In The Name Of God

Power Electronics

Power Transistors

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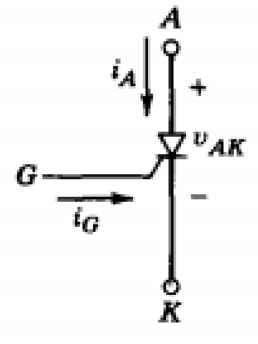
THYRISTORS

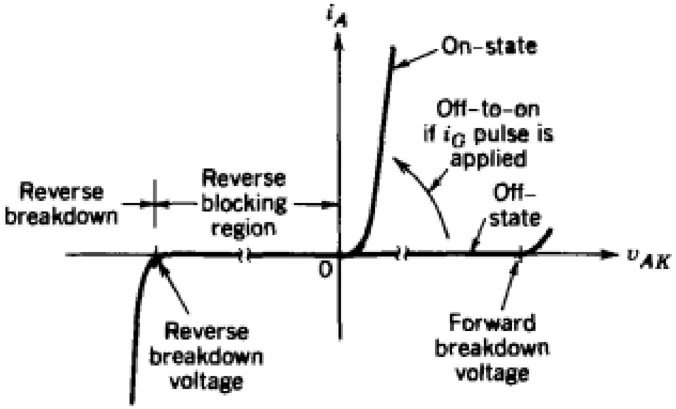
The circuit symbol for the thyristor and its *i–v* characteristic are shown in Figs. 2-3*a* and 2-3*b*. The main current flows from the anode (A) to the cathode (K). In its off-state, the thyristor can block a forward polarity voltage and not conduct, as is shown in Fig. 2-3*b* by the off-state portion of the *i–v* characteristic.

The thyristor can be triggered into the on state by applying a pulse of positive gate current for a short duration provided that the device is in its forward-blocking state. The resulting *i–v* relationship is shown by the on-state portion of the characteristics shown in Fig. 2-3*b*. The forward voltage drop in the on state is only a few volts (typically 1–3 V depending on the device blocking voltage rating).

Once the device begins to conduct, it is latched on and the gate current can be removed. The thyristor cannot be turned off by the gate, and the thyristor conducts as a diode. Only when the anode current tries to go negative, under the influence of the circuit in which the thyristor is connected, does the thyristor turn off and the current go to zero. This allows the gate to regain control in order to turn the device on at some controllable time after it has again entered the forward-blocking state.



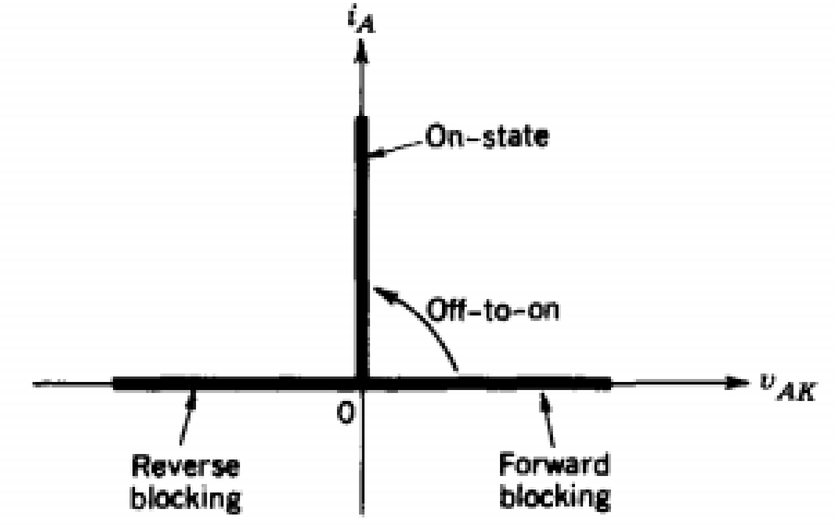
(a)



(b)

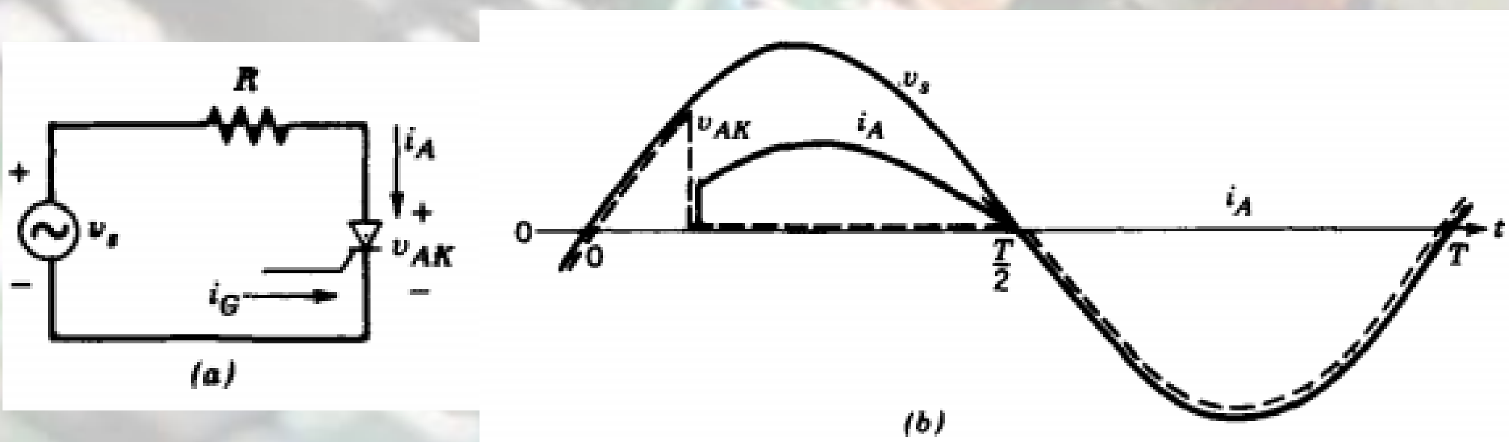
In reverse bias at voltages below the reverse breakdown voltage, only a negligibly small leakage current flows in the thyristor, as is shown in Fig. 2-3*b*. Usually the thyristor voltage ratings for forward- and reverse-blocking voltages are the same. The thyristor current ratings are specified in terms of maximum rms and average currents that it is capable of conducting.

