POSTAL Book Package 2021

Electronics Engineering

Conventional Practice Sets

Electronic Devices and Circuits

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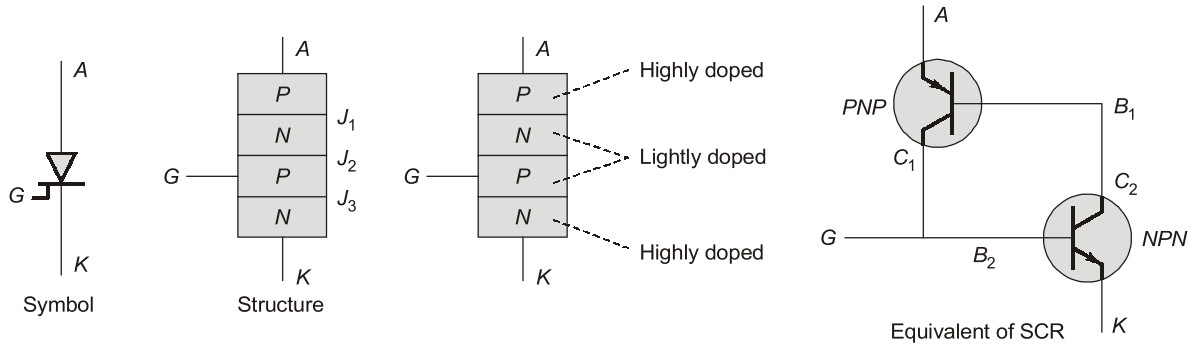
5 CHAPTER
Power Switching Devices and Circuits

Practice Questions : Level-I

Q.1 What are SCRs? Draw the symbol and its *V-I* characteristics. Explain its operation.

Solution:

- SCR is a thyristor family member.
- SCR is a 4 layer solid state device with 3 terminals (*A*, *K* and *G*) and having 3 junctions.
- Unidirectional device.



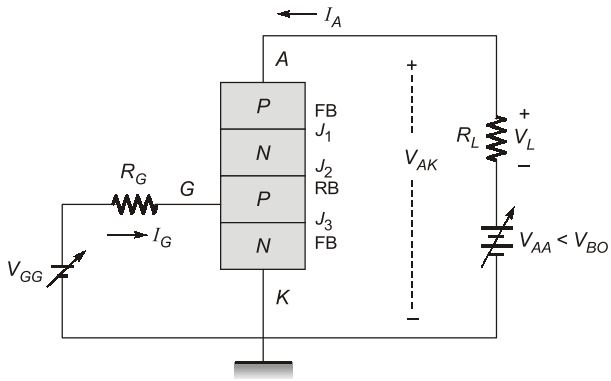
- In SCR internal regions are relatively lightly doped when compared to outermost layer.
- The equivalent circuit of SCR can be represented by one PNP transistor and one NPN transistor connected back to back.
- SCR is a latch.
- Bi-stable device i.e. having stable ON and OFF states.
- SCR can handle large amount of power with a very small amount of power consumption.
- If anode is given a negative voltage with respect to Cathode, then SCR will never conduct.

Current operation of SCR:

Also called Gate operation of SCR

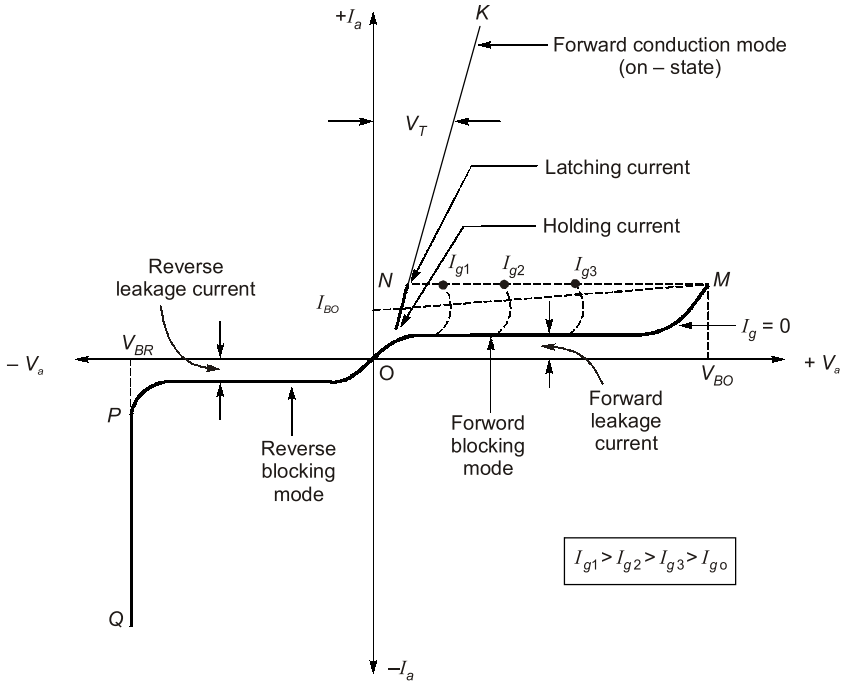
If I_G is kept zero and let $V_{AA} < V_{BO}$

