USB Port Protection: Superior Solutions with Bourns Multifuse and Chip Guard

Introduction: What Multifuse and Chip Guard Products Are

The Bourns Multifuse® (MF) PTC Resettable Fuse protects circuits from potentially destructive overcurrent conditions. The Multifuse line consists of a family of lead-free Polymer Positive Temperature Coefficient (PPTC) devices. The MF devices are either surface mountable – when used with Universal Serial Bus (USB) applications – or radial-leaded when used in certain other circuit protection applications.

MF products of the surface mount style include the MF-SM, MF-MSMF, MF-NSMF, MF-USMF, and devices. The following table illustrates the applications for the relevant product series:

Series	Applications
MF-SM	Used in applications requiring a low-voltage power supply and in loads to be protected, including: ● Computers and peripherals ● General electronics ● Automotive equipment.
MF-NSMF, MF-MSMF*, MF-USMF*	Used in high-density circuit board applications, including: ● Hard disk drives ● PC motherboards ● PC peripherals ● Point-of-sale (POS) equipment ● PCMCIA cards.

*MF product model numbers are specifically dedicated to USB port protection.

Table 1: MF Product Series and Their Applications

The Bourns Chip Guard® (CG) family of electrostatic discharge (ESD) protectors is derived from a multilayer zinc oxide varistor (MLV) technology, which provides heightened electrical performance with a competitive solution for many ESD requirements. The CG device is designed to protect sensitive electronic circuits from the threat of ESD to IEC 61000-4-2 (*Testing and Measurement Techniques – Electrostatic Discharge Immunity Tests*) to Level 4 in the ultra-small 0402 and 0603 chip type packages.

The following table illustrates the specific hardware applications requiring ESD protection that CG products can provide:

Hardware	Applications/Components
Computers	IC (integrated circuit) supply lines IEEE-1394 ports USB (Universal Service Bus) 2.0 ports
Telecom	MOSFET (Metal–Oxide–Semiconductor Field-Effect Transistor) gate protection Ethernet ports
Hand-Held Devices	Low frequency digital and control lines USB OTG (On-The-Go) ports SCSI ports Ethernet ports
POS Equipment	Ethernet ports
Industrial/Medical Equipment	RS232 ports RS485 port

Table 2: Hardware Applications for Which CG Products Can Provide ESD Protection

For the purpose of this paper, we will focus on the capabilities of the MF and CG devices together to suppress or reduce the potentially hazardous effects of electrostatic discharge (ESD), overvoltage, and overcurrent specifically on USB components.

How Each Product Functions

Multifuse (MF)

The MF product is manufactured from a mixture of polymer, carbon, and other proprietary material, placed in a plaque or mold, and then is "punched" out of the mold. You can specify that the MF be customized by adjusting the quantity of each ingredient within the composition or by changing the size of the aperture that you just created.

The MF's conductive carbon chains are embedded in polymer, which creates an environment of low impedance (3 milliohms to 8 ohm). As a result, the component offers low resistance at operating current.

As the PTC (Positive Temperature Coefficient) increases due to current or ambient temperature, the material expands. This expansion increases the impedance from low to high, creating a mostly open circuit, with some leakage current. Once the circuit is tripped, the MF must have power cycled to reset, with the following results:

1. If you leave the power on, the MF does not reset on its own.
2. After an extended period in tripped mode, the component generates heat in a tripped state, causing a very high level of resistance that shuts the component down after cycling. In fact, resistance increases by two orders of magnitude when the circuit trips.

The proper method for resetting the MF is to cycle power for generally one second.

Note that the life of the MF product depends on the surge, duration, and spike of the current. The tripping point is generally twice the holding current, but it must be lower than the leakage current.

Because a larger package of chip types results in larger thermal mass, it heats more slowly than a smaller package. However, a smaller package of chip types trips faster, although higher resistance exists for the same holding current.

For USB protection, two product lines essentially represent MF resettable fuses:

- MF-USMF

Model	V max. Volts	I max. Amps	Hold	Trip	Resistance		Max. Time To Trip		Tripped Power Dissipation
			Amperes at 23°C		Ohms at 23°C		Amperes at 23°C	Seconds at 23°C	Watts at 23°C
			Hold	Trip	RMin.	R1Max.			Type
MF-USMF005	30.0	10	0.05	0.15	2.800	50.000	0.25	1.50	0.6
MF-USMF010	30.0	10	010	0.30	0.800	15.000	0.50	0.60	0.6
MF-USMF020	30.0	10	0.20	0.40	0.400	5.000	8.00	0.02	0.6
MF-USMF035	6.0	40	0.35	0.75	0.200	1.300	8.00	0.20	0.6
MF-USMF050	13.2	40	0.50	1.00	0.180	0.900	8.00	0.10	0.6
MF-USMF075	6.0	40	0.75	1.50	0.070	0.450	8.00	0.10	0.6
MF-USMF110	6.0	40	1.10	2.20	0.050	0.210	5.00	1.00	0.6
MF-USMF150	6.0	40	1.50	3.00	0.030	0.110	5.00	5.00	0.6
MF-USMF175X*	6.0	40	1.75	3.50	0.020	0.090	8.00	1.00	0.7

*CSA approval pending.

Table 3: MF-USMF Specifications

- MF-MSMF

Model	V max. Volts	I max. Amps	Hold	Trip	Resistance		Max. Time To Trip		Tripped Power Dissipation
			Amperes at 23°C		Ohms at 23°C		Amperes at 23°C	Seconds at 23°C	Watts at 23°C
			Hold	Trip	RMin.	R1Max.			Type
MF-MSMF010	60.0	40	0.10	0.30	0.700	15.000	0.50	1.50	0.8
MF-MSMF014	60.0	40	0.14	0.34	0.400	6.500	1.50	0.15	0.8
MF-MSMF020	30.0	80	0.20	0.40	0.400	6.000	6.00	0.06	0.8
MF-MSMF020/60	60.0	40	0.20	0.40	0.400	6.000	1.50	0.15	0.8
MF-MSMF030	30.0	10	0.30	0.60	0.300	3.000	8.00	0.10	0.8
MF-MSMF050	15.0	100	0.50	1.00	0.150	1.000	8.00	0.15	0.8
MF-MSMF075	13.2	100	0.75	1.50	0.110	0.450	8.00	0.20	0.8
MF-MSMF075/24	24.0	40	0.75	1.50	0.110	0.450	8.00	0.20	0.8
MF-MSMF110	6.0	100	1.10	2.20	0.040	0.210	8.00	0.30	0.8
MF-MSMF110/16	16.0	100	1.10	2.20	0.040	0.210	8.00	0.30	0.8
MF-MSMF125	6.0	100	1.25	2.50	0.035	0.140	8.00	0.40	0.8

			Hold	Trip	Resistance		Max. Time To Trip		Tripped Power Dissipation
MF-MSMF150	6.0	100	1.50	3.00	0.030	0.120	8.00	0.50	0.8
MF-MSMF150/24X*	24.0	20	1.50	3.00	0.030	0.120	8.00	1.50	1.0
MF-MSMF160	8.0	100	1.60	2.80	0.035	0.099	8.00	2.00	0.8
MF-MSMF200	8.0	40	2.00	4.00	0.020	0.080	8.00	3.00	0.8
MF-MSMF250/16	16.0	100	2.50	5.00	0.015	0.100	8.00	5.00	0.8
MF-MSMF260	6.0	100	2.60	5.20	0.015	0.080	8.00	5.00	0.8

*Features Multifuse®Free Xpansion DesignTM for MF-MSMF Series (CSA/TÜV pending).

Table 4: MF-MSMF Specifications

Since the USB is always 5V, the MF's minimum voltage of 6V provides at least a full 20% margin (1V) over the USB required voltage for an additional cushion of protection.

Chip Guard

As power line voltage varies by 5-30 V, the CG provides parts that accommodate this range of voltage. Because the Transient Voltage Suppressor (TVS) used to have high capacitance (2000-6000 pF), the Schottky diode was a more popular solution for suppression of electrostatic discharges and voltage than the CG, which employs TVS technology. Some designers have historically preferred the former because it has offered a price advantage over similar solutions.

Features and Benefits

However, the CG is also competitively priced, while offering low capacitance (3-5pF). As a result, Bourns' TVS solution now makes the CG more appealing than the Schottky option. Other features and benefits that the CG provides include:

- Enhanced ESD and Electrical Fast Transient (EFT) protection
- Surge protection
- Because low capacitance does not interfere with antennae or high data rates, it results in quicker, cleaner data transmission.

The CG also employs an air gap/air space discharge-technology fabricated in surface mount devices (SMD 0603/0402 chip type), which enables the device to:

- Distinctly control ESD and EFT;
- Use only 0.50 pF of the 10 pF maximum capacitance of the USB device;
- Generate a low leakage current of <= 5nA (nano-amp), compared to <= 1uA (micro-amp) for most TVS components;
- Along with polymer technology (see below), its air gap/air space discharge capabilities provide bidirectional protection; and
- Have a useful life of about 1000 *hits*, which is the approximate number of ESD events occurring that can trip the device.

Another significant feature of the CG is its polymer technology fabricated in surface mount devices (SMD 1206/0603 chip type). This enables the device to cause voltage charges to jump across the device in “stepping stone” fashion, with the distance between metal components determining the frequency of this “stepping stone” effect.

Port and ESD Protection

Importance of Port Protection

USB (Universal Service Bus)

USB port protection functionality is necessary to maintain the system from such potentially damaging events as hot plugging, short circuits, ESD, faulty equipment, user error, etc.

USB Standards and Electrical Requirements

The centerpiece of USB technology is “plug and play” functionality that has become an industry standard for computer peripherals and digital media. In fact, USB ports are now used for charging and power transfer almost as much as for data transfer.

Standard (Version)	Speed	Notes
1.1 (previous)	12 MBps	
2.0 (current)	480 Mbps	USB OTG for portable devices
3.0 (pending release)	4.8 GBps	1.5A, up from current ~1A

Table 5: USB Standards

Electrical Requirements

Measure	Requirement
Operational Voltage	4.4-5.25 V DC
Short circuit current	5A, UL60950–TTT < 5A/60 seconds
Max. operating current for low power port (LPP)	100 mA
Max. operating current for high power port (HPP)	500 mA
Total line capacitance	= < 10 pF (USB 2.0)*

*With the USB data port equipped with MF and CG using only 0.5 pF, leaving up to 9.5 capacitance available.

Table 6: Electrical Requirements

Typical Concerns for Protection

- *Overcurrent*

Overcurrent Concern	Threshold
Low resistance	= < 700 milliohms (mohms), 350 millivolts (mV) max. drop
Operating current, no trip (LPP)	> 100 milliamps (mA)
Operating current, no trip (HPP)	> 500 mA
5A trip	< 60 seconds (UL60950)

Table 7: Overcurrent Concerns and Thresholds

- *Overvoltage*

Overvoltage Concern	Threshold
ESD protection per human body model (HBM)	Based on IEC Standard, IEC 61000-4-2.
Total line capacitance	= < 10 pF (USB 2.0)
Signal clamping voltage	= < 6V

Table 8: Overvoltage Concerns and Thresholds

It must be noted that which packages of chip types, including the typical 1812, the new 0805 and 0402, and the pending 0603, are chosen for a board assembly depends on different design criteria. These criteria include board space and functional requirements such as resistance and speed. For example, a smaller device tends to operate faster, but typically has a higher resistance. If lower resistance is necessary or more important than conserving board space, then designers must choose larger chip packages and/or other components.

Importance of ESD Protection

What is ESD?

Electrostatic discharge (ESD) is the transfer of an electrical charge between two surfaces of unequal potential. ESD is not harmful to humans, but it is dangerous to sensitive electronic components and is the principal reason for integrated circuit (IC) malfunctions:

- An electronic device destroyed by ESD occurs when the discharge has bored through the layers of the device so that the reference design chip is obliterated.
- An electronic device damaged by ESD might result in a trace being almost severed, causing intermittent operation. Alternatively, ESD can create an actual *open* circuit on this trace.
- By means of practical comparison, wearing a pair of jeans can generate up to 300V of static electricity, while walking on a carpet can generate up to 10,000V.

ESD transients are modeled under several industry standards, including:

- Human Body Model (HBM), based on IEC Standard, IEC 61000-4-2;
- Charged Device Model (CDM); and

- Machine Model (MM).

In turn, different levels of IEC 61000-4-2 standards exist:

- Level 2 is the minimum standard for European consumer electronics.
- The Bourns CG is presently designed to meet the Level 4 standard, but Bourns engineers plan to update the design to meet the Level 6 standard in the near future.

Types of ESD Suppressing Devices

1. Polymer ESD Suppressor

The polymer ESD suppressor uses a printed circuit board (PCB) manufacturing process and discharges polymer space. The processor works through the breakdown of polymer inserted between the electrodes.

Advantages

There are three primary advantages of using a polymer ESD suppressor to protect electronic components from ESD. To accomplish this, the suppressor has the following properties:

- It generates low current leakage.
- It withstands a higher ESD pulse.
- It generates ultra-low breakdown voltage.

Disadvantages

Conversely, there are also three primary disadvantages of using a polymer ESD suppressor to protect electronic components from ESD. These are:

- The PCB manufacturing process, with a minimum chip type of 0603, limits its device size.
- The suppressor generates high trigger voltage.
- The suppressor generates high clamping voltage.

2. MLV ESD Suppressor

The MLV ESD suppressor uses a *thick* film manufacturing process. The processor works through the breakdown of zinc oxide.

Advantages

The greatest advantage of using a conventional MLV ESD suppressor to protect electronic components from ESD is that it generates lower breakdown voltage.

Disadvantages

However, there can be several notable disadvantages of using a MLV ESD suppressor to protect electronic components from ESD, including:

- It tends to generate higher current leakage.
- It provides limited device capacitance (1.5pF).
- It withstands a lower ESD pulse in low-capacitance devices.
- It generates high clamping voltage in low capacitance devices (~100V).

3. TVSD (Transient Voltage Suppressing Diode) ESD Suppressor

Unlike the MLV ESD suppressor, the TVSD ESD suppressor uses a *thin* film manufacturing process, but its processor works through the breakdown of the P/N junction, rather than that of zinc oxide.

Advantages

The two main advantages of using a TVSD ESD suppressor to protect electronic components from ESD include:

- It generates lower trigger voltage.
- It generates lower clamping voltage.

Disadvantages

The disadvantages of using this technology include:

- The suppressor also tends to generate higher current leakage.
- The suppressor also provides limited device capacitance (1.5pF).
- The suppressor is of a limited device size.

4. Air Gap ESD Suppressor

Like the MLV ESD suppressor, the air gap ESD suppressor uses a thick film process and discharges air gaps. The processor works through the breakdown of gas seeping between the electrodes.

Advantages

The four primary advantages of using an air gap ESD suppressor to protect electronic components from ESD are:

- It generates low current leakage.
- It generates ultra-low capacitance.
- It withstands a higher ESD pulse.
- It generates lower clamping voltage.

Disadvantages

On the other hand, the one significant disadvantage of this technology is that the air gap ESD suppressor tends to generate high trigger voltage.

Why Choose Bourns?

For over 60 years, Bourns has grown because of the company's continued commitment to provide value for its customers. Bourns invests in innovative new products through internal development and through strategic acquisition of companies or product lines. It serves hardware markets as diverse as computers and peripherals, telecommunications, POS equipment, and industrial and medical hardware. Bourns' commitment to excellence in design, customer service, and established track record in circuit and ESD protection for at least four decades sets it apart from its competition in terms of quality and integrity.

Indeed, Bourns consistently ranks among the top-rated suppliers in the country, as demonstrated by the abundance of ISO, QS, OHSAS, UL, and other certifications it has received for its product lines. For more information, see http://www.bourns.com/AboutBourns.aspx?name=Certificates and Tables 9 and 10 below.

Multifuse Bus Standards

IEEE 1394	High Performance Serial Bus Standard
USB	Universal Serial Bus Standard

Table 9: Multifuse Bus Standards

Multifuse® Agency Approvals

	UL (Underwriters Laboratories)	**CSA (Canadian Standards Association)**	**TÜV (Technischer Überwachungsverein, Germany**
File Numbers	**E174545**	**CA110338-1**	**9772280**
MF-USMF (USB)	Approved	Approved	Approved
MF-MSMF (USB)	Approved	Approved	Approved
MF-SM	Approved	Approved	Approved
MF-NSMF	Approved	Approved	Approved
MF-R	Approved	Approved	Approved
MF-RX/72	Approved	Approved	Approved
MF-RX	Approved	Approved	Approved
MF-SMDF	Approved	Approved	Approved
MF-S	Approved	Approved	Approved
MF-LS	Approved	Approved	Approved
MF-LR	Approved	Approved	Approved
MF-VS	Approved	Approved	Approved
MF-R/600	Approved	Approved	Approved
MF-RX/250	Approved	Approved	Approved
MF-SVS	Approved	Approved	Approved

Table 10: Multifuse Agency Approvals

Conclusion

Because most computer users neglect using the *Safely Remove Hardware* feature, USB ports are vulnerable to electrostatic discharges caused by manually removing “plug and play” devices. In common user scenarios like this, the principal reasons the Bourns' MF and CG devices together provide the ideal solution for ESD protection include:

- They can protect any two such ports;
- They utilize only 0.5pF, leaving 9.5pF available of the 10pF maximum capacitance for the interface;
- Their MLV technology results in generation of lower breakdown voltage; and
- Their costs are at least competitive with comparable ESD technologies such as polymer, TVSD, and air gap.

Besides USB, ChipGuard is versatile in protecting other applications, as noted in Table 2. Antenna and video interfaces, for example, can take advantage of the same CG ESD suppressors and TVS/Schottky diode solutions as those used in USB port protection.