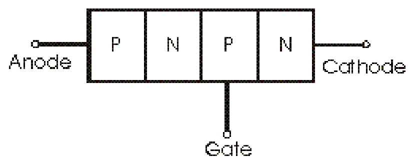
What is a thyristor?

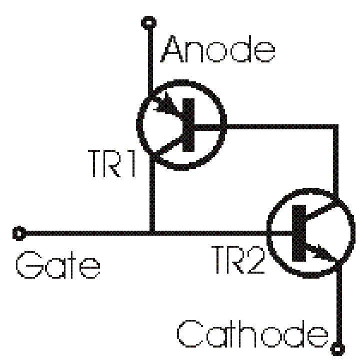
- The thyristor may be considered a rather an unusual form of electronics component *because it consists of **four layers** of differently doped silicon rather than the **three layers*** of the conventional bipolar transistors.
- Whereas conventional transistors may have a p-n-p or n-p-n structure with the electrodes named collector, base and emitter, *the thyristor has a p-n-p-n structure* with the outer layers with their electrodes referred to as the anode (n-type) and the cathode (p-type).
- The control terminal of the SCR is named the gate and it is connected to the p-type layer that adjoins the cathode layer.



Structure of a thyristor or silicon controlled rectifier (SCR)

- Thyristors are usually manufactured from silicon, although, in theory other types of semiconductor could be used.
  - The first reason for using silicon for thyristors is that silicon is the ideal choice because of its overall properties.
  - It is able to handle the voltage and currents required for high power applications. Additionally it has good thermal properties.
  - The second major reason is that silicon technology is well established and it is widely used for a variety of semiconductor electronics components.
  - As a result it is very cheap and easy for semiconductor manufacturers to use.

How does a thyristor work?



Thyristor equivalent circuit

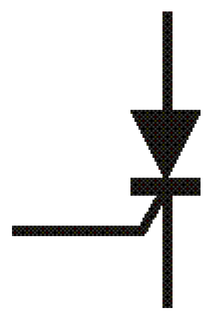
- The way in which a thyristor operates is different to other devices. Normally no current flows across the device. However if a supply is connected across the device, and a small amount of current is injected into the gate, then the device will "fire" and conduct. It will remain in the conducting state until the supply is removed.
- The thyristor circuit can be considered as two back to back transistors.
  - The first transistor with its emitter connected to the cathode of the thyristor is an n-p-n device, whereas a second transistor with its emitter connected to the anode of the thyristor, SCR is a p-n-p variety. The gate is connected to the base of the n-p-n transistor as shown below.
  - When a voltage is applied across a thyristor no current flows because neither transistor is conducting. As a result there is no complete path across the device. If a small current is passed through the gate electrode, this will turn "on" the transistor TR2. When this occurs it will cause the collector of TR2 to fall towards the voltage on the emitter, i.e. the

cathode of the whole device. When this occurs it will cause current to flow through the base of TR1 and turn this transistor "on". Again this will now try to pull the voltage on the collector of TR1 towards its emitter voltage. This will cause current to flow in the emitter of TR2, causing its "on" state to be maintained. In this way it only requires a small trigger pulse on the gate to turn the thyristor on. Once switched on, the thyristor can only be turned off by removing the supply voltage.

It can be seen that current will only flow in one direction through the thyristor. If a reverse voltage is applied, then no current will flow, even if some gate current is applied. In this way for thyristor circuits used for AC, operation only occurs over one half of the AC waveform. For the other half of the cycle the device remains inoperative and no current can flow.

Thyristor symbol

The thyristor symbol is easy to recognize. Like the circuit symbols for most electronic components, the symbols may vary slightly dependent upon who has generated them, but in general it is as shown below. The thyristor symbol effectively shows a diode rectifier symbol with a control gate.