- Junctions J_1 and J_3 are FB and J_2 is RB.
- Internal resistance of SCR is very large ($\geq 1\ M\Omega$).
- The function of Gate is trigger the SCR by sending a proper I_G.
- Once SCR is triggered by sending proper I_G, the SCR will be loosing total control on I_A and SCR will continue to remain is ON STATE.
- Once SCR is ON, it will not respond to the Gate.
- SCR can be switched OFF by using any one of the following methods:
  - (i) Disconnect V_{AA}.
  - (ii) Give anode Anode a negative voltage with respect to cathode.
  - (iii) Reduce V_{AA} so that I_A reduces and falls below certain value of current I_H (Holding current) and SCR will go to OFF.



- The firing voltage of SCR $\propto \frac{1}{I_G}$ i.e. by applying larger values of I_G we can trigger the SCR.

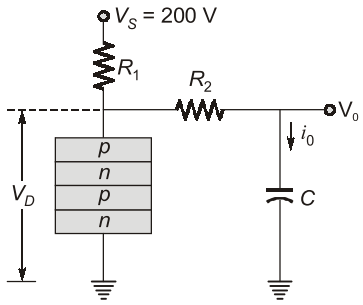
VI characteristic of SCR is given below:



Q.2 Use the device to design a simple circuit to generate a continuous sawtooth wave of amplitude 100 volts, and repetitive frequency of 500 Hz. The following data is available regarding the four layer diode: V_{BO} = 100 V, I_A = 20 A, I_H = 20 mA.

Solution:

The circuit to generate a continuous sawtooth wave using a four layer *p-n-p-n* diode is shown here.



When the diode is OFF, it is effectively open and capacitor *C* charges to 200 V through R_1 & R_2. When $V_D = V_0$ reaches V_{BO} (= 100 V), the diode turns ON and acts like a (say 1 V = V_H) battery. The capacitor now discharges to V_H through R_2. When $i_D = i_0$ reaches the holding current I_H = 20 mA, the diode switches off and *C* begins to charge again also, I_A = 20 A.

When diode is ON:

$$V_0 = V_\infty - (V_\infty - V_1)\, e^{-t/T_{ON}}$$

where V_∞ = 1 V and V_1 = 100 V

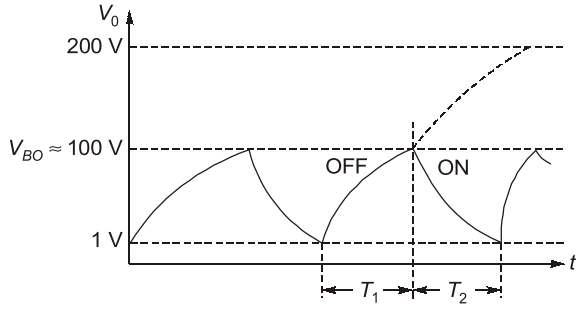
$$\therefore \quad V_0 = 1 + 99\, e^{-t/T_{ON}} \qquad \text{...(i)}$$

where $T_{ON} = R_2 C$

Now, $$i_0 = C\frac{dV_0}{dt}$$

$$\Rightarrow \quad i_0 = \frac{-99}{T_{ON}} e^{-t/T_{ON}}$$

At $t = T_2$, $i_0 = -20 \times 10^{-3}$ A (Given)



