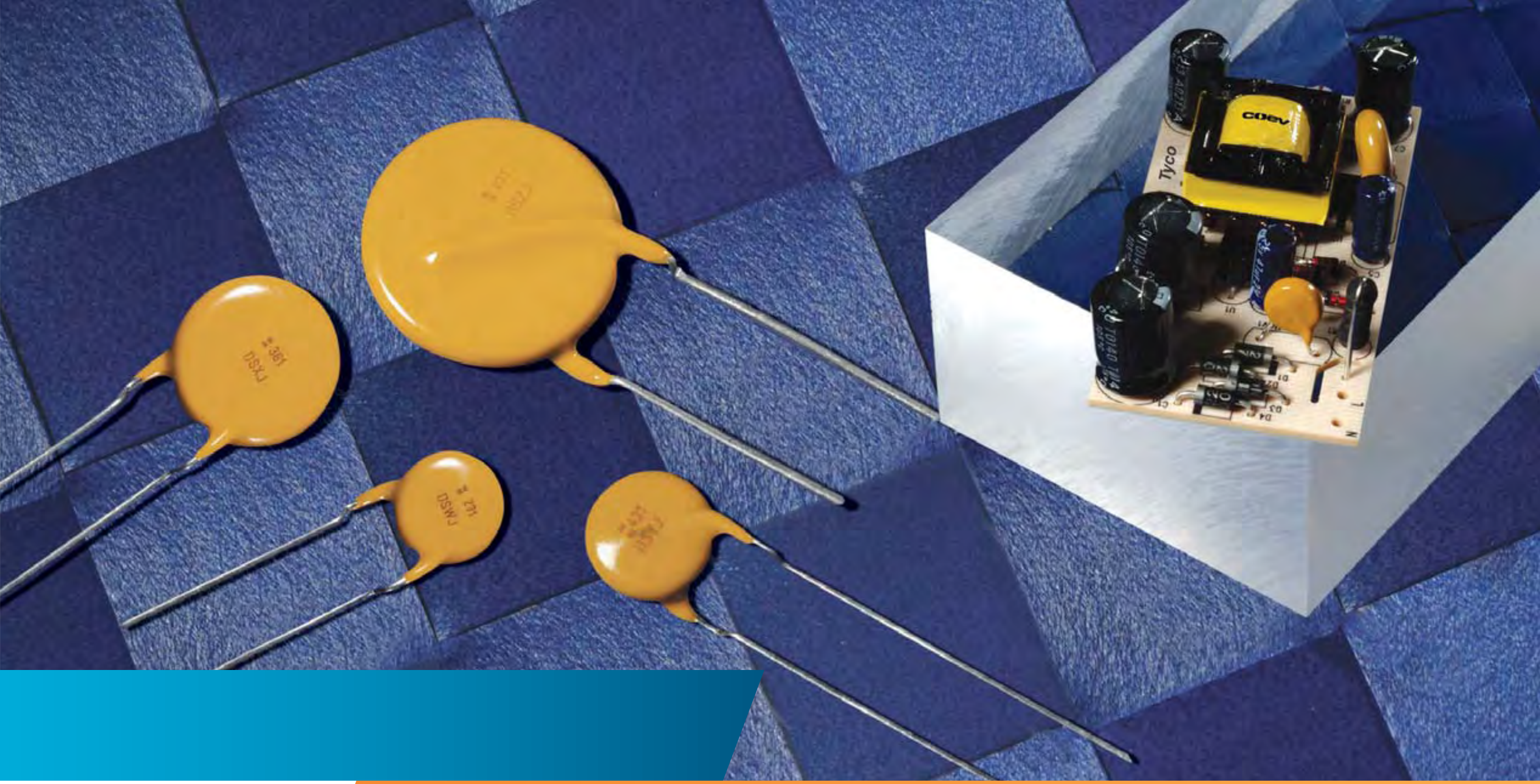


Fundamentals of ROV Varistor Technology

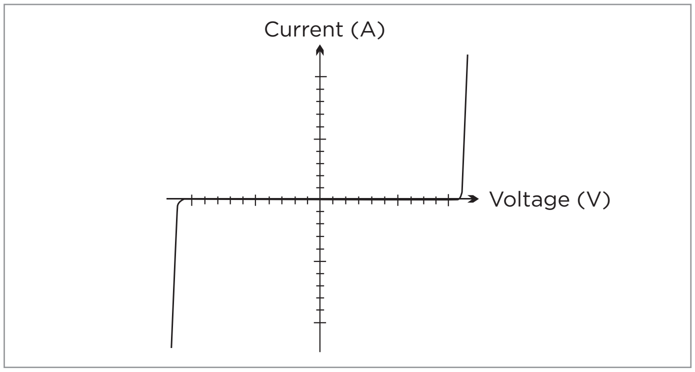
A varistor is a variable resistor—a voltage dependent, non-linear device whose resistance decreases as the voltage applied across the device increases. The voltage-current relationship (commonly represented in a V-I characteristic curve) of a varistor device is defined and depicted by the equation below and the graph in Figure 1.

$I = KV^{\alpha}$ Where:

K : Is a constant dependent on the geometry and materials of the varistor device

$\alpha = \frac{\log(I_1/I_2)}{\log(V_1/V_2)}$: Represents the degree of non-linearity of the device's conduction ; (I^1,I^2) and (V^1,V^2) are the current and voltage values used in the measurement of α.

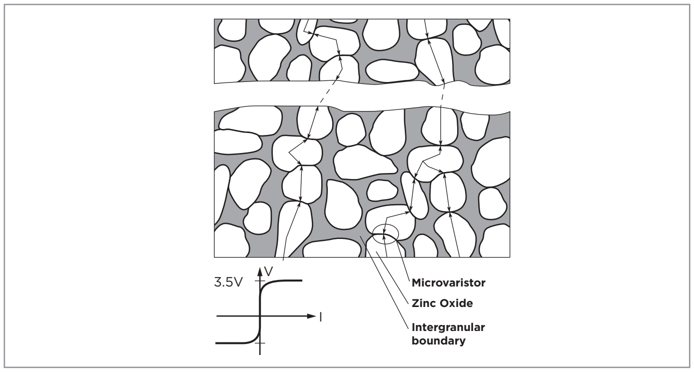
Figure 1. Typical V-I Characteristic Curve of a Varistor



The symmetrical and steep breakdown characteristics depicted in the V-I characteristic curve enable varistors to provide fast transient voltage suppression. The alpha, "α", of the device represents the degree of non-linearity, or steepness of the V-I characteristic curve. In general, high alpha values are desirable since they provide a more stable clamping voltage (i.e., the voltage across the device remains relatively constant for a large increase in current).

An ROV device is a varistor fabricated using a Zinc Oxide (ZnO) powder, sintered with other metal oxide ceramics. The resulting structure is a polycrystalline ceramic that consists of distributed ZnO grains, separated by other metal oxide ceramics. This polycrystalline structure is depicted in Figure 2.

Figure 2. Polycrystalline Structure of a Metal Oxide Varistor



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The boundary of two adjacent ZnO grains creates a p-n junction-like semiconductor characteristic which blocks current conduction at low voltage levels and provides non-linear current conduction at higher voltage levels.

The number of adjacent ZnO grain boundaries (connected in series or in parallel) in a device determines the electrical properties of the device such as varistor voltage, current handling capability and energy absorption capability:

Varistor voltage:

A greater number of adjacent boundaries in series (i.e., the thickness of the device) leads to a higher varistor voltage value

Current handling:

A greater number of adjacent boundaries in parallel (i.e., the area of the device) leads to a higher current handling capability

Energy absorption:

A greater number of adjacent boundaries in series and parallel (i.e., the volume of the device) leads to higher energy absorption capability