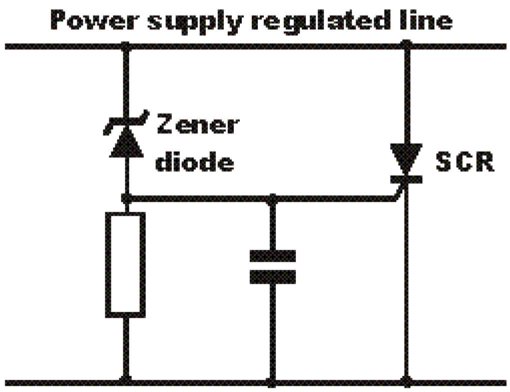


Thyristor symbol used in circuit diagrams

Thyristor circuit

There are many thyristor circuits that are in common use. They can be used in many applications from AC control as in the case of motor or light dimmers to other circuits including power supply crowbar circuits.

The circuit below shows a power supply crowbar circuit. It can be used to protect circuitry within the main equipment from the effects of the failure of the series regulator in a power supply. If the series regulator fails short circuit, then high voltages can be paled on the power rail inside the equipment and this could result in serious damage to the overall equipment.



Thyristor overvoltage crowbar circuit

The SCR over voltage crowbar or protection circuit is connected between the output of the power supply and ground. The zener diode voltage is chosen to be slightly above that of the output rail. Typically a 5 volt rail may run with a 6.2 volt zener diode. When the zener diode voltage is reached, current will flow through the zener and trigger the silicon controlled rectifier or thyristor. This will then provide a short circuit to ground, thereby protecting the circuitry that is being supplied form any damage.

Further details of this circuit can be found in the "Analogue Circuits" section of this website.

Summary

Thyristors are widely used in many areas of analogue electronics. Thyristor circuits can be used for many power applications as these electronics components are above to switch high currents very easily. In addition to this these electronics components are very cheap and they are widely available.

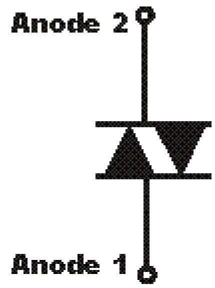
What is a Diac?

A diac is a full-wave or bi-directional semiconductor switch that can be turned on in both forward and reverse polarities. The name diac comes from the words **<u>Di</u>**ode **<u>AC</u>** switch. The diac is an electronics component that is widely used to assist even triggering of a triac when used in AC switches and as a result they are often found in light dimmers such as those used in domestic lighting. These electronic components are also widely used in starter circuits for fluorescent lamps.

Although the term is not often seen, they may also be called symmetrical trigger diodes - a term resulting from the symmetry of their characteristic curve.

Diac symbol

The diac symbol used to depict this electronic component in circuit diagrams can be remembered as a combination of what may appear to be two diodes in parallel with each other but connected in opposite directions.



Circuit symbol for the diac

Owing to the fact that diacs are bi-direction devices the terminals cannot be labelled as anode and cathode as they are for a diode. Instead they may be labelled as A1 and A2 or MT1 ("Main Terminal") and MT2.

Diac operation

Diac circuits use the fact that a diac only conducts current only after a certain breakdown voltage has been exceeded. The actual breakdown voltage will depend upon the specification for the particular component type.

When the diac breakdown voltage occurs, the resistance of the component decreases abruptly and this leads to a sharp decrease in the voltage drop across the diac, and a corresponding increase in current. The diac will remain in its conducing state until the current flow through it drops below a particular value known as the holding current. When the current falls below the holding current, the diac switches back to its high resistance, or non-conducting state.

Diacs are widely used in AC applications and it is found that the device is "reset" to its non-conducting state, each time the voltage on the cycle falls so that the current falls below the holding current. As the behaviour of the device is approximately equal in both directions, it can provide a method of providing equal switching for both halves of an AC cycle, e.g for triacs.

Most diacs have a breakdown voltage of around 30 volts, although the exact specifications will depend upon the particular type of device.. Interestingly their behaviour is somewhat similar to that of a neon lamp, although they offer a far more precise switch on voltage and thereby provide a far better degree of switching equalisation.

