Power semiconductor Devices

of

Power Electronics

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Thyristor

The thyristor or silicon controlled rectifier SCR is a device that is widely used for controlling or switching power and often high voltage AC or DC circuits.

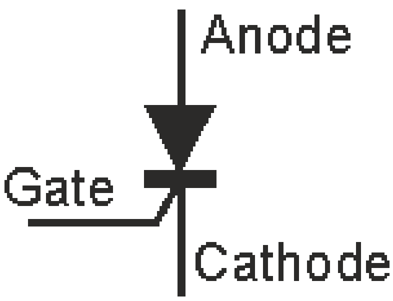
Thyristors are able to switch large levels of power are accordingly they used in a wide variety of different applications. Thyristors even finds uses in low power electronics where they are used in many circuits from light dimmers to power supply over voltage protection.

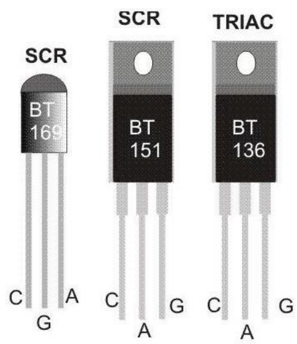
Thyristor applications:

- AC power control (including lights, motors, etc).
- Overvoltage protection for power supplies.
- AC power switching.
- Control elements in phase angle triggered controllers.

Thyristor symbol:

The thyristor symbol shows the traditional diode symbol with a control gate entering near the junction. It has three terminals: Anode, cathode and gate. As can be imagined from its circuit symbol shown, the device is a "one way device".





Thyristor Operation:

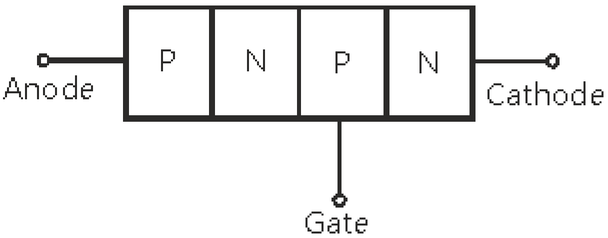
The thyristor or SCR will not conduct initially. It requires a certain level of current to flow in the gate to "fire" it. Once fired, the thyristor will remain in conduction until the voltage across the anode and cathode is removed (this obviously happens at the end of the half cycle over which the thyristor conducts). The next half cycle will be blocked as a result of the rectifier action. It will then require current in the gate circuit to fire the SCR again.

Other types of thyristor or SCR:

- ***Reverse conducting thyristor, RCT.***
- ***Gate Assisted Turn-Off Thyristor, GATT.***
- ***Gate Turn-Off Thyristor, GTO.***
- ***Asymmetric Thyristor.***

Basic thyristor structure:

The thyristor consists of a four layer p-n-p-n or n-p-n-p structure with the outer layers are referred to as the anode (p-type) and cathode (n-type). The control terminal of the thyristor is named the gate and it is connected to the p-type layer located next to the cathode.



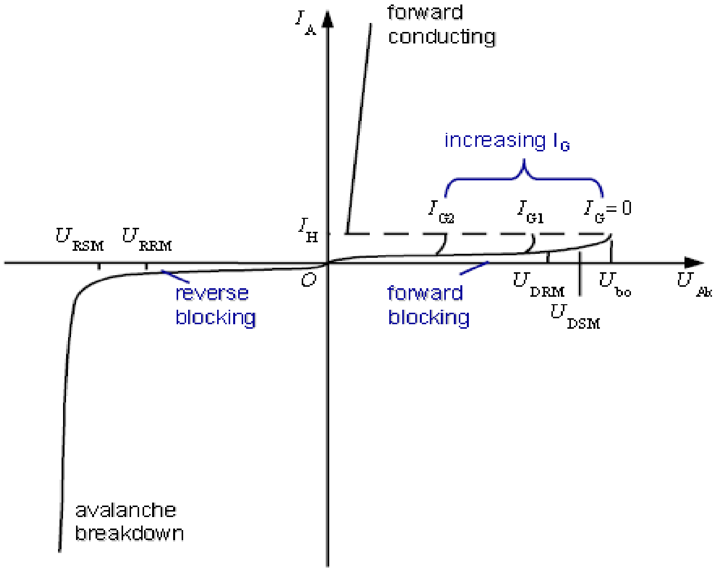
Structure of a thyristor or silicon controlled rectifier, SCR

As a result the thyristor has three junctions rather than the one junction of a diode, and two within transistors.

