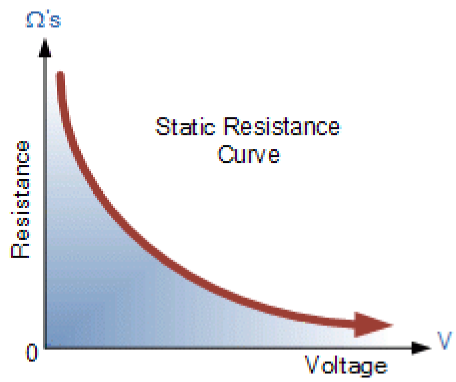


Varistor Tutorial

The Varistor is a passive two-terminal solid state semiconductor device that is used to provide protection to electrical and electronic circuits

Unlike the fuse or circuit breaker which offers over-current protection, the varistor provides over-voltage protection by means of voltage-clamping in a similar way to the zener diode.

The word "Varistor" is a combination of the words VARI-able resi-STOR used to describe their mode of operation way back in their early days of development which is a little misleading since a varistor can not be manually varied like a potentiometer or rheostat.

But unlike a variable resistor whose resistance value can be manually varied between its minimum and maximum values, the varistor changes its resistance value automatically with the change in voltage across it making it a voltage-dependant, non-linear resistor or VDR for short.

A Varistor

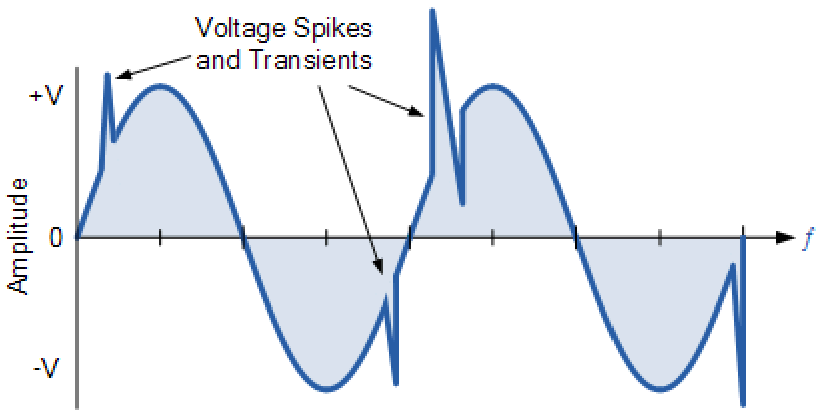
Nowadays the resistive body of a varistor is made from semiconductor material making it a type of semiconductor resistor with a non-ohmic symmetrical voltage and current characteristics suitable for both AC and DC voltage applications.

In many ways the varistor looks similar in size and design to a capacitor and is often confused as being one. However, a capacitor cannot suppress voltage surges in the same way a varistor can. When a high voltage surge is applied to a circuit, the outcome is usually catastrophic to the circuit, therefore the varistor plays an important role in the protection of delicate electronic circuits from switching spikes and over voltage transients.

Transient surges originate from a variety of electrical circuits and sources regardless of whether they operate from an AC or DC supply as they are often generated within the circuit itself or transmitted into the circuit from external sources. Transients within a circuit can rise rapidly increasing the voltage to several thousand volts, and it is these voltage spikes which must be prevented from appearing across delicate electronic circuits and components.

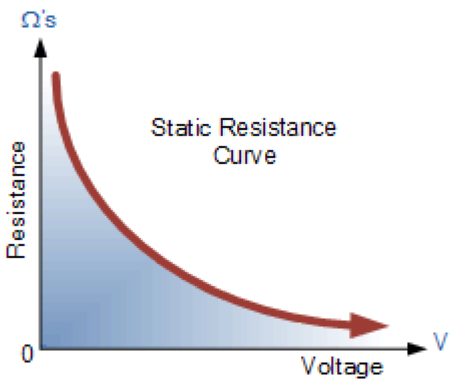
One of the most common sources of voltage transients is the L(di/dt) effect caused by the switching of inductive coils and transformer magnetizing currents, DC motor switching applications and surges from the switching-on of fluorescent lighting circuits or other supply surges.

AC Waveform Transients



Varistors are connected in circuits across a mains supply either phase-to-neutral, phase-to-phase for AC operation, or positive-to-negative for DC operation and have a voltage rating to suit their application. A varistor can also be used for DC voltage stabilization and especially for electronic circuit protection against over voltage pulses.

