Reliable Electronic Solutions

MSP™ Reliability White Paper

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OVERVIEW

The Bourns MSP™ Protector unit is utilized in many tele-communications applications where precise protection is needed for Broad Band Services (xDSL) and Plain Old Telephone Services (POTS) in Central Offices (CO), Network Interface Devices (NIDs) and Optical Network Units (ONUs), as well as Cable Comm Cable Access Units, where it protects the two wire input power connections.

This protector consists of four functional elements: a three element gas discharge tube (GDT), 2 matched metal oxide varistors (MOVs) fast transient protectors and a “Fail Safe” with switch grade short circuit contacts for thermal overload protection and safety.

These four elements make up the Multi Stage Protector assembly (MSP™). The proper operation of these elements in concert result in the total protection of the lines across which they are installed.

MOV RELIABILITY AND MTBF

MOVs are a polycrystalline ceramic. They are composed primarily of zinc oxide with small additions of bismuth, cobalt, manganese and other metal oxides. The individual zinc oxide crystalline grains are highly conductive. The intergranular boundaries, which are composed of the added oxides, are highly resistive. A sintering process during MOV production produces a "micro-varistor" where ever two zinc oxide grains are in direct contact. This micro-varistor essentially acts as a bi-directional zener diode with a protection level of approximately 3.5 volts. The MOV is cylindrical in shape. The zener voltage of the MOV is the series sum of the mean number of individual micro-varistors which span the thickness of the cylinder, and thus is equal to the thickness of the cylinder divided by the diameter of the zinc oxide grains, times the 3.5 volt zener voltage.

MOV failure occurs due to the fusing of the individual zinc oxide grains. This fusing is a function of the number and severity of surges encountered, and excessive leakage currents caused by high temperature and/or sustained swells of line voltage. The fusing of the zinc oxide grains reduces the number of grain boundaries, and thus reduces the zener voltage of the MOV. When the zener voltage of the MOV drops within the applied circuit voltage, grain growth rate increases exponentially and a solid low impedance zinc oxide channel is created across the MOV. The resistance of the channel is proportional to the bulk state resistivity of zinc oxide times the channel diameter. This resistance generates sufficient heat to activate the MSP™ failsafe shorting mechanism.

The failure mode of the MOVs in the MSP™ gas tube protector assembly is thus a low impedance which is current driven to a dead short. The equipment will remain protected by the low resistance short, but will be non-functional due to the grounding of the signal. The failsafe shorting mechanism prevents any fire hazard.

To estimate the MTBF thus requires that we evaluate the surge capability and long term temperature accelerated overvoltage immunity of the MSP™ gas tube protector assembly.

MOV RELIABILITY AND MTBF: SURGE CAPABILITY

Requirements for surge capability of telephone surge protectors in the United States are contained in Telcordia GR-CORE-1361. Telcordia GR-CORE-1361 surge requirements are based on Bell Labs estimates of the surge life required to ensure a field survival rate of 90% after 20 years in station protector telecommunications application (customer end of the line) in the high lightning (60-100 thunderstorm days per year) environment found in the Southeastern United States. The basic surge life requirements of this specification have remained unchanged for 20 years. Post-mortem analysis of failed protectors reported by BellCore in 1997 showed that field failures are invariably due to failure of the parallel air back-up gap, contact corrosion, or insect infestation.

(Note that since the MSP™ gas tube protector assembly uses the MOV in place of the air back-up gap, this failure mode is eliminated.)

In all units analyzed, the gas tube was found to be in good condition. Since the tubes tested were designed to meet Bellcore GR-CORE-1361, the lack of failed gas tubes in the BellCore analysis is considered to be field verification of the adequacy of the surge life requirements. Bourns station protectors have been deployed on approximately 80 million telephone lines in the United States, and based on this field experience, Bourns is in full agreement with these conclusions.

The surge capability of the MSP™ gas tube protector assembly easily exceeds the requirements of GR-CORE-1361. This specification requires that DC Breakdown voltage stay within the range of 265-600 V, and Impulse Breakdown at 100 V/μs remain under 1000 V for the duration of the test.

