trigger pulse.

2.3 APPLICATIONS

- One unique property of UJT is that it can be triggered by (or an output can be taken from) *any one of its three terminals*.

- Once triggered, the emitter current *IE* of the UJT increases regeneratively till it reaches a limiting value determined by the external power supply. Because of this particular behavior , UJT is used in a variety of circuit applications.

- Some of which are :

i. phase control
ii. sine wave generator
iii. switching
iv. Pulse generator
v. sawtooth generator
vi. timing and triggercircuits,
vii.voltage or current regulated supplies

References

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