Diac applications

One of the major uses of diacs within triac circuits. The diac is placed in series with the gate of a triac to provide a more symmetrical switching characteristic. It is found that triacs do not fire symmetrically as a result of slight differences between the two halves of the device. This results in harmonics being generated, and the less symmetrical the device fires, the greater the level of harmonics produced. It is generally undesirable to have high levels of harmonics in a power system.

To help in overcoming this problem, a diac is often placed in series with the gate. This device helps make the switching more even for both halves of the cycle. This results from the fact that the diac switching characteristic is far more even than that of the triac. Since the diac prevents any gate current flowing until the trigger voltage has reached a certain voltage in either direction, this makes the firing point of the triac more even in both directions. In view of their usefulness, diacs may often be built into the gate terminal of a triac.

Summary

Diacs are a widely used electronic component. The chief application of diacs is for use in conjunction with triacs to equalise their switching characteristics. By equalising the switching characteristics of these triacs, the level of harmonics generated when switching AC signals can be reduced. Despite this, for large applications, two thyristors are generally used. Nevertheless the diac / triac combination is very useful for lower power applications including light dimmers, etc.

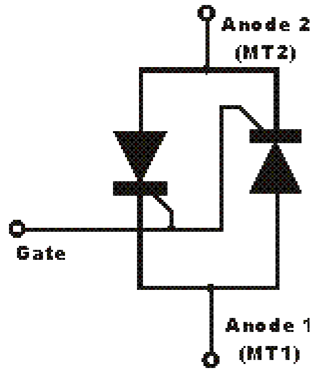
What is a Triac?

Like a thyristor, a triac has three terminals. However the names of these are a little more difficult to assign, because the main current carrying terminals are connected to what is effectively a cathode of one thyristor, and the anode of another within the overall device. There is a gate which acts as a trigger to turn the device on. In addition to this the other terminals are both called Anodes, or Main Terminals These are usually designated Anode 1 and Anode 2 or Main Terminal 1 and Main Terminal 2 (MT1 and MT2). When using triacs it is both MT1 and MT2 have very similar properties.

How does a triac work?

Before looking at how a triac works, it helps to have an understanding of haow a thyristor works. In this way the basic concepts can be grasped for the simpler device and then applied to a triac which is more complicated. The operation of the thyristor is covered in the article in this section and accessible through the "Related Articles" box on the left of the page and below the main menu.

For the operation of the triac, it can be imagined from the circuit symbol that the triac consists of two thyristors in parallel but around different ways. The operation of the triac can be looked on in this fashion, although the actual operation at the semiconductor level is rather more complicated.



Equivalent circuit of a triac

When the voltage on the MT1 is positive with regard to MT2 and a positive gate voltage is applied, one of the thyristors conducts. When the voltage is reversed and a negative voltage is applied to the gate, the other thyristor conducts. This is provided that there is sufficient voltage across the device to enable a minimum holding current to flow.

Using triacs

there are a number of points to note when using triacs. Although these devices operate very well, to get the best performance out of them it is necessary to understand a few hints on tips on using triacs.

It is found that because of their internal construction and the slight differences between the two halves, triacs do not fire symmetrically. This results in harmonics being generated: the less symmetrical the triac fires, the greater the level of harmonics that are produced. It is not normally desirable to have high levels of harmonics in a power system and as a result triacs are not favoured for high power systems. Instead for these systems two thyristors may be used as it is easier to control their firing.

To help in overcoming the problem non-symmetrical firing ad the resulting harmonics, a device known as a diac (diode AC switch) is often placed in series with the gate of the triac. The inclusion of this device helps make the switching more even for both halves of the cycle. This results from the fact that the diac switching characteristic is far more even than that of the triac. Since the diac prevents any gate current flowing until the trigger voltage has reached a certain voltage in either direction, this makes the firing point of the triac more even in both directions.

Overview of using triacs

Triacs are ideal devices for use in many AC small power applications. Triac circuits for use as dimmers are widespread and they are simple and easy to implement. When using triacs, diacs are often included in the circuit as mentioned above to help reduce the level of harmonics produced.