For simulation of 20 years of induced lightning, GR-CORE-1361 requires 100 surges of 100 A 10/1000 μs. As shown in the following table, the MSP™ gas tube protector assembly can withstand more than 5000 surges of 100 A 10/1000 μs, some 50 times the Telcordia requirement.

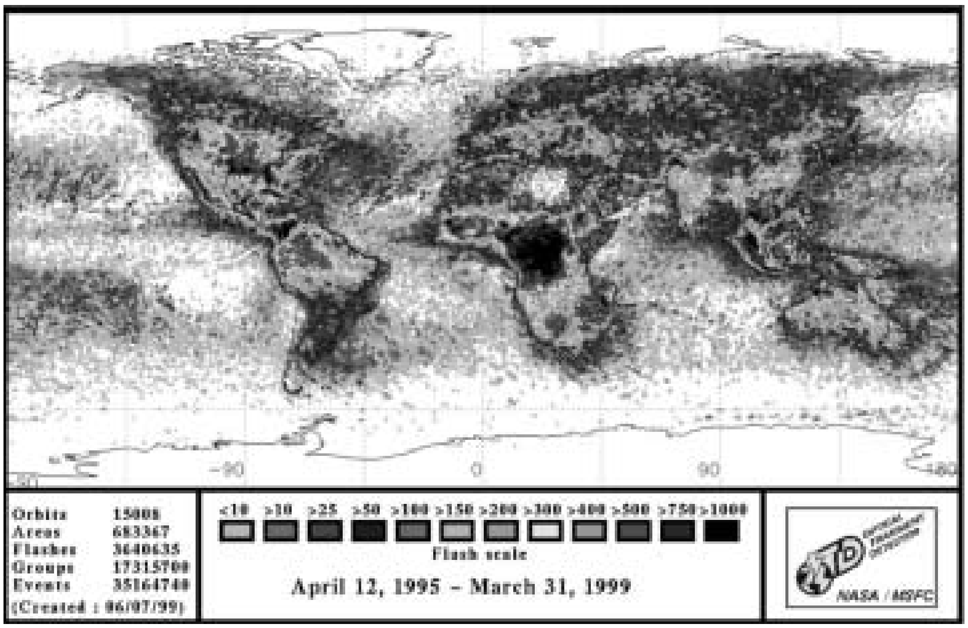
MSP™ gas tube protector assembly after 5000 operations of 100 A 10/1000 μs													
P/N	Insulation Resistance	DC Breakdown @ 1 kV/s						Impulse Breakdown @ 100 V/μs					
		+	+	+	-	-	-	+	+	+	-	-	-
1A *	>100 MΩ	387	384	387	366	367	368	515	524	525	527	528	528
1B *	>100 MΩ	419	419	419	360	363	368	571	573	274	575	576	575
2A	>100 MΩ	395	397	396	372	377	379	555	559	561	562	564	563
2B	>100 MΩ	404	405	405	371	386	391	545	546	549	552	553	552
3A	>100 MΩ	377	379	378	330	335	339	546	548	547	549	551	550
3B	>100 MΩ	395	393	392	349	353	356	542	545	545	547	546	546
4A	>100 MΩ	412	412	413	363	367	369	532	534	535	538	539	539
4B	>100 MΩ	415	415	415	386	384	387	535	538	539	540	541	544
5A	>100 MΩ	376	378	379	319	321	326	545	548	549	549	550	553
5B	>100 MΩ	337	341	339	311	316	321	541	548	547	547	547	548
Summary		Ave = 374, Max = 419, Min = 311						Ave = 547, Max = 576, Min = 515					

* A designates Tip to Ground of the protector unit
B designates Ring to Ground of the protector unit

For simulation of 20 years of conducted lightning currents, GR-CORE-1361 requires 5 surges of 2000 A 10/250 μs. As shown in the table below, the MSP™ gas tube protector assembly can withstand more than 100 surges of 2000 A 10/250 μs, some 20 times the Telcordia requirement.

MSP™ gas tube protector assembly after 100 operations of 2 kA 10/250 μs													
P/N	Insulation Resistance	DC Breakdown @ 1 kV/s						Impulse Breakdown @ 100 V/μs					
		+	+	+	-	-	-	+	+	+	-	-	-
1A	>100 MΩ	345	345	346	363	360	358	538	546	548	551	550	551
1B	>100 MΩ	361	361	361	405	404	405	579	582	584	585	587	586
2A	>100 MΩ	345	348	346	373	360	356	563	568	569	569	571	572
2B	>100 MΩ	326	326	329	391	380	378	560	562	561	565	563	565
3A	>100 MΩ	354	354	352	386	382	382	573	577	576	579	579	579
3B	>100 MΩ	323	321	321	389	389	391	579	581	582	584	582	586
4A	>100 MΩ	338	338	339	345	354	353	592	598	597	598	599	600
4B	>100 MΩ	333	334	333	392	377	391	572	582	584	586	588	588
5A	>100 MΩ	325	325	326	340	342	346	556	557	561	563	562	563
5B	>100 MΩ	316	313	313	360	370	368	593	597	599	600	594	602
6A	>100 MΩ	377	374	376	357	357	358	557	565	566	567	567	567
6B	>100 MΩ	375	380	376	377	382	377	546	547	548	549	549	550
7A	>100 MΩ	381	384	381	362	362	364	546	547	548	551	550	550
7B	>100 MΩ	428	429	429	412	403	403	551	554	554	556	557	556
8A	>100 MΩ	385	387	396	360	365	363	575	575	576	578	578	580
8B	>100 MΩ	430	429	430	386	385	386	555	557	558	559	560	560
9A	>100 MΩ	407	408	405	396	396	377	554	555	555	557	558	559
9B	>100 MΩ	395	396	396	383	383	386	546	547	549	549	549	550
10A	>100 MΩ	432	432	432	408	413	410	555	555	555	557	557	557
10B	>100 MΩ	414	414	414	404	406	363	539	549	559	567	559	544
Summary		Ave = 374, Max = 432, Min = 313						Ave = 567, Max = 602, Min = 544					

The previous data demonstrates the capability of the MSP™ gas tube protector assembly to exceed the surge capability required for a service life of 20 years in the Southeastern United States. As can be seen in the world lightning activity map below, the Southeastern United States is comparable in lightning activity to lightning hot spots in the rest of the world. This map represents four years of accumulated data from the Optical Transient Detector Satellite launched by NASA in 1995.

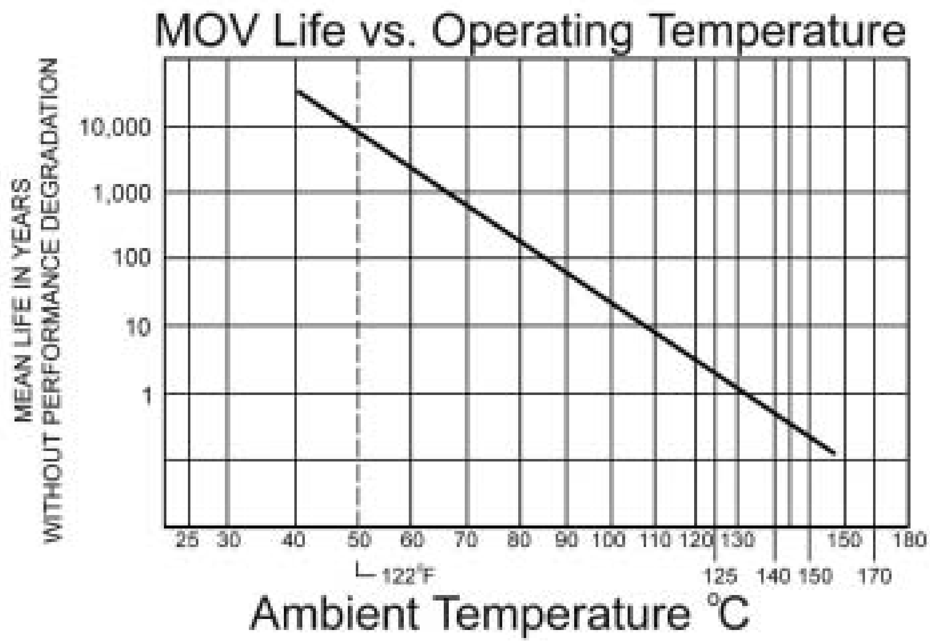


Based on the above, Bourns is extremely confident that the MSP™ gas tube protector assembly will exceed a 90% survival rate after 20 years in highest lightning areas in most the world.

MOV RELIABILITY & MTBF: TEMPERATURE ACCELERATED OVERVOLTA GE IMMUNITY

As stated previously, the failure of an MOV from zinc oxide grain growth is a function of the number and severity of surges encountered, and excessive leakage currents caused by high temperature and/or sustained swells of line voltage. Given the robust surge capability of the MSP™ Multi Stage Protector assembly the following explores its long-term temperature accelerated overvoltage immunity.

The basic life vs. maximum steady state temperature for a zinc oxide MOV is shown below. The line on the graph represents the number of years the MOV can sustain its maximum continuous operating voltage (MCOV) without its zener voltage changing by more than ±10%. This relationship, which was originally derived when MOVs were first commercially developed in the 1970s, has been proven by multi-year accelerated testing.



Bourns reports that they have manufactured MOV based surge protectors for protection of the AC power service of telecommunications facilities since 1979. Further, they report that they have employed an MCOV of 150 V rms for use on nominal 120 Vac line to neutral power systems, and an MCOV of 300 V rms for use on nominal 230 Vac line to neutral power systems. Bourns AC surge protectors are used on the majority of telecommunications installations in the United States. The current failure rate of heavy duty units designed to meet Telcordia surge requirements, based on actual repairs preformed and repair parts supplied, is approximately 0.1% per year. Throughout the 20 year field history, Bourns reports that they have not noted any increased incidence of failure with age.

The MOVs in the MSP™ protector assembly have a zener voltage of 430 V ±10%, and a MCOV of 275 Vrms. The MCOV is thus fully three times the typical Cable Plant line voltage of 90 V. Given the 3x derating, and Bourns field history with considerably less derating, Bourns is confident that the MOVs in the MSP™ gas tube protector assembly will demonstrate a MTBF of greater than 100 years in the worst temperature environments to be found in application.

Based on the foregoing analysis, it is Bourns' professional opinion that the MOVs in the MSP ™ assembly will have a greater than 90% survival after 20 years in the most severe surge and temperature environments in the world.

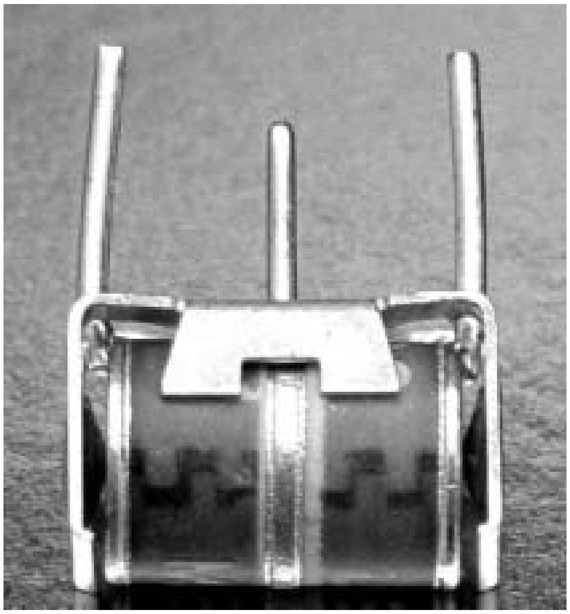
DESCRIPTION AND OPERATION OF SWITCH GRADE FAILSAFE

One of the key technologies in the MSP™ Multi Stage Protector assembly is the use of the Bourns switch grade failsafe. The switch grade failsafe provides far more reliable operation than the more traditional solder compression or burn through type failsafes.

The purpose of the failsafe is to create a dead short to ground should the protector overheat due to sustained conduction. Original failsafes were of a solder compression design. In this design, a solder pellet is placed in a spring-loaded sandwich. When the protector generates sufficient heat to melt the solder, the pellet compresses and the spring action closes the failsafe shorting contacts. With this type of design, thermal expansion/contraction during device cooling and day/night temperature extremes can remove the spring pressure and cause additional arcing. The least expensive type of failsafe design is the insulation burn through type. With an insulation burn through type of design, the heat from the protector must burn through an insulator separating a spring loaded ground clip from the protector line terminals. Reliability is limited by the ability to completely burn out the insulator material without creating a fire hazard. An offshoot of the insulation burn through design additionally uses the insulator as an air back-up gap. This requires that the insulator material be approximately 0.003 inch thick, and porous to allow arcing at a slightly higher voltage than the protector assembly. This type of design is prone to failure from moisture adsorption/absorption by, or contamination of, the 0.003 inch insulation media.

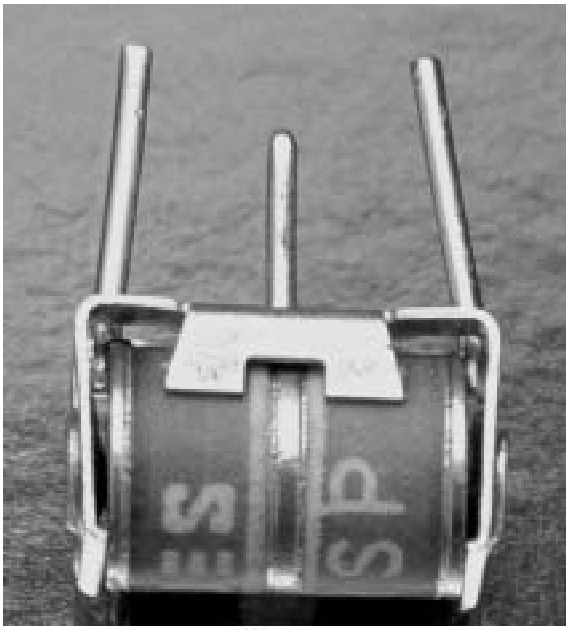
The Bourns switch grade failsafe uses tin/lead alloy electrical grade spring loaded contacts separated by 0.010 inch minimum (0.015-0.020 inch nominal). Since there is no media between the contacts which can become contaminated or absorb moisture reliability is greatly improved and typical failures caused by contamination or excessive thermal accumulation will not occur.

When the failsafe is activated, the contacts close creating a short circuit of less than 10 mΩ. There is no insulating media between the contacts which can create a fire hazard, and there is no solder pellet that can cause additional arcing due to thermal expansion/contraction.



The failsafe mechanism consists of spring loaded tin/lead plated electrical grade contacts. The outer clip is electrically connected to the gas tube center lead. The inner conductor is the gas tube end electrode. The spacing between the contacts is set to be greater than 0.010 inch (typically 0.015-0.020 inch). There is no insulating media between the contacts, which could absorb moisture or become contaminated.

A metal pin is soldered to the clip. The inside end of the pin directly rests on the MOV pellet, placing the MOV in a spring loaded sandwich between the gas tube electrode and the ground clip. The solder used is a eutectic alloy of silver, copper antimony and tin. It is specially formulated for long-term creep resistance and high shear and tensile strength. Since it is eutectic, a single temperature point divides the solid and liquid states with no intermediate plastic state. Its eutectic melting point is 216 C. Heat generated by either the gas tube or the MOV will melt the eutectic alloy causing the tin/lead plated spring loaded contacts to snap closed.



With the failsafe activated, the tin/lead plated electrical grade contacts are held closed by spring tension. This creates a dead short from each input to ground of less than ten milliohms. There is neither an insulation burn through media that can degrade contact resistance, nor is there a compressed solder pellet which can create thermal cycling problems.

SUMMARY

The MSP™ assembly will have a greater than 90% survival after 20 years in the most severe surge and temperature environments in most of the World. The MSP™ assembly, with its switch grade failsafe and the use of MOVs in place of commonly used air back-up gaps will eliminate early field failures caused by thermal overload conditions and contamination.