When diode is OFF:

$$V_0 = V_\infty - (V_\infty - V_1)\, e^{-t/T_{OFF}}$$

where $V_\infty = 200$ V and $V_1 = 1.1$ V

$$T_{OFF} = (R_1 + R_2)C \approx RC$$

At $t = T_1$, $V_0 = 100$ V

$\because$ Repetitive frequency $= f = \dfrac{1}{T_1 + T_2} = 500$ Hz

After solving all the above equations we get,
$R_1 = 1\ \text{M}\Omega$, $R_2 = 100\ \Omega$ and $C = 5\ \mu\text{F}$.

Q3 For an SCR, the gate cathode characteristic has a straight-line slope of 130. For trigger source voltage of 15 volt and allowable gate power dissipation of 0.5 watts. Determine the Gate-source resistance?

Solution:

Here given that, Power $= V_g I_g = 0.5$ Watt ...(i)

and $\dfrac{V_g}{I_g} = 130$ ...(ii)

So, $130\, I_g^2 = 0.5$ [From equation (i) and (ii)]

or $I_g^2 = \dfrac{0.5}{130}$

or $I_g = \sqrt{3.846 \times 10^{-3}} = 0.062$ A

$\therefore$ $I_g = 62$ mA

So, gate voltage $= V_g = 130\, I_g$

$\Rightarrow$ $V_g = 8.06$ volt

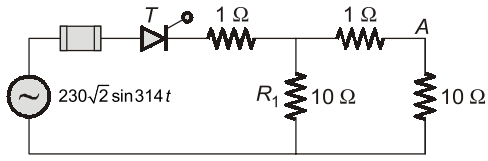
In the SCR, for the Gate circuit we have,

$$E_s = I_g R_s + V_g = 0.062 \times R_s + 8.06$$

or $\dfrac{15 - 8.06}{0.062} = R_s$

$\therefore$ Gate-source resistance $(R_s) = 111.94\ \Omega$

Q4 Thyristor shown in the figure has I^2t rating of 20 A^2 sec. If terminal 'A' get short circuited to the ground. Calculate the fault clearance time so that SCR is not damaged.



Solution:

The worst possible fault current should be considered for calculating the fault clearance time. Maximum fault current occurs when source voltage is at its peak value = $230\sqrt{2}$ volt, when terminal 'A' gets shorted circuited to the ground, the resistance offered to source is equal to,

$$\frac{10 \times 1}{11} + (1) = \frac{21}{11}\ \Omega$$

Assuming maximum fault current = $\dfrac{230\sqrt{2} \times 11}{21}$ A, which is to remain constant during the short clearance time (t_c) we get,

$$\int_0^{t_c} i^2\,dt = \int_0^{t_c}\left(\frac{230\sqrt{2}\times 11}{21}\right)^2 \cdot dt = 20\ \text{A}^2$$

or $$t_c = 20\left[\frac{21}{230\sqrt{2}\times 11}\right]^2 \times 1000\ \text{ms}$$

$\Rightarrow$ $$t_c = 0.6892\ \text{m-sec}$$

Practice Questions : Level-II

Q.5 For an SCR, gate-cathode characteristic is given by the equation,

$$V_g = 1 + 10\,I_g$$

The Gate source voltage is a rectangular pulse of 15 V with 20 μ-sec duration. For an average gate power dissipation of 0.3 Watt and a peak gate-drive power of 5 Watt.

Calculate:

(a) the resistance to be connected in series with the SCR gate.

(b) the triggering frequency.

(c) the duty cycle of the triggering pulse.