Using the same arguments as for diodes, the thyristor can be represented by the idealized characteristics shown in Fig. 2-3*c* in analyzing converter topologies.

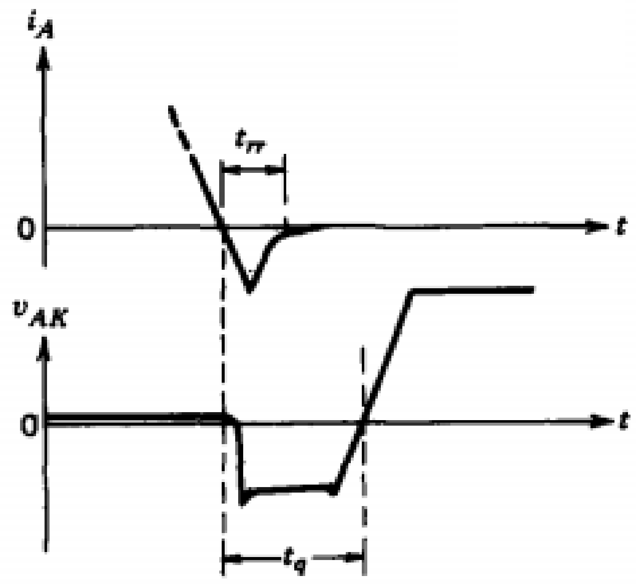


(c)

In an application such as the simple circuit shown in Fig. 2-4*a*, control can be exercised over the instant of current conduction during the positive half cycle of source voltage. When the thyristor current tries to reverse itself when the source voltage goes negative, the idealized thyristor would have its current become zero immediately after $t = \frac{1}{2}T$, as is shown in the waveform in Fig. 2-4*b*.



However, as specified in the thyristor data sheets and illustrated by the waveforms in Fig. 2-4*c*, the thyristor current reverses itself before becoming zero. The important parameter is not the time it takes for the current to become zero from its negative value, but rather the turn-off time interval t_q defined in Fig. 2-4*c* from the zero crossover of the current to the zero crossover of the voltage across the thyristor. During t_q a reverse voltage must be maintained across the thyristor, and only after this time is the device capable of blocking a forward voltage without going into its on state. If a forward voltage is applied to the thyristor before this interval has passed, the device may prematurely turn on, and damage to the device and/or circuit could result. Thyristor data sheets specify t_q with a specified reverse voltage applied during this interval as well as a specified rate of rise of voltage beyond this interval. This interval t_q is sometimes called the circuit-commutated recovery time of the thyristor.



(c)

Depending on the application requirements, various types of thyristors are available. In addition to voltage and current ratings, turn-off time t_q, and the forward voltage drop, other characteristics that must be considered include the rate of rise of the current (di/dt) at turn-on and the rate of rise of voltage (dv/dt) at turn-off.

1. *Phase-control thyristors*. Sometimes termed *converter thyristors*, these are used primarily for rectifying line-frequency voltages and currents in applications such as phase-controlled rectifiers for dc and ac motor drives and in high-voltage dc power transmission. The main device requirements are large voltage and current-handling capabilities and a low on-state voltage drop. This type of thyristor has been produced in wafer diameters of up to 10 cm, where the average current is about 4000 A with blocking voltages of 5–7 kV. On-state voltages range from 1.5 V for 1000-V devices to 3.0 V for the 5–7-kV devices.
2. *Inverter-grade thyristors*. These are designed to have small turn-off times t_q in addition to low on-state voltages, although on-state voltages are larger in devices with shorter values of t_q. These devices are available with ratings up to 2500 V and 1500 A. Their turn-off times are usually in the range of a few microseconds to 100 μs depending on their blocking voltage ratings and on-state voltage drops.

3. *Light-activated thyristors*. These can be triggered on by a pulse of light guided by optical fibers to a special sensitive region of the thyristor. The light-activated triggering on the thyristor uses the ability of light of appropriate wavelengths to generate excess electron–hole pairs in the silicon. The primary use of these thyristors are in high-voltage applications such as high-voltage dc transmission where many thyristors are connected in series to make up a converter valve. The differing high potentials that each device sees with respect to ground poses significant difficulties in providing triggering pulses. Light-activated thyristors have been reported with ratings of 4 kV and 3 kA, on-state voltages of about 2 V, and light trigger power requirements of 5 mW.

Other variations of these thyristors are gate-assisted turn-off thyristors (GATTs), asymmetrical silicon-controlled rectifiers (ASCRs), and reverse-conducting thyristors (RCTs). These are utilized based on the application.