Thyristor operation modes:

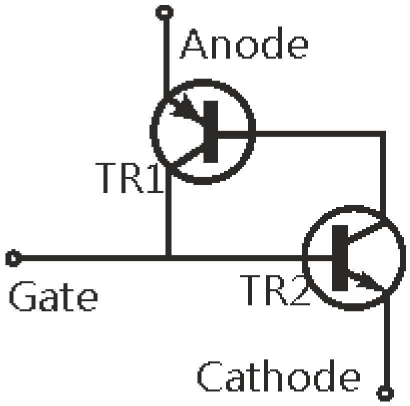
The thyristor has three basic states:

- **Reverse Blocking:** In this mode the thyristor blocks the current in the same way as that of a reverse biased diode.
- **Forward Blocking:** In this mode the thyristor operation is such that it blocks forward current connection that would normally be carried by a forward biased diode.
- **Forward Conducting:** In this mode the thyristor has been triggered into conduction. It will remain conducting until the forward current drops below a threshold value known as the "holding current" I_H .



Modes of operation of a silicon controlled rectifier, SCR

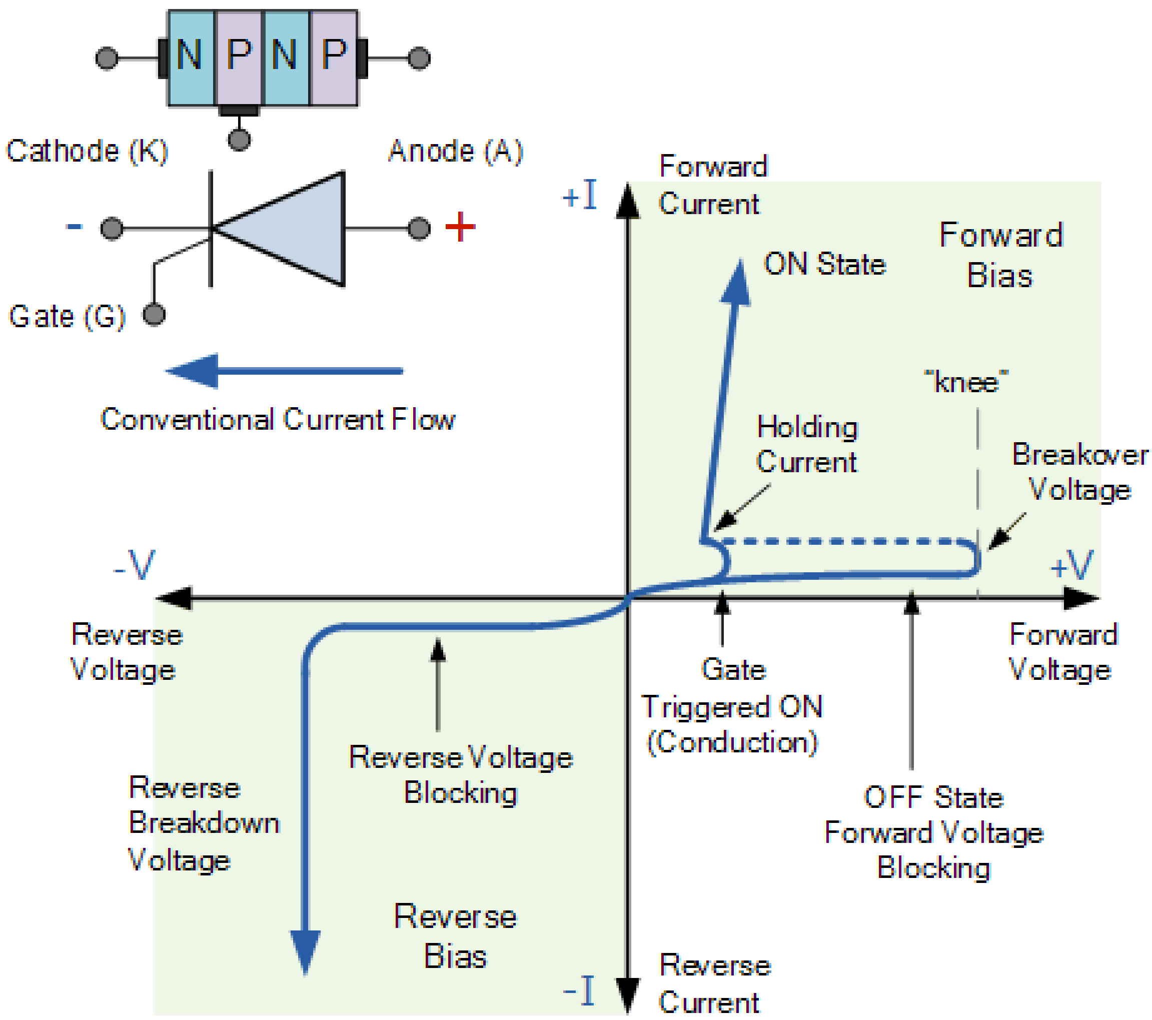
For the thyristor operation, and looking at the simplified block structure it can be seen that the device may be considered as two back to back transistors. The transistor with its emitter connected to the cathode of the thyristor is a n-p-n device whereas the transistor with its emitter connected to the anode of the SCR is a p-n-p variety. The gate is connected to the base of the n-p-n transistor.



Equivalent circuit of a thyristor or silicon controlled rectifier (SCR)

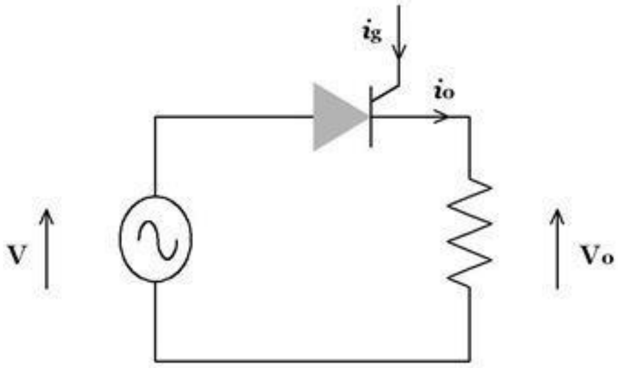
Characteristics of Thyristor:

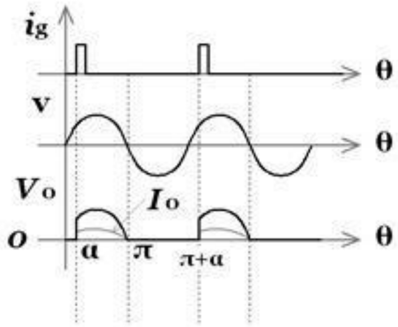
The characteristics of a thyristor is shown below:



Principles of phase-controlled converter operation:

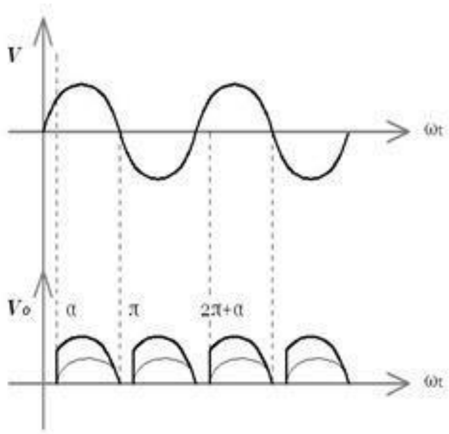
Half wave controlled rectifier:



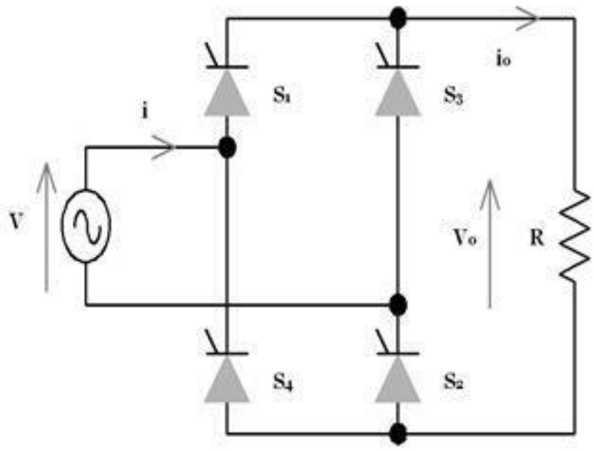


α=Firing/trigger angle/ delay angle

Full Controlled Rectifier with R Load:



α = Firing/trigger angle

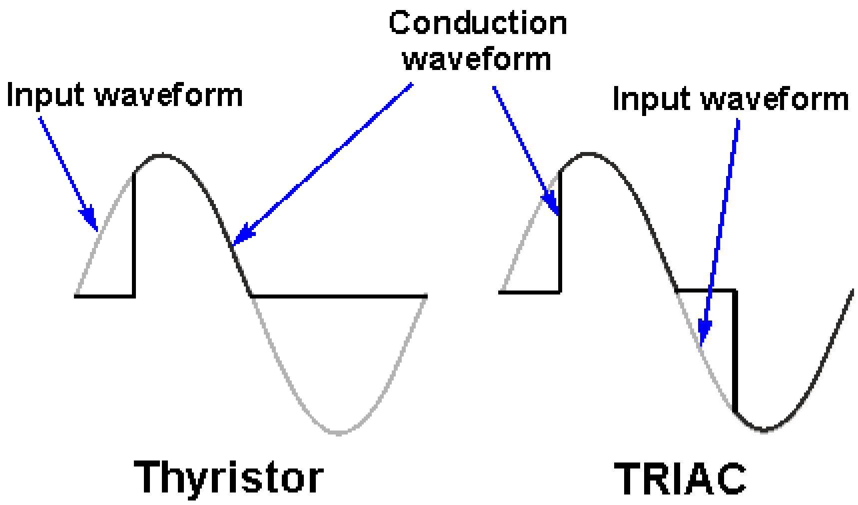


TRIAC

The TRIAC is a three terminal semiconductor device for controlling current. It gains its name from the term **TRI**ode for **A**lternating **C**urrent. It is effectively a development of the SCR or thyristor, but unlike the thyristor which is only able to conduct in one direction, the TRIAC is a bidirectional device.

TRIAC / thyristor comparison:

The TRIAC is an ideal device to use for AC switching applications because it can control the current flow over both halves of an alternating cycle. A thyristor is only able to control them over one half of a cycle. During the remaining half no conduction occurs and accordingly only half the waveform can be utilised.

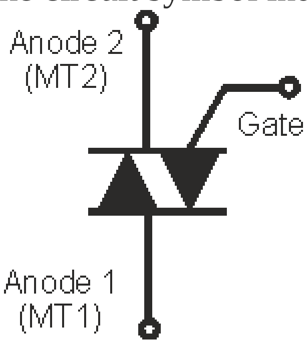


Typical / idealised TRIAC & thyristor switching waveforms

The fact that the TRIAC can be used to control current switching on both halves of an alternating waveform allows much better power utilisation. However the TRIAC is not always as convenient for some high power applications where its switching is more difficult.

TRIAC symbol:

Seen from the outside it may be viewed as two back to back thyristors and this is what the circuit symbol indicates.



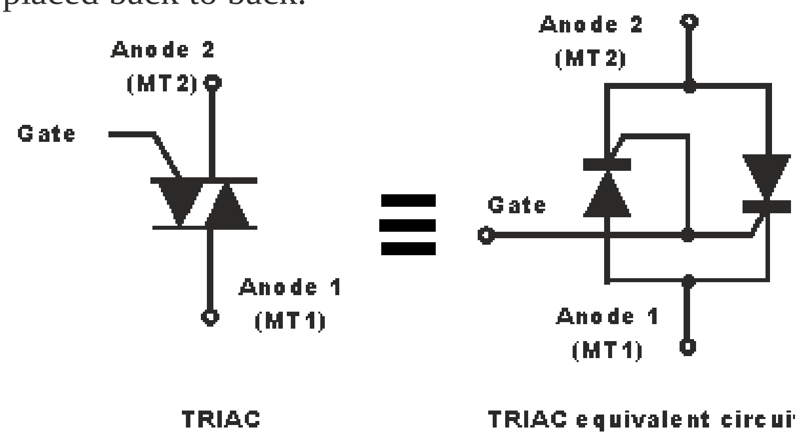
TRIAC symbol for circuit diagrams

On the TRIAC symbol there are three terminals. These are the Gate and two other terminals are often referred to as an "Anode" or "Main Terminal". As the TRIAC has two of these they are labelled either Anode 1 and Anode 2 or Main Terminal, MT1 and MT2.

TRIAC basics:

The TRIAC provides AC switching for electrical systems. Like the thyristor, the TRIACs are used in many electrical switching applications. They find particular use for circuits in light dimmers, etc., where they enable both halves of the AC cycle to be used. This makes them more efficient in terms of the usage of the power available.

It is possible to view the operation of a TRIAC in terms of two thyristors placed back to back.



TRIAC equivalent as two thyristors

When requiring to switch both halves of an AC waveform there are two options that are normally considered. One is to use a TRIAC, and the other is to use two thyristors connected back to back - one thyristor is used to switch one half of the cycle and the second connected in the reverse direction operates on the other half cycle.

Applications:

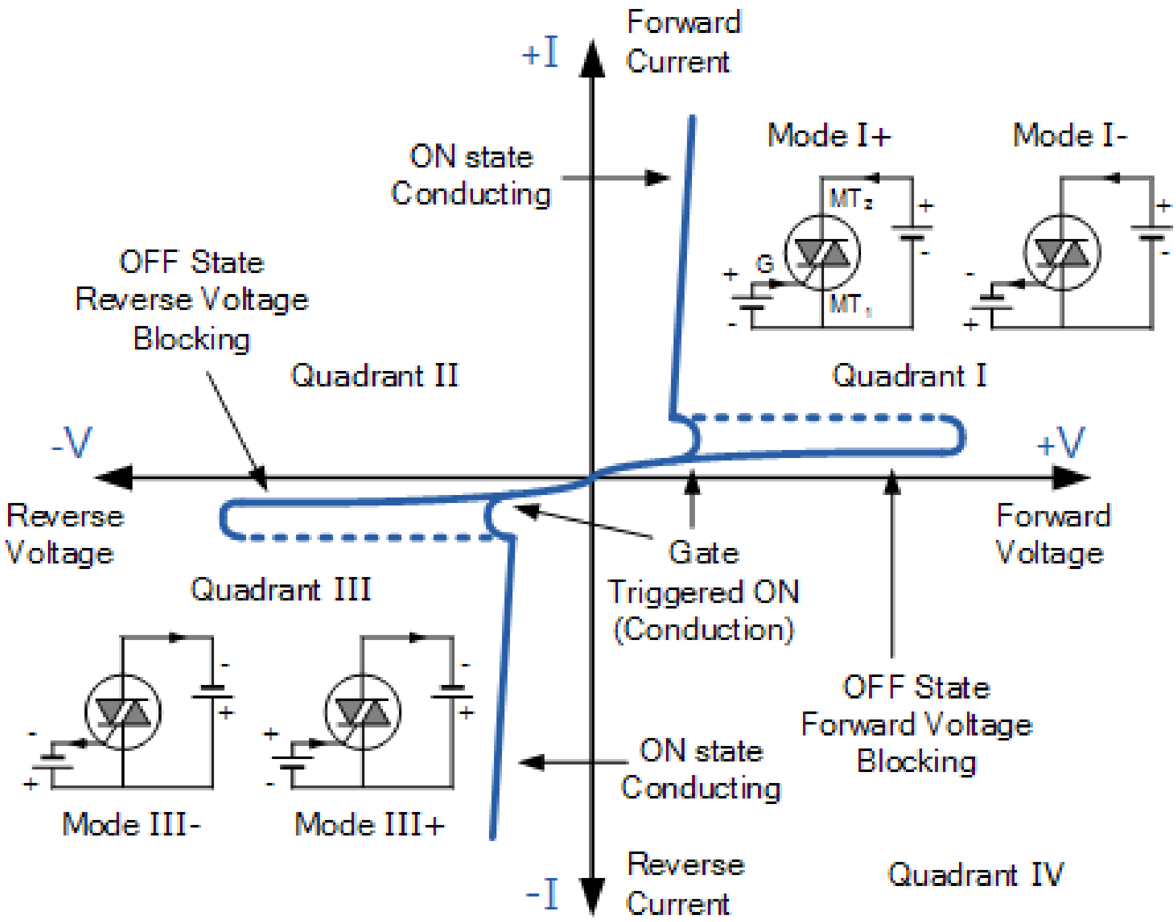
TRIACs are still used for many electrical switching applications:

- Domestic light dimmers
- Electric fan speed controls
- Small motor controls
- Control of small AC powered domestic appliances

The TRIAC is easy to use and provides cost advantages over the use of two thyristors for many low power applications. Where higher powers are needed, two thyristors placed in "anti-parallel" are almost always used.

TRIAC Characteristics:

The characteristics of a TRIAC is shown below:



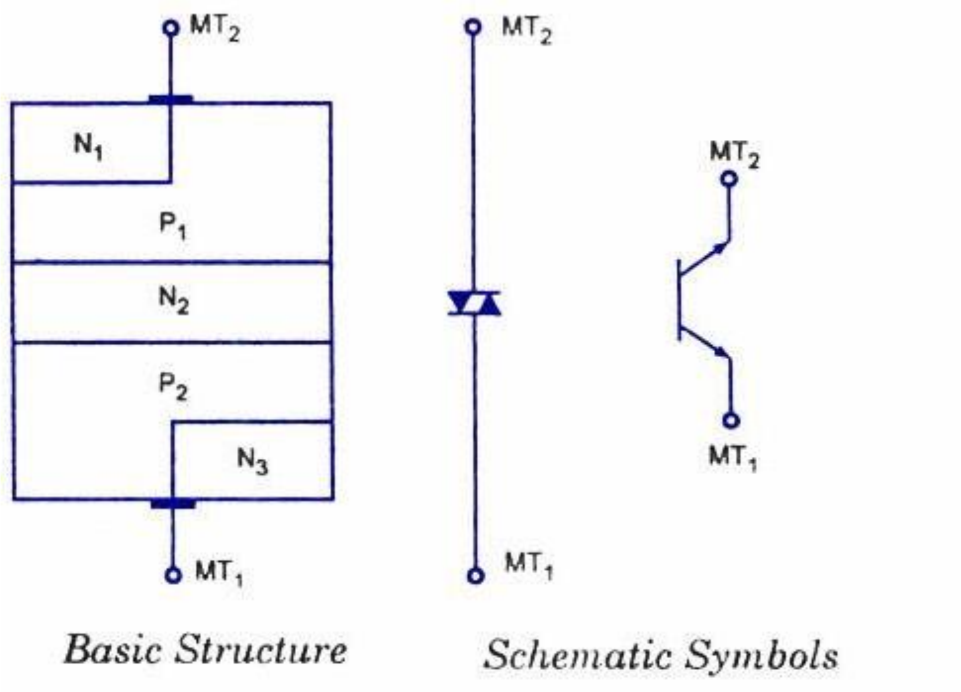
DIAC

The DIAC is a full-wave or bi-directional semiconductor switch that can be turned on in both forward and reverse polarities.
The DIAC gains its name from the contraction of the words **DI**ode **A**lternating **C**urrent.

The DIAC is widely used to assist even triggering of a TRIAC when used in AC switches. DIACs are mainly used in dimmer applications and also in starter circuits for florescent lamps.

Circuit symbol:

The DIAC circuit symbol is generated from the two triangles held between two lines as shown below. In some way this demonstrates the structure of the device which can be considered also as two junctions.

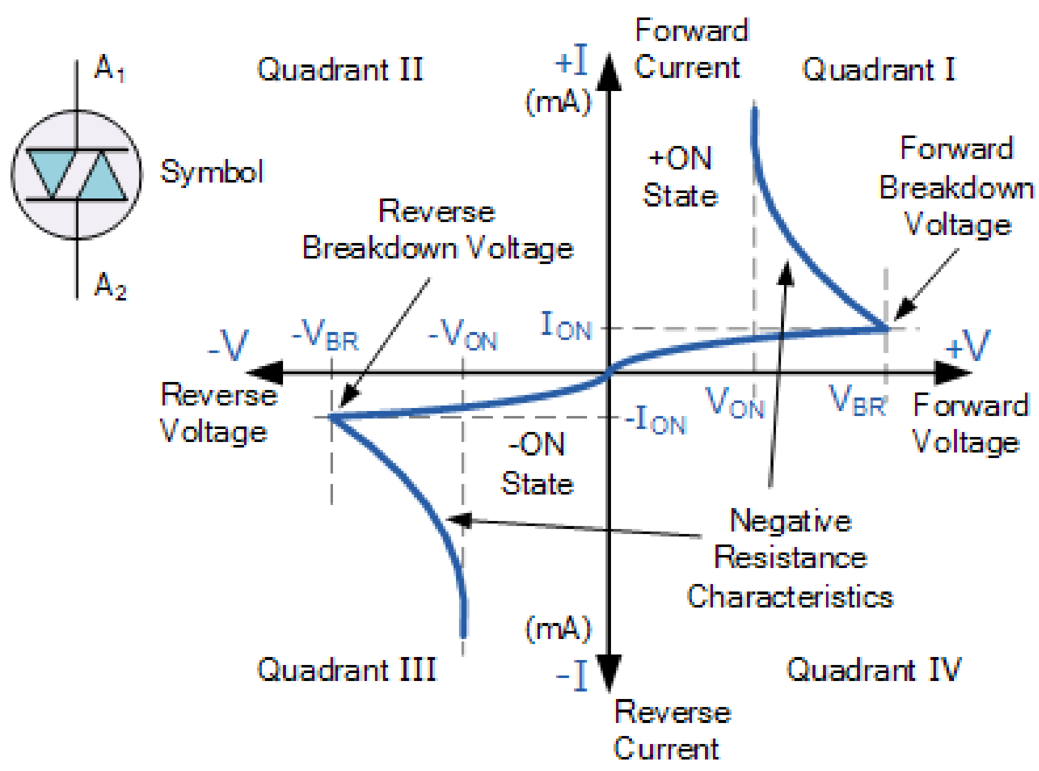


Circuit symbol for the DIAC

The two terminals of the device are normally designated either Anode 1 and Anode 2 or Main Terminals 1 and 2, i.e. MT1 and MT2.

Characteristics of DIAC:

The characteristics of a DIAC is shown below:



Operation:

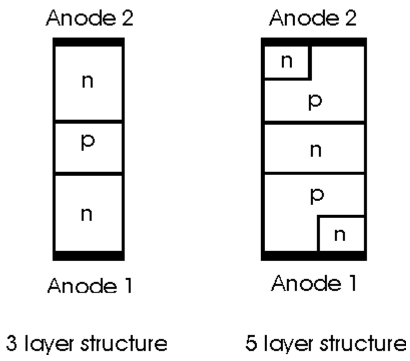
- The DIAC is essentially a diode that conducts after a 'break-over' voltage, designated V_{BO}, is exceeded.
- The diode remains in its conduction state until the current through it drops below what is termed the holding current, which is normally designated by the letters I_H.
- Its behavior is bi-directional and therefore its operation occurs on both halves of an alternating cycle.

Structure of the DIAC:

The DIAC can be fabricated as either a three layer or a five layer structure.

- The three layer version of the device is the more common and can have a break-over voltage of around 30 V. Operation is almost symmetrical owing to the symmetry of the device.

- A five layer DIAC structure is also available. This does not act in quite the same manner, although it produces an I-V curve that is very similar to the three layer version. It can be considered as two break-over diodes connected back to back.



The structure of a DIAC

For most applications a three layer version of the DIAC is used. It provides sufficient improvement in switching characteristics. For some applications the five layer device may be used.

The End