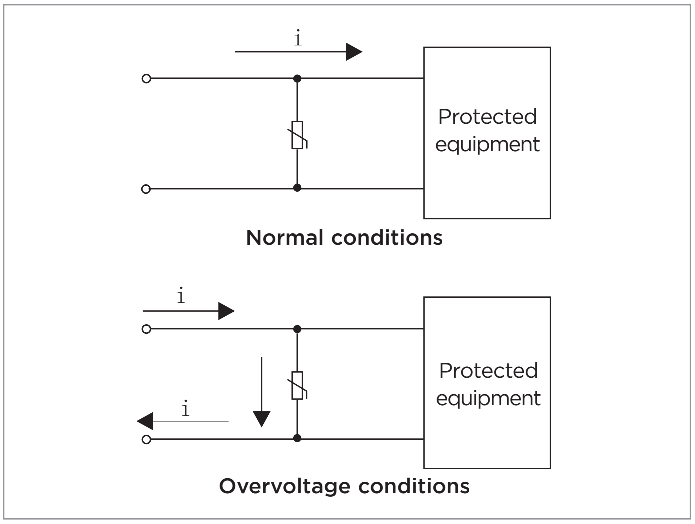
Since ROVs are composed of many ZnO grains spread throughout the device, they are able to effectively and uniformly absorb energy and dissipate heat throughout the device.

Fundamentals of ROV Overvoltage Protection Theory

Electronic equipment and components have been designed to function properly when used within their specified current and voltage ratings. When these ratings are exceeded during operation, the equipment or components may sustain permanent damage and they may cease to operate. Common sources of overvoltage conditions are lightning, AC power contact and power induction. Other electrical components may be susceptible to shifts in system ground potential, increasing the need for overvoltage protection.

ROV devices may be installed in parallel with the equipment or components to be protected. In the event of an overvoltage condition, ROV devices switch rapidly from a high to a low impedance state, thus clamping the transient voltage across the components to a safe operating level. Under normal operating conditions, the overvoltage device appears as a high impedance device (virtually open circuit, with minimal leakage current) and should not affect normal system operation. (Refer to Figure 3.)

Figure 3. Varistor Operation Conditions



Examples of Applications

Power Supply Protection

Table 1. Varistor Selection Examples for Power Supplies

Power Supply Voltage	Suggested ROV Device
100–120 V_{AC}	ROV*DDS*201K (ROV*DDS*221K, ROV*DDS*241K, ROV*DDS*271K)[1]
240 V_{AC}	ROV*DDS*K391K (ROV*DDS*431K, ROV*DDS*471K)[1]
12 V_{DC}	ROV*DDS*220L
24 V_{DC}	ROV*DDS*390K
48 V_{DC}	ROV*DDS*680K

DD : Diameter of the varistor device

S : Series (-: Standard series; H: High surge series; E: Extra high surge series)

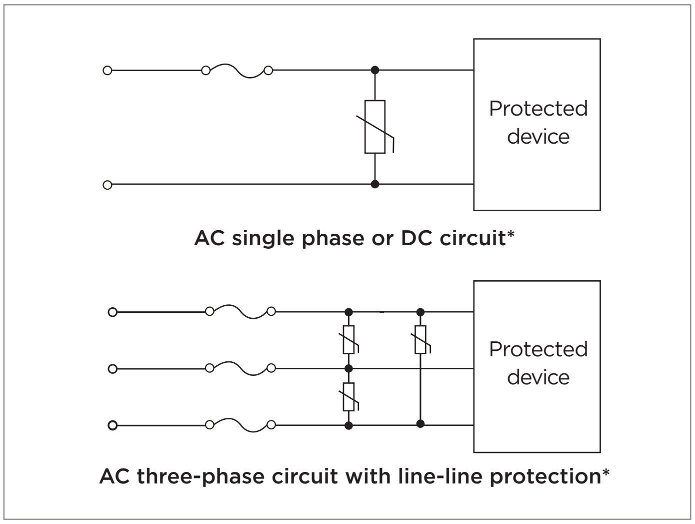
K : ±10% tolerance in varistor voltage

L : ±20% tolerance in varistor voltage

1 : These varistor voltage ROV devices may be used if there is high variance in the input voltage

* In some applications, a polymeric PTC device such as a Raychem Circuit Protection's PolySwitch device may be used instead of a fuse to provide a preferred solution.

Figure 4. Power Supply Protection



Line Voltage Protection

Table 2. Varistor Selection Examples for Line-Ground Circuits

Line Voltage	Possible ROV Device
110 V_{AC}	ROV*DDS*201K and higher[1]
220 V_{AC}	ROV*DDS*361K and higher[1]

DD : Diameter of the varistor device

S : Series (-: Standard series; H: High surge series; E: Extra high surge series)

K : ±10% tolerance in varistor voltage

L : ±20% tolerance in varistor voltage

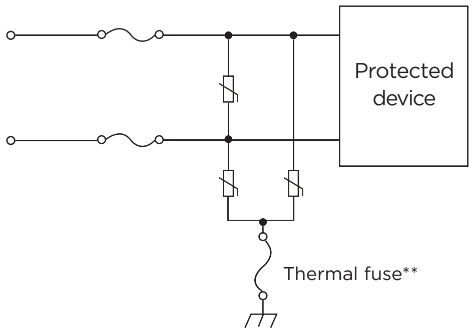
1 : A higher varistor voltage ROV device could be used if there is the possibility of floating voltage in the circuit

* In some applications, a polymeric PTC device such as a Tyco Electronics PolySwitch device may be used instead of a fuse to provide a preferred solution.

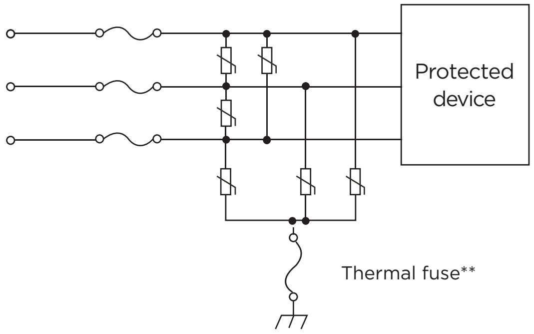
** Fuse current selection if thermal fuse is used in series with varistor to protect from follow-on surge current if varistor is damaged.

Varistor diameter	5mm	7mm	10mm	14mm	20mm
Nominal fuse current	≦1A	≦3A	≦5A	≦10A	≦15A

Figure 5. Line Voltage Protection



AC single phase circuit with line-line and line-ground protection*



AC three-phase circuit with line-line and line-ground protection*

Figure 6. Appliance Protection

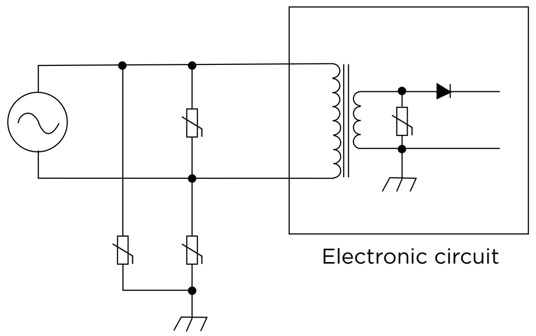


Figure 7. Security System Protection

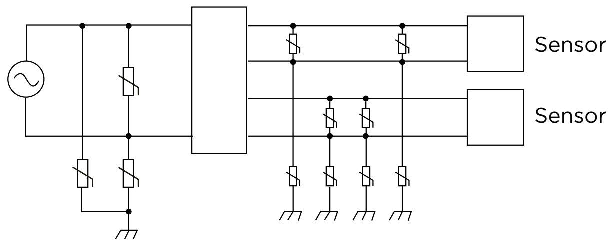


Figure 8. Motor Protection

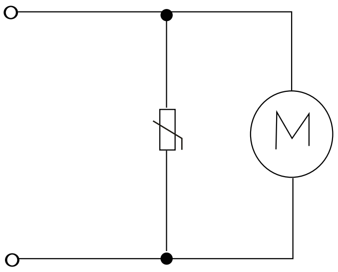
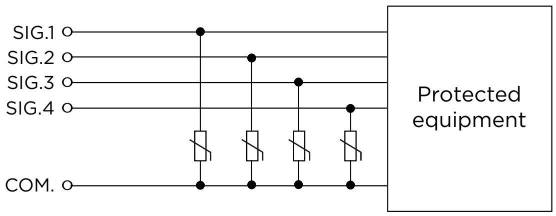


Figure 9. Data Line Protection



Selection Guide for ROV Devices

Step 1. Determine the circuit's operating parameters (complete as much of the following information as possible).

Complete the following information about the circuit, if known:

1-a. Source and path of the transient _________ Source _________ Path

1-b. Normal operating voltage of protected equipment or device _________ (V_{RMS} AC) or _________ (V_{DC})

1-c. Tolerance of normal operating voltage (1-b) _________ (V) or _________ Unknown

1-d. Maximum allowable voltage of protected equipment or device _________ (V_{RMS} AC) or _________ (V_{DC})

1-e. Maximum expected surge current* and number of hits _________ (A) _________ (# of hits)
**Specify 8x20μs waveform equivalent of surge current*

1-f. Maximum energy applied to device in surge event _________ (Joules) (E=1.4xVxIxT)

1-g. Maximum power applied to device in surge event _________ (W) (P=VxI)

1-h. Maximum allowable varistor capacitance* (@1kHz; $0V_{DC}$ bias) _________ (pF)
**This is the maximum capacitance of the varistor device that will not impair the functionality of the circuit*

1-i. Required safety standards _________ Name of standard(s) required (UL, CSA, VDE)

Step 2. Calculate the required varistor voltage value.

2-a. The required varistor voltage value should be equal to: (the operating voltage of the protected equipment or device*) + (the tolerance of the operating voltage). If the tolerance is not known, multiply the operating voltage of protected equipment or device by 1.10 to 1.25 (i.e.10-25% above operating voltage value).
**If the operating voltage is in AC (V_{RMS}), convert to V_{DC}.*

_____ Operating voltage AC (V_{RMS}) X 1.414 = _____ Operating voltage (V_{DC})

_____ Operating voltage of equipment or device (V_{DC}) + _____ Tolerance (V) =_____ Required varistor voltage (V)

or

_____Operating voltage of equipment or device (V_{DC}) X _____ (1.10 to 1.25) = _____ Required varistor voltage (V)

Step 3. Select a varistor that meets the following requirements.

If the response to one of the requirements below is "False", refer to the appropriate corrective action notes (A-F) at bottom of list:

3-a. Varistor voltage value - Tolerance of varistor $\geqq$ Required varistor voltage value (2-a) _______True _______False (A)

3-b. Varistor maximum clamping voltage value $\leqq$ Maximum allowable voltage of protected equipment or device (1-d)* _______True _______False (B)
**Max.current should be less than or equal to the current at which maximum clamping voltage is measured.*

3-c. Varistor maximum peak current value $\geqq$ Maximum expected surge current (1-e)* _______True _______False (C)
**If surge current waveform is not 8 x 20μs, use Pulse Lifetime Ratings curves.*

3-d. Varistor maximum energy rating $\geqq$ Maximum energy applied to system (1-f) _______True _______False (D)

3-e. Varistor maximum rated power $\geqq$ Maximum power applied to system (1-g) _______True _______False (E)

3-f. Varistor capacitance $\leqq$ Maximum allowable system capacitance (1-h) _______True _______False (F)

Corrective action notes:

A. Select next varistor on the list (i.e.next varistor with increasing varistor voltage value) and then re-verify 3-a.
B. Select previous varistor on the list (i.e.previous varistor with decreasing varistor voltage value) and then re-verify 3-b.
C. Select next varistor diameter level and then re-verify 3-c*.
D. Select next varistor diameter level and then re-verify 3-d*.
E. Select next varistor diameter level and then re-verify 3-e*
F. Select lower varistor diameter level and then re-verify 3-c, 3-d, 3-e and 3-f*.

** If varistor voltage is below 82V, selecting an 82V ROV may be preferable over a higher diameter part.*

Step 4. Verify the following system conditions.

4-a. Leakage current of the selected varistor is appropriate for the circuit _______True _______False

4-b. Verify the performance of the varistor under fault conditions* _______Verified

**This selection guide is intended to assist the user in selecting a Raychem Circuit Protection ROV device. However, users should independently evaluate the suitability of, and test each ROV device in their application.*

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