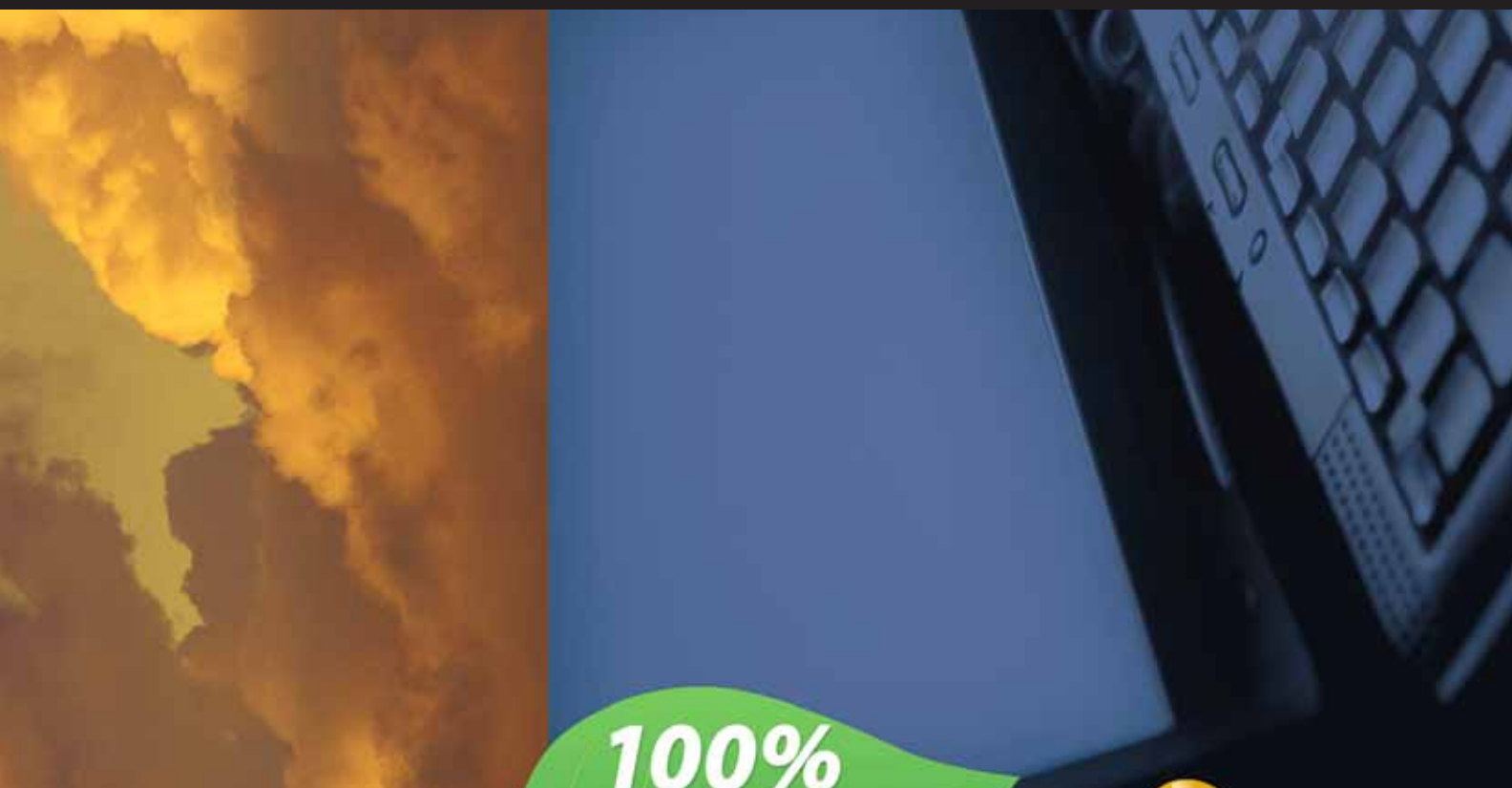


Bourns® Lead Free Multifuse® Polymer PTCs



100%
LEAD
FREE



Circuit Protection Solutions

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Abstract

In today's environmentally conscious world there is a strong movement away from the use of lead in favor of alternative products. This is happening across all industry sectors. We have been introduced to lead free paint, lead free castings, lead free fuel and many other lead free products. As electronic goods become disposable commodities the electronics sector has become the principal driver of this trend. The majority of electronic companies are now evaluating lead free solders. Manufacturers are producing lead free components and the sector as a whole is moving very quickly to lead free electronic devices. Bourns® Multifuse® Polymer PTC product line meets the requirements of the global community with a product family of lead free surface mount products. In terms of Bourns general strategic policy, the movement to a lead free surface mount component is consistent with our overall environmental policy. Our principal manufacturing and design site for Bourns® Multifuse® products is ISO 14001 certified, reflecting our strong commitment to the environment. The effective introduction of the ISO 14001 standard has allowed Bourns to achieve reductions in both environmental risk and costs. Achieving this voluntary registration demonstrates Bourns pledge to the global community and illustrates company environmental awareness.

Introduction

The development of lead free surface mount Bourns® Multifuse® Polymer PTC devices involved converting the tin lead plating on product terminations to a lead free alternative. Strict criteria were developed to guide the selection of the optimum material.

- 1. The lead free termination should have no adverse effect on the ability of the component to solder to an interconnecting substrate.*
- 2. The strength of the bond between the terminal and the substrate must be maintained at the existing high level, significantly above the industry standard (JIS-C-6429).*
- 3. The devices must be compatible with traditional tin lead solders as well as lead free solders.*
- 4. The devices must have the ability to withstand the peak temperature of the standard reflow temperature profile of both types of solder, typically 245 °C for tin lead and 260 °C for lead free.*
- 5. The components should be exposed to the industry accepted accelerated steam aging process (Reference J-STD-002A) to evaluate the long-term durability and reliability of the lead free terminations.*
- 6. Storage under normal conditions (40 °C Max 75 % RH Max) should have no adverse effect on the solderability of the device.*
- 7. Whisker growth should be evaluated by an industry accepted accelerated growth test procedure.*
- 8. The components must be qualified to Bourns internal and independent agency standards (UL, CSA and TÜV).*
- 9. The product must maintain its commercial competitive advantage.*

The tin lead terminations of our 1812 (MF-MSMD) and 1210 (MF-USMD) product families have been replaced with an electroless nickel immersion gold (ENIG) termination that maintains the high performances and quality standards of the existing Bourns® Multifuse® product family. Subsequently, Bourns has released a 2018 (MF-SMDF) and a 1206 (MF-NSMF) product family with ENIG terminations. A second option of a 100 % tin termination is also available on the product families referenced above. The terminations of the larger 3425 and 2920 (MF-SM) product families are only available with 100 % tin plated terminations.

This report details the procedures used to ensure the above criteria were met. The first section outlines the current legislation driving the trend towards lead free products. A brief summary of the European, US, and Japanese lead free legislation is outlined for general information (and is not intended as legal advice). The test and results section details the methods used to ensure the components meet or exceed the relevant industry standards as well as Bourns own internal standards developed over 50 years of component manufacturing and design. A complete section is dedicated to solderability. The objective of this section is to clearly outline how solderability is categorized. Finally the conclusion section outlines the findings and recommendations of our evaluation.

Lead Free Legislation as of 2004

EUROPEAN UNION DIRECTIVE



In parallel to the drive initiated by environmentally conscious corporations, legislation has been drafted to accelerate the change to non-toxic products. This legislation will directly affect the solder, electronic component and assembly industries. The European Union's directive, the Reduction on Hazardous Substances (RoHS) sets phase-out dates for the use of lead (Pb) and several other materials used in electronic products. The RoHS requires that on July 1, 2006, the targeted materials, including lead may no longer be used unless there is an exemption provided in the rule. This legislation has a direct impact on the type of solder and components that can be used in electronic devices.

JAPANESE MINISTRY OF TRADE



The Japanese Ministry of Trade (MITI) has drafted a recycling law for electrical appliances. This does not yet include a phase-out of the use of lead, but it is expected to do so in the near future. The recycling law will require consumer and business users of electrical appliances to return end-of-life goods to retailers or local authorities for recycling. A key factor will be the elimination of lead based products.

US LEGISLATION



Although there is no federal legislation yet in the US, there are a number of states electronics recycling initiatives to consider. In addition, the Environmental Protection Agency (EPA) has recently proposed a crackdown on lead emissions from manufacturing plants. This action may speed the industry to embrace lead free solder much more quickly than originally planned.

BOURNS COMMITMENT TO LEAD FREE COMPONENTS



The remainder of the report outlines the specification of Bourns® surface mount Multifuse® Polymer PTC devices and the procedure used to qualify these devices.

Bourns® Lead Free Surface Mount Multifuse® Polymer PTC Product Portfolio

Bourns® Multifuse® Polymer PTC lead free surface mount components' (MF-SMDF, MF-MSMF, and MF-NSMF) standard metal termination finish is electroless nickel immersion gold (ENIG). The finish gives the components long shelf life and the precious metal topcoat provides excellent electrical connectivity. The ENIG finished components fully comply with the solderability characteristics defined in the joint industry standard ANSI/J-STD-002 Category 2.

Bourns offers an alternative electroless 100 % tin (Sn) termination finish to the standard ENIG finish. This option is available for applications requiring the soldering characteristics of ANSI/J-STD-002, Category 3.

CATEGORY 2 TYPICAL COATING DURABILITY FOR NON-TIN AND NON-TIN LEAD FINISHES

This category is intended for surfaces finished with other than Sn or Sn/Pb coatings that will be soldered after an extended time from the time of testing. Standard Bourns® Multifuse® Polymer PTC surface mount products have an ENIG coated terminal consistent with this category. These parts were tested and found to comply with the tests and procedures outlined in Category 2.

CATEGORY 3 TYPICAL COATING DURABILITY DEFAULT FOR TIN AND TIN LEAD FINISHES

A category intended for surfaces finished with Sn or Sn/Pb coatings, which will be soldered after an extended storage from the time of testing. The Bourns® Multifuse® Polymer PTC devices with an optional Sn finish fall into this category and all products with the optional Sn finish meet or exceed the requirements of this category.

BOURNS® MULTIFUSE® SURFACE MOUNT COMPONENT TERMINATIONS



*MF-SM (Metal Frame)
Product Design
Sn or Sn/Pb Termination.*



*MF-MSMD Product Design
Sn/Pb Termination*



*MF-SMDF, MF-MSMF and
MF-NSMF Product Design
ENIG Termination*

Package Size	Conventional Model Number	Conventional Termination	Lead Free Model Number	Lead Free Termination Material
3425 mils / 8763 mm	MF-SMXXX	Sn/Pb plating	MF-SMXXX-X-99	Sn
2920 mils / 7555 mm	MF-SMXXX	Sn/Pb plating	MF-SMXXX-X-99	Sn
2018 mils / 5050 mm	N/A	N/A	MF-SMDFXXX	ENIG Plating
1812 mils / 4532 mm	MF-MSMDXXX	Sn/Pb plating	MF-MSMFXXX	ENIG Plating
1210 mils / 3225 mm	MF-USMDXXX	Sn/Pb plating	N/A	N/A
1206 mils / 3216 mm	N/A	N/A	MF-NSMFXXX	ENIG Plating
Telecom Surface Mount	MF-SMXXX/250	Sn	MF-SMXXX/250	Sn

PART NUMBER EXPLANATION

MF-SM150/33-2-99

MFBourns® Multifuse® Product Designator

SMThe letters between MF and the digits represent the product series, i.e. MSMD and MSMF 1812, USMD1210, NSMF 1206 and SMDF 2018. SM is common for all Metal (Sn coated Brass) frame designs; no size distinction

150The digits following the product designator represent the hold current of the device for example 150 = 1.5 amps or 110 = 1.10 amps

/33Indicates high voltage model

-2Packaging option -2 = Tape & Reel -1 = Bulk Packaging

-99Lead free option for MF-SM products. For the lead free version of the MF-MSMD and MF-USMD products, please see MF-MSMF, MF-NSMF and MF-USMF*.

Bourns® Lead Free Radial Multifuse® Polymer PTC Product Portfolio



The majority of Bourns® Radial Multifuse® Polymer PTC products are lead free as standard.

The low voltage products (60 V or below) use Sn/Pb solder to attach the metal body to the PTC body. To order these products as lead free simply place a -99 at the end of the part number and the lead will be attached by a Sn/Ag solder. (All radial products manufactured after March 2005 will be lead free as standard so the need to add a -99 at the end of the low voltage product name will no longer be necessary.)

The MF-RX/72, MF-RX/250 and MF-R/600 product families are all lead free as standard.

Model Description	Typical Conventional Model Number	Conventional Specification	Lead Free Model Number	Standard Lead Free Specification
Low Voltage Radial Model	MF-R110-2	Sn/Pb Solder attaches lead to PTC body	MF-R110-2-99	Sn/Ag Solder attaches lead to PTC body
Low Voltage RX series Same Hold Current Higher Voltage Rating	MF-RX110-2	Sn/Pb Solder attaches lead to PTC body	MF-RX110/72-2*	Sn/Ag Solder attaches lead to PTC body
High Voltage Radial Model	MF-RX012/250-2	Sn/Pb Solder attaches lead to PTC body	MF-RX012/250-2	Sn/Ag Solder attaches lead to PTC body
90 Volt R Series	MF-R055/90-2	Sn/Ag Solder	MF-R055/90-2	Sn/Ag Solder attaches lead to PTC body
600 Volt R Series	MF-R015/600-2	Sn/Ag Solder	MF-R015/600-2	Sn/Ag Solder attaches lead to PTC body

* The 72V rated MF-RX/72 product is the lead free equivalent of the MF-RX product.

PART NUMBER EXPLANATION

MF-R110-2-99

MF Bourns® Multifuse® Product Designator

R The letters between MF and the digits represent the product series, the radial series R or the RX series

012 The digits following the product designator represent the hold current of the device for example

110 = 1.10 amps

/250 = Standard rated part, /250 = 250 Volt interrupt rated part

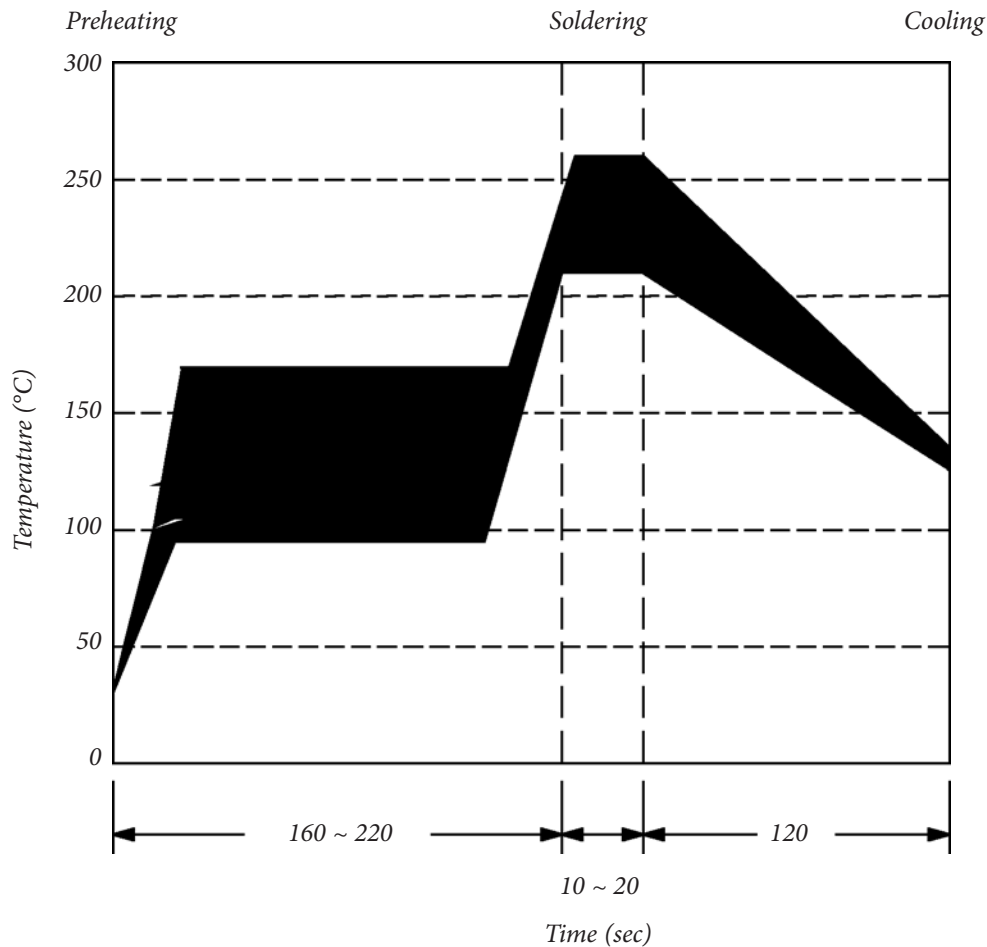
-2 Packaging option -2 = Tape & Reel -1 = Bulk Packaging

