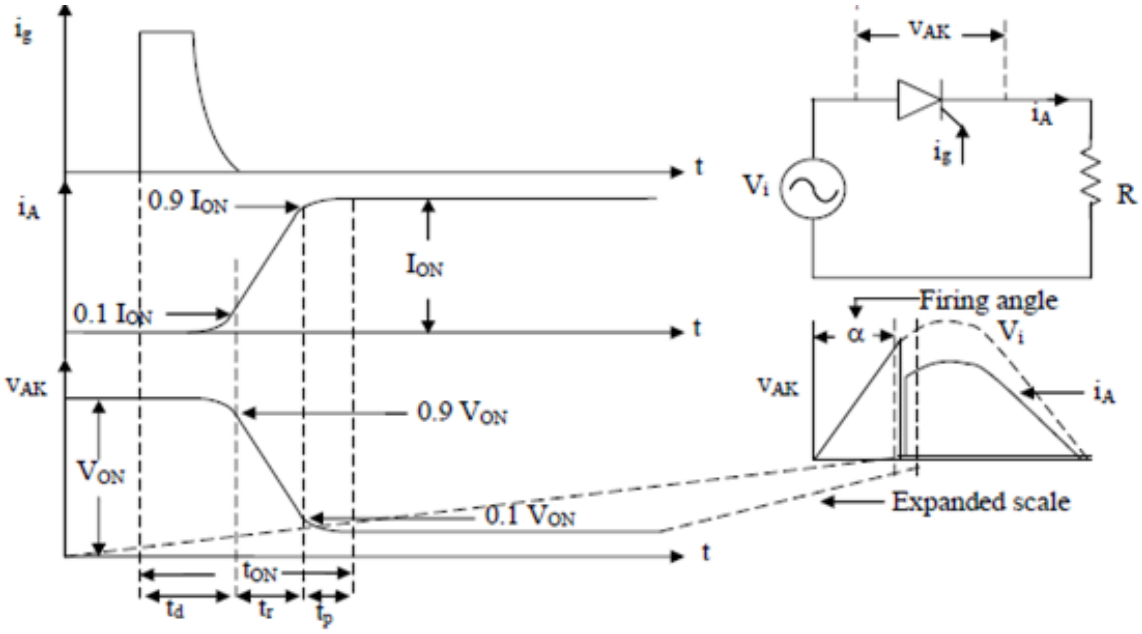
Unit 2: Silicon Controlled Rectifier (SCR)

Module 4: Turn-on and Turn-off time, di/dt and dv/dt ratings, factors affecting characteristics/ratings of SCR

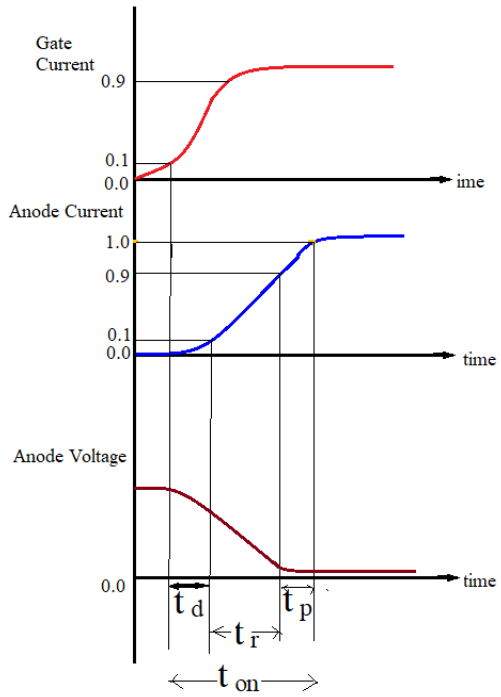
Turn on Switching Characteristics:

A forward biased thyristor is turned on by applying a positive gate voltage between the gate and cathode as shown in figure. Figure below shows the waveforms of the gate current (ig), anode current (iA) and anode cathode voltage (VAK) in an expanded time scale during Turn on. The total switching period being much smaller compared to the cycle time, iA and VAK before and after switching will appear flat. As shown in Figure there is a transition time "tON" from forward off state to forward on state. This transition time is called the thyristor turn of time and can be divided into three separate intervals namely, (i) delay time (td) (ii) rise time (tr) and (iii) spread time (tp).



