Preventing Component Circuit Damage from Above Range Current with Reliable Overcurrent Protection
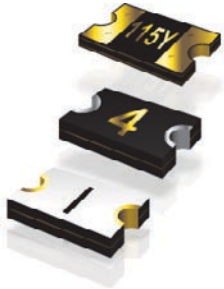
**Multifuse®
Devices**

MF-MSMF

MF-PSMF

MF-FSMF

Introduction

As the demand for electronic components continues to grow in more diverse and complex embedded systems, it becomes crucial to protect sensitive applications against overcurrent conditions. Reliable circuit protection is a fundamental design consideration for cost-effective, long-lasting products. Each time a user plugs in, operates or leaves devices unattended, it is essential that there is a mechanism in place to ensure no above range current damages the very circuits that allow the device to work. Since most applications will not be accessible conveniently for replacement, such as with a conventional fuse or household circuit breaker, the concept of a resettable fuse has been adopted nearly universally. Some interface standards even require resettable overcurrent protection, recognizing and reminding designers in advance about the importance of robust circuit protection. The capability of delivering a smaller, faster, and lighter product than the competition truly begins at the component level, where parts are pushing the envelope with regard to minimal board space requirements and versatile use environments.

Overcurrent and overtemperature conditions are a reality that can lead to costly field failures. Ignoring the need for overcurrent protection is not an option, so the question remains as to how to incorporate this feature without sacrificing the design constraints or objectives. This white paper will detail some of the latest advances in circuit protection technology integrated into Bourns' line of resettable Multifuse® products that now incorporate a new space-saving *freeXpansion*™ manufacturing process.

From the inside out, Multifuse® devices are specifically designed to shield a wide range of applications against the potentially destructive effects of these conditions and provide exceptional protection. Once system requirements are defined and circuit analysis has determined the operating parameters, as illustrated by example in this paper, it is straightforward to select the component appropriate for a given design. A wide range of speed, voltage and current limits among the Multifuse® devices and specific series for products like USB, which by standard requires resettable overcurrent protection, ensures that the ideal component can be incorporated in a given design without sacrificing board real estate.

Multifuse® Devices
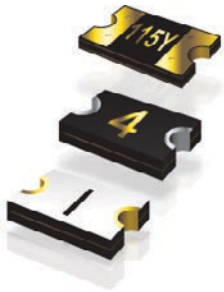
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Inside Multifuse® Resettable Fuse Technology

Multifuse® devices are manufactured from a mixture of polymer, carbon, and other proprietary materials placed in a mold and then "punched" out of the mold. The characteristics of a given Multifuse® device can be customized by adjusting the quantity of each ingredient within the composition or by changing the area of the cutout.

Conductive carbon chains embedded in plastic in the Multifuse® design create an environment of low impedance - 3 milliohms to 8 ohms. The proximity of the carbon chains in this crystalline structure provides for easy current flow and the component offers low resistance at operating current. As is common to many materials, these resettable fuses exhibit a positive temperature coefficient (PTC) effect when heated. As the PTC increases due to current or ambient temperature, the material expands. This expansion increases the impedance from low to high, effectively creating an open circuit with some leakage current.

Unique to resettable fuses such as Multifuse® devices is the exponential rather than linear increase in resistance with rising temperature. The black carbon impregnated in the plastic becomes isolated as temperature increases, turning the crystalline polymer amorphous instead to prevent current flow and thus increasing the resistance at a rate of I_2R. In fact, resistance increases by two orders of magnitude when the circuit trips. It is this transformation of the material from low resistance to high resistance when a Multifuse® device trips, that allows this resettable fuse to protect the load from overcurrent. Once the current is removed, the material will cool and return to its highly conductive low resistance crystalline state.

It is important for designers to understand that after the device has tripped and current is removed, the Multifuse® device must be power cycled to reset. If the power is left on following a trip event, the Multifuse® device does not reset on its own. After an extended period in tripped mode, the component continues generating heat in the tripped state, causing a very high level of resistance that will prevent the device from resetting even after power has been cycled. The proper method for resetting a Multifuse® device is to cycle power to the device typically within one second. When the power source is removed, the device simply resets itself.

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What Makes Multifuse® Devices Unique

Bourns has developed a new manufacturing process technology called *freeXpansion™* that is being rolled out across its surface mount polymer PTC Multifuse® product line. The expansion of materials during a trip and the contraction of materials upon reset occurs without any mechanical restrictions in MultiFuse® devices with *freeXpansion™* technology. Enabling smaller surface mount package sizes, *freeXpansion™* technology made the launch of the new 0603 size family possible. Additional *freeXpansion™* benefits include the ability for Multifuse® devices to handle larger currents and voltages with improved resistance stability.

Bourns' surface mount *freeXpansion™* Multifuse® devices offer a technology advantage in the 0603 package size leading the circuit protection trend in miniaturization as global demand continues to grow. Several series of Multifuse® devices will take advantage of this technology to meet the voltage and current requirements delivering reliable overcurrent and overtemperature protection for a wide range of consumer electronics, automotive electronics, USB interface, and video interface applications. One example of a targeted application is USB 3.0, which was released in November 2008 and specifies higher operating currents than its USB 2.0 predecessor.

Multifuse® Series	Part Number
MF-MSMF	MF-MSMF150/24X-2
MS-PSMF	All
MF-FSMF	All

Table 1: *Multifuse® freeXpansion™ devices*

Selecting the Appropriate Multifuse® Device

The operational life of a Multifuse® device depends on the surge, duration and spike of the current to which it is exposed in a given system. Multifuse® devices have been designed and tested to meet industry standards for the most demanding environments and applications, making the selection of the appropriate device simple from series to specific component. Only the tripping point, voltage requirements, and package size are necessary considerations for Multifuse® device selection. Because a larger chip package results in larger thermal mass, the material heats slower than a smaller package. A smaller package trips faster, although it will have higher resistance for the same holding current. Multifuse® devices are able to trip in a fraction of a second, and the proper Multifuse® component can be chosen to protect the load for a given design based on the maximal allowable trip time. The 0603 package provides a clear advantage for space-constrained applications where reducing board space is a top priority.

Given the expansion of electronic devices and the increase in human interface with those electronics, there is more need for creative overcurrent solutions to ensure efficient use of all system resources. Several examples will illustrate the design and selection process when using Bourns® Multifuse® devices for overcurrent protection.

General Calculations

When numerous loads are sharing the same power supply it can be advantageous to allow each load to operate independently or in subsets instead of hinging the operation of every load on the system current condition. It is possible to instantiate multiple PTCs for multiple nodes sharing a power supply, as shown in the figure below. In this case, Ohm's law will calculate simply the current condition for each node and therefore determine which PTC to choose based on the current in each node.
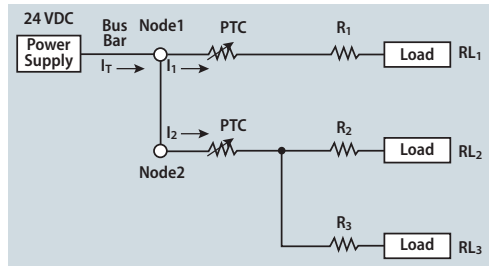

Figure 1: *General PTC example*

For the given example the power supply is 24 V and resistor values are R_1=2 ohms, RL_1=6 ohms, R_2=5 ohms, RL_2=19 ohms, R_3=10 ohms, RL_3=14 ohms. Resistance at Node 1 is given by the series resistance calculation R_1+RL_1=8 ohms. Resistance at Node 2 is given by the parallel resistance calculation $(1/((1/(R_2+RL_2))+(1/(R_3+RL_3))))$=12 ohms. The current IT going into the nodes is equal to the sum of the current going into the nodes and is given by $I_T=I_1+I_2$. Using $V=I_R$ to calculate the current I_1=V/8 ohms = 3 A. I_2=V/12 ohms = 2 A. The total current I_T=5 A. Based on these results, the holding current of the PPTC chosen for Node 1 shall be 3 A or greater and the PPTC chosen for Node 2 shall be 2 A or greater. For each selection it is important to verify that Imax is at least 5 A to meet the current of the system. If the PTC on either of the branches trips then the current flowing in the system is reduced to the current of the remaining operating branch. Had there instead been a single PTC placed between the power supply and Node 1, the selected PTC would require a holding current of I_T=5 A and I_{max} > 5 A. Given that the power supply operates at 24 V nominally, selecting a component with margin is advisable. As such, the appropriate choices would be a 30 V or greater part with Imax > 5 A for the former case and a 30 V or greater part with Ihold > 5 A for the latter case.

There are several Multifuse® product lines geared to meet the demands of a specific application. Power over Ethernet (PoE), USB, and Firewire are three such applications. Selection of the component is quite simple based on the current seen at the various ports in the system.

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Power over Ethernet

For PoE overcurrent protection, one Multifuse® device is specifically designed to meet the 350 mA interface at up to 57 V. The figure below illustrates how one PTC placed at the power supply provides overcurrent protection in a circuit laden with transformers. This overcurrent protection is necessary only at the source.
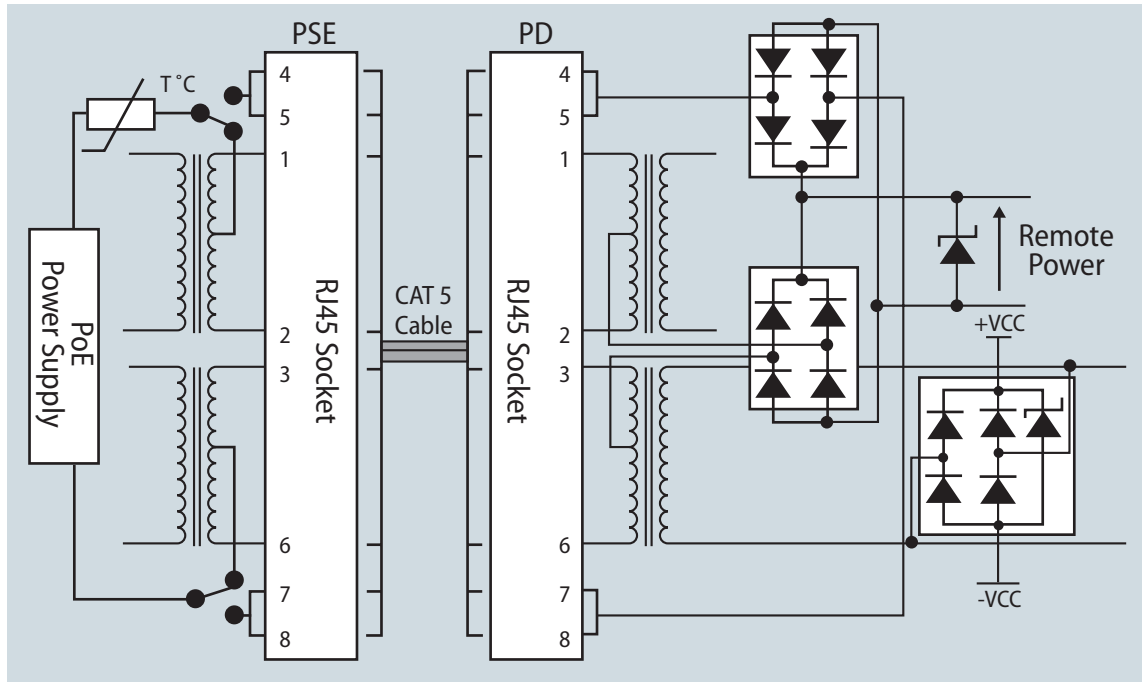
Figure 2: PoE Interface Example

USB

USB is a four-wire interface with a pair of data lines, power, and ground, and it is a requirement that a resettable circuit is used for overcurrent protection. For any design using a USB interface it is only essential to provide overcurrent protection on the power line, and all three power and data lines will utilize overvoltage protection, as illustrated below.
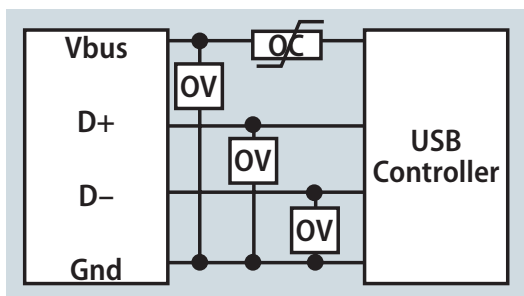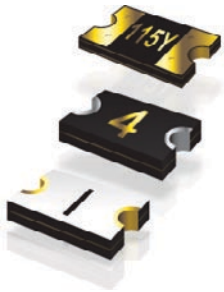
Figure 3: USB Interface Example

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As seen in the general USB interface example, it is possible to use one PTC device for several USB controllers or one PTC device per USB controller. This decision is made based on the resistance and current in each load and the board space available. An additional consideration when choosing a Multifuse® device for a USB application is maintaining a low resistance, namely under 700 milliohms with a voltage drop below 350 mV. With the introduction of USB 3.0, current requirements are greater which may lend designing a dedicated PTC for each line.

Since the USB standard operating voltage is always 5 V, the Multifuse® device's minimum voltage of 6 V provides at least a 20 percent margin (1_V) over the USB required voltage for an additional cushion of protection. The short circuit current as defined by the USB specification is 5 A. After 60 seconds of operation a maximal operating current of 5 A is allowed for a USB port. However the normal operating current for low power ports is 100 mA and for high power ports only 500 mA, both of which are far beneath the 5 A short circuit level.

A wide range of Multifuse® parts are available for USB designs at a 6 V rating. Once the current and trip time for a device are determined it is simple to select the appropriate part. For USB protection, Multifuse® resettable fuses are represented by two product lines which differ in their current handling capabilities:

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-USMF035	6.0	40	0.35	0.75	0.200	1.300	8.00	0.20	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

Features Multifuse® freeXpansion™ Design for MF-USMF Series

Table 2: *MF-USMF Specifications for USB designs*

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Model	V max. Volts	I max. Amps	Hold	Trip	Resistance		Max. Time To Trip		Tripped Power Dissipation
			Amperes at 23℃		Ohms at 23℃		Amperes at 23℃	Seconds at 23℃	Watts at 23℃
			Hold	Trip	RMin.	R1Max.			Type
MF-MSMF110	6.0	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
MF-MSMF150	6.0	100	1.50	3.00	0.030	0.120	8.00	0.50	0.8
MF-MSMF260	6.0	100	2.60	5.20	0.015	0.080	8.00	5.00	0.8

Table 3: *MF-MSMF Specifications*

Firewire

Firewire, also known as IEEE-1394, is similar to USB in its design though resettable fuses are not required. All power sources of the interface require overcurrent protection per the IEEE-1394 standard. The example below illustrates overcurrent protection on the voltage line and overvoltage protection on the voltage and data lines. As with USB, the Multifuse® device is capable of handling overcurrent for one controller or multiple controllers based on the needs of the system and the number of loads. Typically up to four controllers can share a single Multifuse® device. There are four power levels for devices in the Firewire standard, and the maximum of each is 30 V, which is significantly higher than that of USB at 5 V. Current ranges from 100 mA to 1.5 A based on 15 W, 30 W, 45 W, and 3 W maximal power for the four respective power levels.
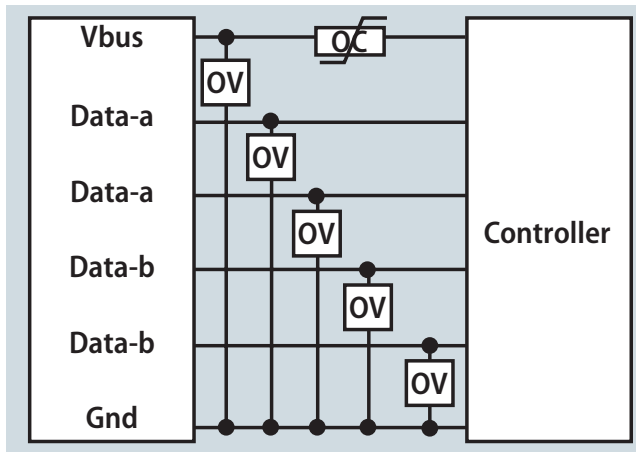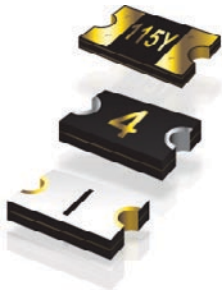

Figure 4: *Block diagram of IEEE-1394 protection*

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Why Choose Bourns

For over 60 years, Bourns has grown continually because of the company's ongoing commitment to provide superior value for its customers. Bourns invests in innovative new products through internal development and through strategic acquisition of companies or product lines. Just one example of the extraordinary research and design capability is the *freeXpansion*™ technology developed by Bourns engineers.

Bourns 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 protection for at least four decades sets it apart from its competition in terms of quality and integrity. Indeed, it is clear why Bourns consistently ranks among the top-rated suppliers in the country.

Conclusion

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*

Table 4: *Selecting the Right Multifuse® Product for an Application*

Protection for overcurrent is essential to the reliability and lifetime of electronics in a wide range of applications. The simplicity with which Bourns® Multifuse® devices fit into overcurrent protection circuits and the new *freeXpansion*™ technology make it an obvious choice. Armed with Ohm's law, interface standards, and a powerful selection for a wide range of current and voltage requirements, it is easy to select the Multifuse® device ideal for providing overcurrent protection in any design.

For further technical support and for complete circuit protection solutions, please visit
www.bourns.com