Solution:

(a) For an SCR, we have given,

$$V_g = 1 + 10\,I_g \qquad \text{...(i)}$$

For pulse-triggering of SCRs during pulse-on period, we have

(peak-gate voltage) × (peak-gate current) = peak-gate drive power i.e. P_{gm} ...(ii)

As the gate rectangular pulse width is 20 μ-sec (i.e. less than 100 μ-sec), so there is no any dc data will be applicable. Had the gate pulse width been more than 100 μ-sec, the relation given,

$$V_g = 1 + 10\,I_g$$

$$V_g \times I_g = (1 + 10\,I_g)\,I_g$$

$\Rightarrow$ $10\,I_g^2 + I_g = 0.3$ Watt, will holds good but as the dc data not applied here, we should note that:

$$(1 + 10\,I_g)\times I_g = 5$$

$\Rightarrow$ $$10\,I_g^2 + I_g - 5 = 0 \qquad \text{...(iii)}$$

$\therefore$ $$I_g = 0.659\ \text{A or } -0.759\ \text{A}$$

So, we get the value of $I_g = 0.659$ A

Hence, amplitude of the current pulse = 0.659 A

Now, during the pulse-ON period,

$$E_s = I_g + I_g{\cdot}R_s$$

$$= I_g R_s + (10\,I_g + 1) \qquad \text{[From equation (i)]}$$

$\Rightarrow$ $$R_s = \frac{E_s - V_g}{I_g} = \frac{15 - 1 - (10\times 0.659)}{0.659}$$

$\therefore$ $$R_s = 11.24\ \Omega$$

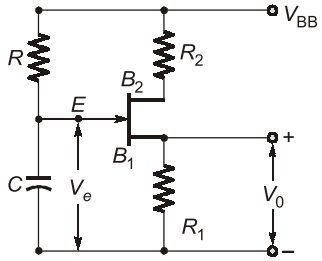
(b) Since, $$P_{gm} = \frac{P_{gaV}}{fT} \qquad \text{[Here, } T = 20\ \mu\text{-sec]}$$

and Triggering frequency $(f) = \frac{P_{gaV}}{T \times P_{gm}}$

$\Rightarrow$ $$f = \frac{0.3\times 10^6}{20\times 5} = 3\ \text{kHz}$$

(c) $$\text{Duty cycle} = d = fT = 3\times 10^3 \times 20 \times 10^{-6} = 0.06$$

Q.6 A relaxation oscillator using an UJT as shown in figure below, is to be designing for triggering of an SCR. The data of an UJT is
$\eta = 0.72$, $I_P = 0.6$ mA, $V_P = 18$ V, $V_v = 1$ V, $I_v = 2.5$ mA, $R_{BB} = 5$ kΩ, normal leakage current with emitter open = 4.2 mA, firing frequency is 2 kHz. Then for $C = 0.04$ μF, determine the value of R, R_1 and R_2.



Solution:

In an UJT, the time required (T) for a capacitor (C) to charge from initial voltage 'V_v' to peak point voltage 'V_p' through a large resistor 'R' can be obtained as:

$$T = \frac{1}{f} = RC\,In\left(\frac{1}{1-\eta}\right) \qquad \text{...(i)}$$

$$\Rightarrow \quad R = \frac{1}{fC\,In\left(\frac{1}{1-\eta}\right)} = \frac{10^6}{2000 \times 0.04 \times In(3.57)}$$

$$\therefore \quad R = 9.82\ \text{k}\Omega$$

As, V_D is not given so,

$$V_p = \eta\, V_{BB}$$

$$\Rightarrow \quad V_{BB} = \frac{V_p}{\eta} = \frac{18}{0.72} = 25\ \text{V}$$

we know that, $$R_2 = \frac{10^4}{\eta V_{BB}} = \frac{10^4}{0.72 \times 25} = 555.5\ \Omega$$

As given that, emitter is open,

So, $$V_{BB} = \text{normal leakage current}\ (R_1 + R_2 + R_{BB})$$

$$\Rightarrow \quad R_1 + R_2 + R_{BB} = \frac{25 \times 10^3}{4.2} = 5.95 \times 10^3\ \Omega$$

$$\Rightarrow \quad R_1 = (5952.38 - 5000 - 555.5)\ \Omega$$

$$\therefore \quad R_1 = 397\ \Omega$$

Q.7 What are Opto-isolators? Where do they find application? Discuss their propagation delay, operating voltage range and power dissipation.

Solution:

The opto-isolators which is also called opto-coupler are the device which are optically coupled but electrically isolated that incorporate many characteristics.

⇒ A schematic arrangement of opto-coupler is given below: