Applications of Metal Oxide Varistors (MOV) in Power Supply

With the rapid development of modern society and the increasing number of various electrical equipment, the reliability of their power systems have directly affected people's work and lives. Metal Oxide Varistor (MOV) is one of the most common safety devices in power systems. This paper will elaborate MOV's principle, structure, characteristics and selection principle. Then the paper will analyze and summarize the typical applications of MOV in power systems. It will also verify proves MOV's reliable surge protection capability through test data of real cases.

1. Principles of Metal Oxide Varistors (MOV)

MOV refers to the metal oxide varistors. MOV has a symmetrical volt-ampere characteristic curve (as shown in Figure 1). When MOV is applied, it is generally connected in parallel in the circuits. When the circuit works normally, it is in a high-impedance state and does not affect the normal operation of the circuit. When an abnormal transient over voltage occurs in the circuit and reaches its on-state voltage (Varistor voltage), MOV will change from the high-impedance state to the low-resistance state, discharging the instantaneous over current caused by the abnormal transient over voltage to the ground. At the same time, the abnormal transient over voltage is clamped within a safe level so as to protect the back-end circuit from the abnormal transient over voltage.

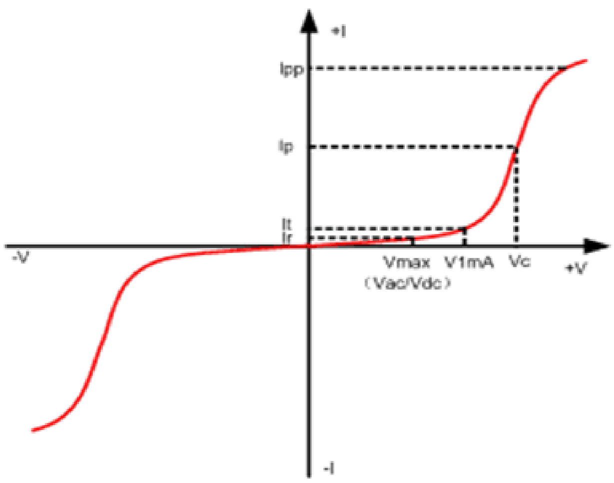


Figure 1 V-I curve

2. Structure and Material of MOV

At present, varistors used in the surge protection of low-voltage electrical appliances on the market are mostly varistors with zinc oxide as the main material. MOV is a kind of polycrystalline semiconductor ceramic device which is mainly made of zinc oxide and doped with various metal oxides through the typical electronic ceramic process. The product structure is as shown in (Figure 2). Products with different temperature resistance and different functions are made of different materials. BrightKing Electronics MOV can be divided into three series: ordinary varistor which is 85℃ MOV that uses 85℃ epoxy resin (powders) as the package material. It can withstand a high temperature of 85℃; high temperature varistor which is 125℃ MOV that uses 125℃ silicone material (liquid) as the package material. It can withstand a high temperature of 125℃; TMOV with temperature fuses which is 85℃ MOV integrating temperature fuses inside. When the temperature reaches the set TMOV's action temperature (which is normally around 125°C), the temperature sensitive device will be disconnected. As a result, the current supplied to MOV is cut off and MOV's temperature no longer rises, thereby preventing the ignition due to the failure of MOV.

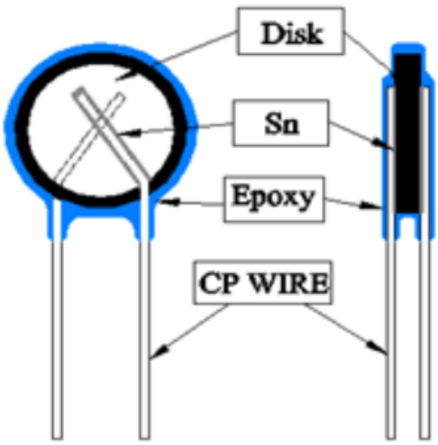


Figure 2 Product Structure

3. Characteristics of MOV

(1) It has a strong surge absorption capability. In the 8/20μs waveform, MOV has a flow range from several hundred amperes to several tens of kiloamperes.
(2) MOV's voltage range is from 18V to 1800V. The voltage accuracy is usually ±10%, which meets the application requirements from low voltages to high voltages;
(3) MOV has various sizes. The diameter varies from 5mm to 53mm;
(4) MOV has a two-way symmetrical breakdown voltage, which is commonly used for the protection of power lines or low-frequency signal lines;
(5) MOV is an aging type device. When it is used for the protection of high-power power ports, it is often used in series with ceramic gas discharge tubes (GDT) or glass gas discharge tubes (SPG) so as to slow down the aging of MOV and extend its service life.

4. Analysis of MOV's Parameters

Part Number		Maximum Allowable Voltage		Varistor Voltage	Maximum Clamping Voltage		Withstanding Surge Current		Maximum Energy (10/1000μs)		Rated Power	Typical Capacitance (Reference)
Standard	High Surge	V_{AC}(V)	V_{DC}(V)	V_{1mA}(V)	I_P(A)	V_C(V)	I (A) Standard	I (A) High Surge	(J) Standard	(J) High Surge	(W)	@1KHz (pf)
561KD14	561KD14J	350	460	560(504~616)	50	925	4500	6000	125	185	0.6	360

● V_{AC} /V_{DC}: it is the AC effective value/DC voltage that can be applied continuously across MOV at a specified temperature. When it is selected, the maximum sustainable operating voltage of MOV V_{AC} /V_{DC} should be greater than or equal to the normal operating voltage of the circuits with a certain margin.

● V_{1mA}: it is the voltage across MOV when a current of 1 mA flowing through MOV. The selection of the varistor voltage should refer to the equation V 1mA =K* Vp, K=(1.5~2). Its aging coefficient, varistor voltage tolerance and power quality should be considered. Vp: it is the voltage peak of the circuit. For example, the voltage peak is 310V for a circuit of 220VAC. The coefficient is taken from the range of 1.5~2. Then the varistor voltage should be selected as V 1mA =K* Vp=310*(1.5~2). The MOV to be selected can be an varistor of 470V~620V. Considering some extreme harsh environmental conditions, the voltage value of MOV can be higher under the premise of protection effects.

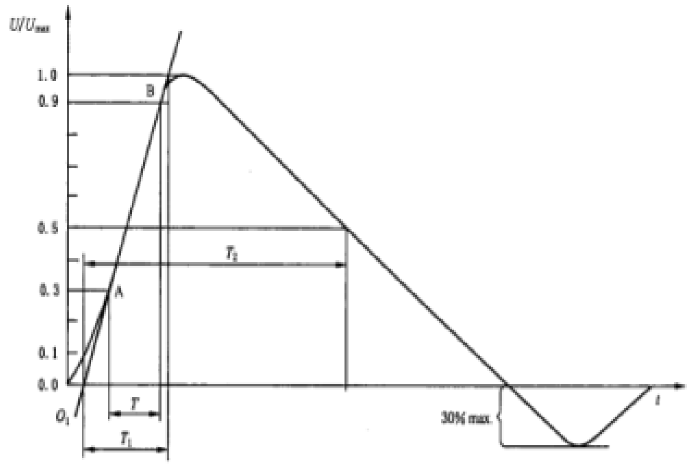
● I_{P}, Vc: the surge current I_P of a specific 8/20μs current waveform. The voltage value Vc across MOV must be less than the maximum voltage that the protected circuit can withstand. Please refer to the specifications (Maximum Leakage Current and Maximum Clamping Voltage Curve) to initially determine whether the surge protection requirements are met.

● Withstanding Surge Current: the peak surge current that can withstand single 8/20μs current waveform. Select and determine the size of MOV according to the level requirements of the lightning protection test of the product. For different surge times or waveforms of other pulse width, please refer to Maximum Surge Current Derating Curve to determine whether the surge protection requirements are met.

5. Applications and Protection Examples of MOV

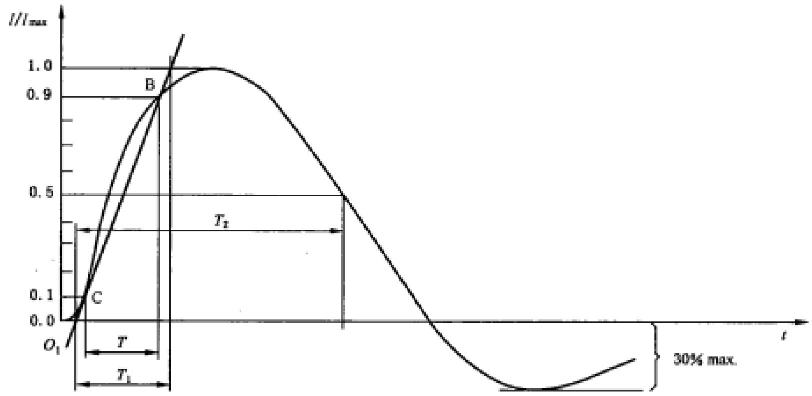
5.1 Surge Protection Strategy and Test Standards

The lightning surge protection strategies usually include suppression, discharge and isolation. According to the surge level that needs to be protected and the surge limit value that the back-end circuit can withstand, the surge protection needs to follow the unified standards for the surge test and measurement. That is, the surge protection needs to follow the IEC61000-4-5 international test standard, which divides the surge protection into four test levels and specifies the test waveforms of the power port as well as the communication port. The following is the test waveform of the power interface combination wave of 1.2/50&8/20μs. The open circuit voltage is shown as below (Figure 3). The short circuit current waveform is shown as below (Figure 4).



Front Time : $T_1 = 1.67 \times T = 1.2 \times (1 \pm 30\%)$ μs
Time to half value : $T_2 = 50 \times (1 \pm 20\%)$ μs

Figure 3 Open Circuit Voltage



Front Time : $T_1 = 1.25 \times T = 8 \times (1 \pm 20\%)$ μs
Time to half value : $T_2 = 20 \times (1 \pm 20\%)$ μs

Figure 4 Short Circuit Current

5.2 Application Areas and Protection solutions

The monomer flow current of metal oxide varistors (MOV) can be 70kA (8/20μs) and the varistor voltage can reach 1800V with a nanosecond grade response speed. So MOV is widely used in the lightning protection of AC power lines and low frequency signal lines. Since MOV is mainly used for the surge protection of power supply interfaces, it has a wide range of applications, including LED driver, industrial control, new energy, security systems, communication systems, consumer electronics, household appliances and instrumentation. The protection circuits for each power interface are as follows:

5.2.1 Surge Protection of AC Power Port

(1) Add an MOV between L and N for the differential mode protection. This scheme is suitable for low power supplies. See Figure 5.

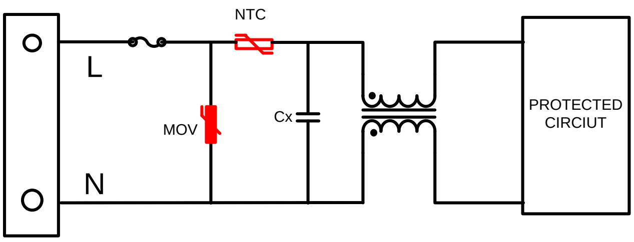


Figure 5

(2) The common mode protected MOV is connected with a GDT to the ground to slow down the aging of MOV. This scheme is suitable for medium and large power supplies. See Figure 6.

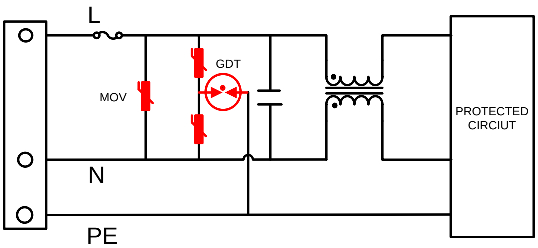


Figure 6

(3) Three-phase power AC, MOV surge protection is used between line and line. See Figure 7.

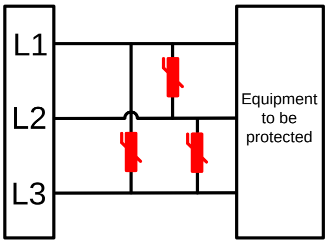


Figure 7

5.2.2 Surge Protection of DC Power Port

(1) MOV is used for the differential mode protection, which is suitable for low power

supplies. See Figure 8.

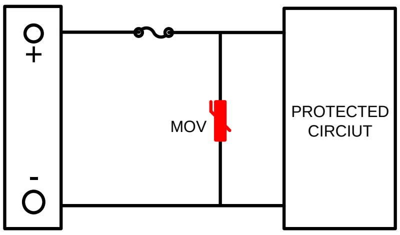


Figure 8

(2) MOV is connected with a GDT to the ground to slow down its aging. See Figure 9

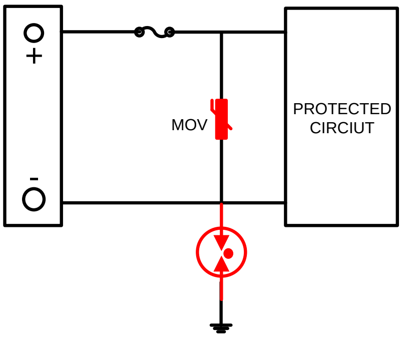


Figure 9

5.2.3 Application Examples of LED Driver Power

The first stage of the LED drive power uses 621KD14J to absorb large surges and conduct the preliminary voltage protection. Then it carries out the over current protection through NTC. After the common-mode inductance, it adopts 621KD14J to further absorb the surges and reduce the residual voltage so as to realize the secondary protection. The basic line is shown in Figure 10.

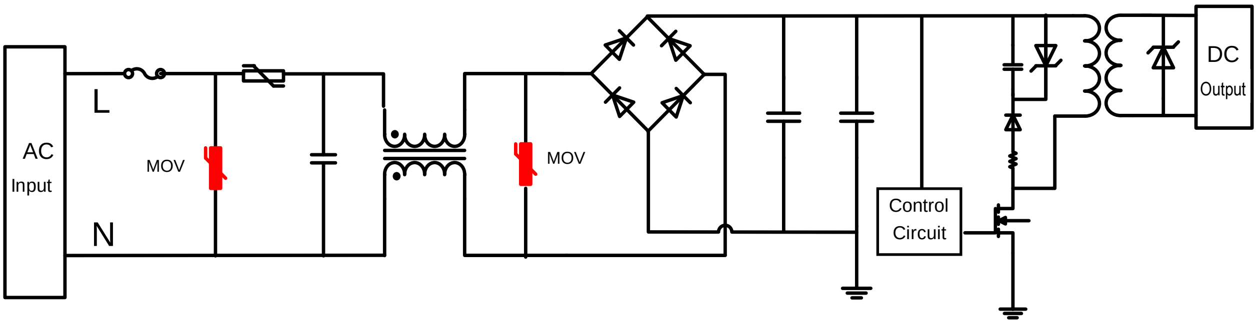


Figure 10. LED Drive Power

The residual voltage value V_C of the first-stage MOV and the protected capacitor is measured by applying AC220VAC, 1.2/50μ S&8/20μ S 4kV/2 ohm to the LED driver under the 90° phase. In the lightning strike state, the varistor voltage V_C=1.2kV and the voltage waveform is as follows (Figure 11), the capacitance V_C=836V and the waveform is as follows (Figure 12).

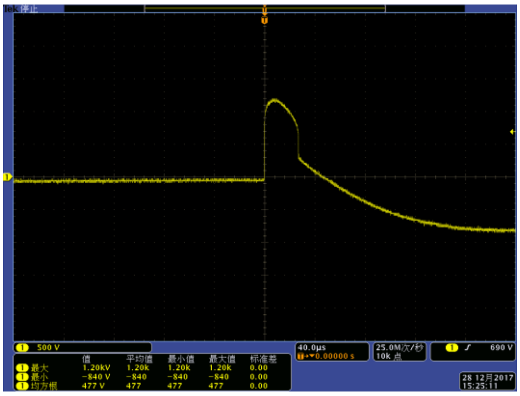


Figure 11 First-level V_C

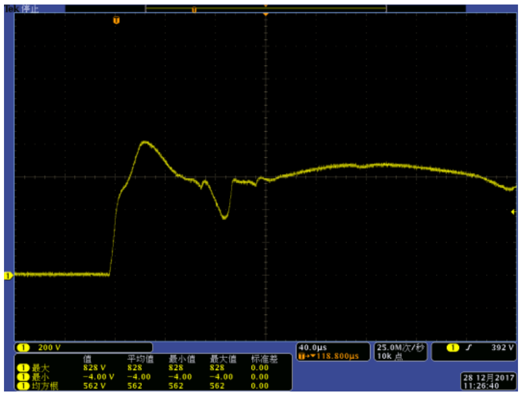


Figure 12 Second-level V_C

6. Conclusion

With the rapid development of technologies and the ever-changing electronic devices, the integration of circuits has made the resistance of some important components to external interference and surge shocks weaker. However, it has also put forward higher requirements to the reliability of the whole electronic devices. MOV has a wide voltage range and its transient pulse absorption capability is strong. It can be found from the examples above that the use of MOV for surge protection can clamp a large over voltage to a safe level that circuits can withstand effectively. Therefore, reasonable surge protection designs based on the electronic circuit withstand capability and the surge level that needs to be withstand can effectively protect the back-end circuits from damage caused by the abnormal transient over-voltage so as to improve the reliability of electronic equipment and extend the service life, thus effectively reducing the repair rate.