Delay time (td): After switching on the gate current the thyristor will start to conduct over the portion of the cathode which is closest to the gate. This conducting area starts spreading at a finite speed until the entire cathode region becomes conductive. Time taken by this process constitute the turn on delay time of a thyristor. It is measured from the instant of application of the gate current to the instant when the anode current rises to 10% of its final value (or VAK falls to 90% of its initial value). Typical value of "td" is a few micro seconds.
Rise time (tr): For a resistive load, "rise time" is the time taken by the anode current to rise from 10% of its final value to 90% of its final value. At the same time the voltage VAK falls from 90% of its initial value to 10% of its initial value. Usual values of maximum allowable diA/dt are in the range of 20-200 A/µs.
Spread time (tp): It is the time taken by the anode current to rise from 90% of its final value to 100%. During this time conduction spreads over the entire cross section of the cathode of

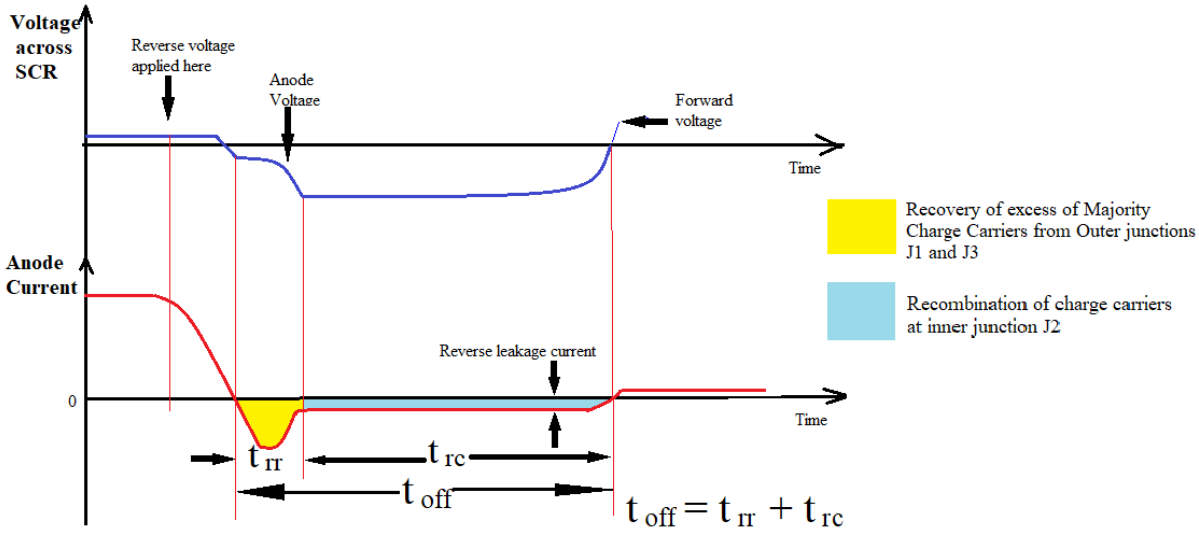
the thyristor. The spreading interval depends on the area of the cathode and on the gate structure of the thyristor.



$$t_{on} = t_d + t_r + t_p$$

Turn off Characteristics

Figure below shows the variation of anode current and anode cathode voltage with time during turn off operation on an expanded scale. Once the thyristor is on, and its anode current is above the latching current level the gate loses control. It can be turned off only by reducing the anode current below holding current. The turn off time tq of a thyristor is defined as the time between the instant anodes current becomes zero and the instant the thyristor regains forward blocking capability. During turn off time, excess minority carriers from all the four layers of the thyristor must be removed. Accordingly tq is divided in to two intervals, the reverse recovery time (trr) and the recombination time (trc). The time interval tq = trr + trc is called "device turn off time" of the thyristor. No forward voltage should appear across the device before the time t.



dv/dt and di/dt ratings of SCR

dv/dt: dv/dt rating of SCR indicates maximum rate of rise of anode voltage that will not trigger the device without any gate signal.

$$i = c \frac{dv}{dt}$$

di/dt: di/dt rating of SCR indicates maximum rate of rise of anode to cathode current. without any damage or harm to an SCR. If the rate of rise of anode current is very rapid compared to the spreading velocity of the charge carriers, local hot spots are created due to concentration of carriers (on account of high current density) in the restricted area of the junctions.

Factors affecting characteristics/ratings of SCR

Junction temperature is one of the most important factor which affects the performance of an SCR.

The junction temperature depends upon the internal power losses of the device and the efficiency of heat transfer mechanism.

The factors contributing toward rise in junction temperature are:

- on-state voltage drop across the device (SCR)
- leakage current in the blocking or off state and
- power dissipation at gate.