Varistor Static Resistance



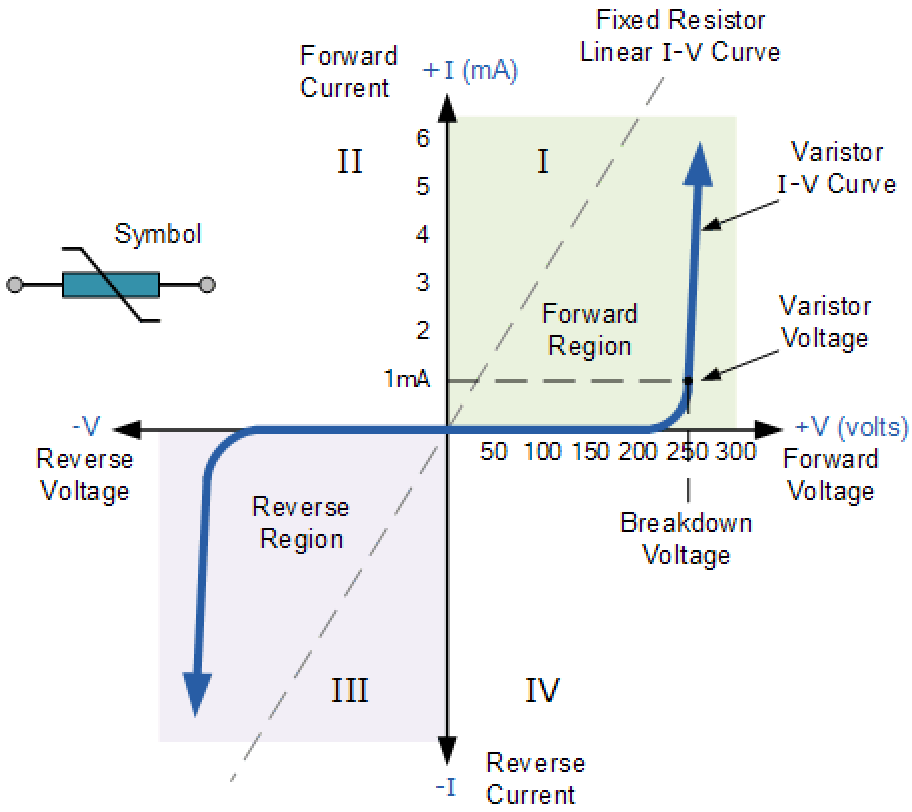
Under normal operation the varistor has a very high resistance, hence part of its name, operating in a similar way to the zener diode by allowing lower threshold voltages to pass unaffected.

However, when the voltage across the varistor (either polarity) exceeds the varistors rated value, its effective resistance decreases strongly with an increasing voltage as shown.

We know from Ohm's Law that the current-voltage (I-V) characteristics of a fixed resistor is a straight line provided that R is kept constant. Then the current is directly proportional to the potential difference across the ends of the resistor.

But the I-V curves of a varistor is not a straight line as a small change of voltage causes a significant change of current. A typical normalised voltage versus current characteristics curve for a standard varistor is given below.

Varistor Characteristics Curve



We can see from above, that the varistor has symmetrical bi-directional characteristics, that is the varistor operates in both directions (quadrant I and III) of a sinusoidal waveform behaving in a similar way to two zener diodes connected back-to-back. When not conducting, the I-V curve shows a linear relationship as the current flowing through the varistor remains constant and low at only a few micro-amperes of "leakage" current. This is due to its high resistance acting as an open circuit and remains constant until the voltage across the varistor (either polarity) reaches a particular "rated voltage".

This rated or clamping voltage is the voltage across the varistor measured with the specified DC current of 1mA. That is, the DC voltage level applied across its terminals that allows a current of 1mA to flow through the varistors resistive body which itself is dependant upon the materials used in its construction. At this voltage level, the varistor begins to change from its insulating state into its conducting state.

When the transient voltage across the varistor is equal to or greater than the rated value, the resistance of the device suddenly becomes very small turning the varistor into a conductor due to the avalanche effect of its semiconductor material. The small leakage current flowing through the varistor rapidly rises but the voltage across it is limited to a level just above the varistor voltage.

In other words, the varistor self-regulates the transient voltage across it by allowing more current to flow through it and because of its steep non-linear I-V curve it can pass widely varying currents over a narrow voltage range clipping-off any voltage spikes.

Varistor Capacitance Values

Since the main conducting region of a varistor between its two terminals behaves like a dielectric, below its clamping voltage the varistor acts like a capacitor rather than resistor. Every semiconductor varistor has a capacitance value that depends directly on its area and varies inversely with its thickness.

When used in DC circuits, the capacitance of the varistor remains more or less constant provided that the applied voltage does not increase above the clamping voltage level, and drops off abruptly near towards its maximum rated continuous DC voltage.

However, in AC circuits, this capacitance can affect the body resistance of the device in the non-conducting leakage region of its I-V characteristics. As they are normally connected in parallel with an electric device to protect it against over voltages, the varistors leakage resistance drops rapidly with an increase in frequency.

This relationship is approximately linear with the frequency and the resulting parallel resistance, its AC reactance, X_C can be calculated using the usual $1/(2\pi f C)$ as for a normal capacitor. Then as the frequency increases so to does its leakage current.

But as well as the silicon semiconductor based varistor, metal oxide varistors have been developed to overcome some of the limitations associated with their silicon carbide cousins.

Metal Oxide Varistor

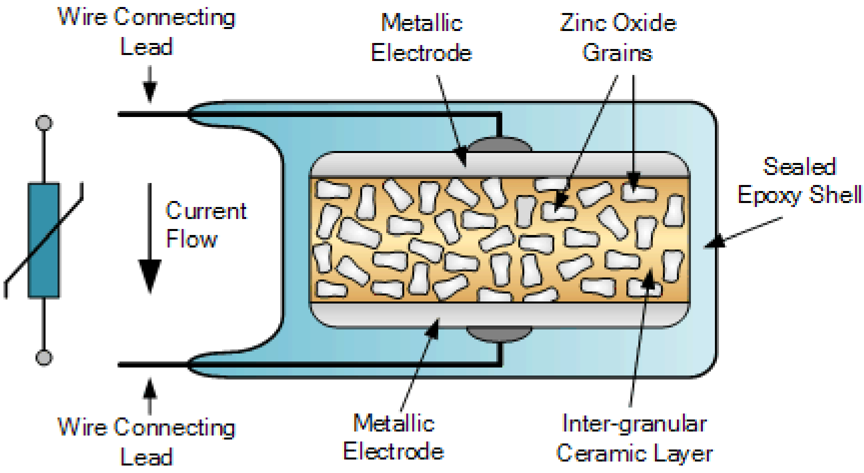
The **Metal Oxide Varistor** or **MOV** for short, is a voltage dependant resistor in which the resistance material is a metallic oxide, primarily zinc oxide (ZnO) pressed into a ceramic like material. Metal oxide varistors consist of approximately 90% zinc oxide as a ceramic base material plus other filler materials for the formation of junctions between the zinc oxide grains.

Metal oxide varistors are now the most common type of voltage clamping device and are available for use at a wide range of voltages and currents. The use of a metallic oxide within their construction means that MOV's are extremely effective in absorbing short term voltage transients and have higher energy handling capabilities.

As with the normal varistor, the metal oxide varistor starts conduction at a specific voltage and stops conduction when the voltage falls below a threshold voltage. The main differences between a standard silicon carbide (SiC) varistor and a MOV type varistor is that the leakage current through the MOV's zinc oxide material is very small current at normal operating conditions and its speed of operation in clamping transients is much faster.

MOV's generally have radial leads and a hard outer blue or black epoxy coating which closely resembles disc ceramic capacitors and can be physically mounted on circuit boards and PCB's in a similar manner. The construction of a typical metal oxide varistor is given as:

Metal Oxide Varistor Construction



To select the correct MOV for a particular application, it is desirable to have some knowledge of the source impedance and the possible pulse power of the transients. For incoming line or phase borne transients, the selection of the correct MOV is a little more difficult as generally the characteristics of the power supply are unknown. In general, MOV selection for the electrical protection of circuits from power supply transients and spikes is often little more than an educated guess.

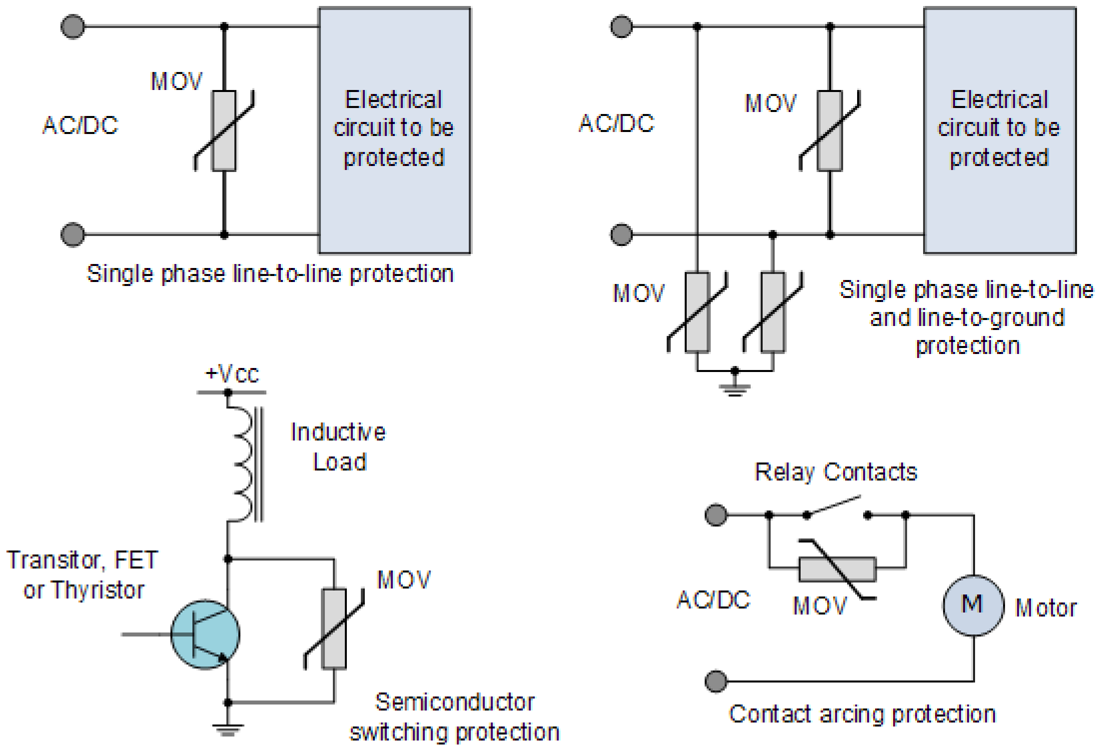
However, metal oxide varistors are available in a wide range of varistor voltages, from about 10 volts to over 1,000 volts AC or DC, so selection can be helped by knowing the supply voltage. For example, selecting a MOV or silicon varistor for that matter, for voltage, its maximum continuous rms voltage rating should be just above the highest expected supply voltage, say 130 volts rms for a 120 volt supply, and 260 volts rms for a 230 volt supply.

The maximum surge current value that a varistor will take depends on the transient pulse width and the number of pulse repetitions. Assumptions can be made upon the the width of a transient pulse which are typically 20 to 50 microseconds (μs) long. If the peak pulse current rating is insufficient, then the varistor may overheat and become damaged. So for a varistor to operate without any failure or degradation, it must be able to quickly dissipate the absorbed energy of the transient pulse and return safely to its pre-pulse condition.

Varistor Applications

Varistors have many advantages and can be used in many different types of applications for the suppression of mains borne transients from domestic appliances and lighting to industrial equipment on both AC or DC power lines. Varistors can be connected directly across mains supplies and across semiconductor switches for protection of transistors, MOSFET's and thyristor bridges.

Varistor Applications



Varistor Summary

In this tutorial we have seen that the basic function of a **Voltage Dependant Resistor**, or VDR, is to protect electronic devices and electrical circuits against voltage surges and spikes, such as those generated by inductive switching transients.

As such varistors are used in sensitive electronic circuits to ensure that if the voltage does suddenly exceeds a predetermined value, the varistor will effectively become a short circuit to protect the circuit that it shunts from excessive voltage as they are able to withstand peak currents of hundreds of amperes.

Varistors are a type of resistor with a non-linear, non-ohmic current voltage characteristic and are a reliable and economical means of providing protection against over voltage transients and surges.

They achieve this by acting as a high resistance blocking device at lower voltages and as a good low resistance conducting device at higher voltages. The effectiveness of a varistor in protecting an electrical or electronic circuit depends on the proper selection of the varistor with regards to voltage, current and energy dissipation.

Metal Oxide Varistors, or MOV's are typically made from a small disk-shaped metal zinc oxide material. They are available in many values for specific voltage ranges. An MOV's voltage rating, called the "varistor voltage" is the voltage across a varistor when a current of 1mA is passed through the device. This varistor voltage level is essentially the point on the I-V characteristic curve when the device starts to conduct. Metal oxide varistors can also be connected in series to increase the clamping voltage rating.

While metal oxide varistors are widely used in many AC power electronics circuits to protect against transient over voltages, there are also other types of solid state voltage suppression devices such as diodes, zener diodes and suppressors which all can be used in some AC or DC voltage suppression applications along with **Varistors**.