-99 Lead Free Option

IMPROVED HEAT RESISTANCE

The new lead free plated Bourns® Multifuse® Polymer PTCs have the ability to be reflow soldered with both lead and lead free solder pastes (e.g. Sn/Ag/Cu). Both types of solder paste require the components to withstand reflow temperatures of 245 °C and 260 °C.


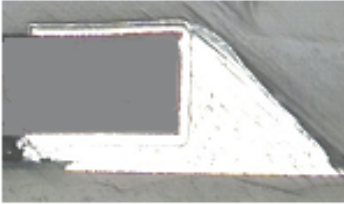
RECOMMENDED REFLOW PROFILES



LEAD FREE SOLDER PASTE

Bourns® Multifuse® Polymer PTCs can be reflow soldered with the majority of commercially available lead free solder pastes. Bourns refers to 96.5/3.5 Tin/Silver as lead free solder paste. 96.5/3.5 Tin/Silver solder paste was used for all lead free testing documented in this paper. For information concerning other specific

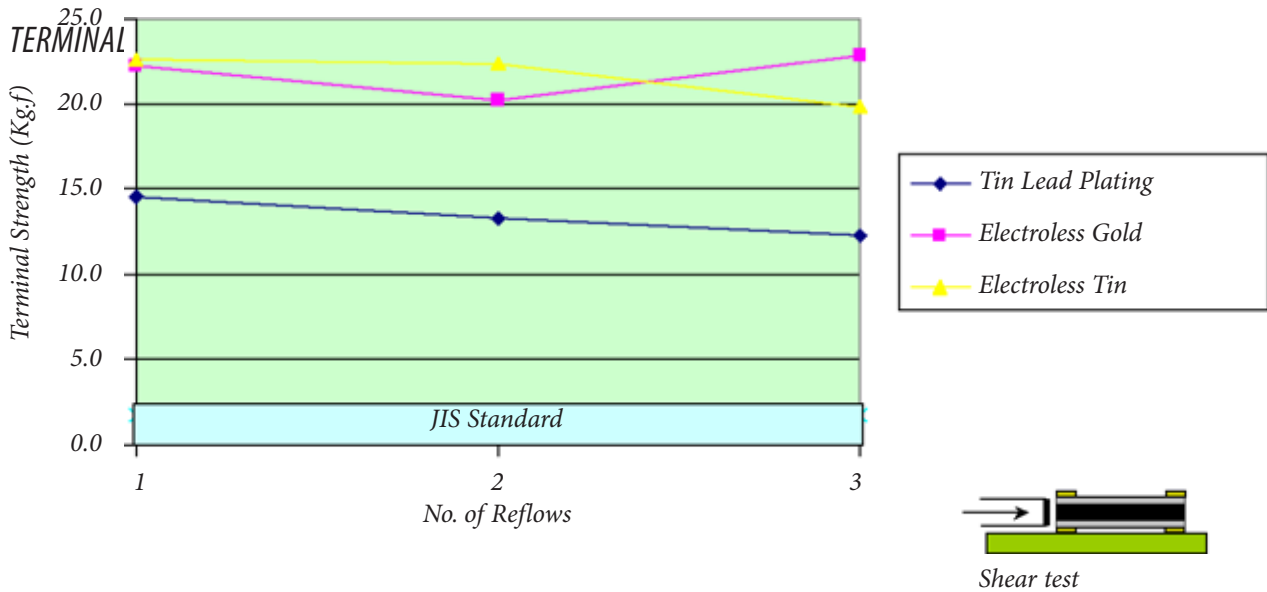
grades of lead free solder pastes please contact your local Bourns representative.

CR Model	MF-MSMD	MF-MSMF
Termination Bonding Solder Paste	 Sn/Pb solder paste	 96.5/3.5 Tin/Silver solder paste

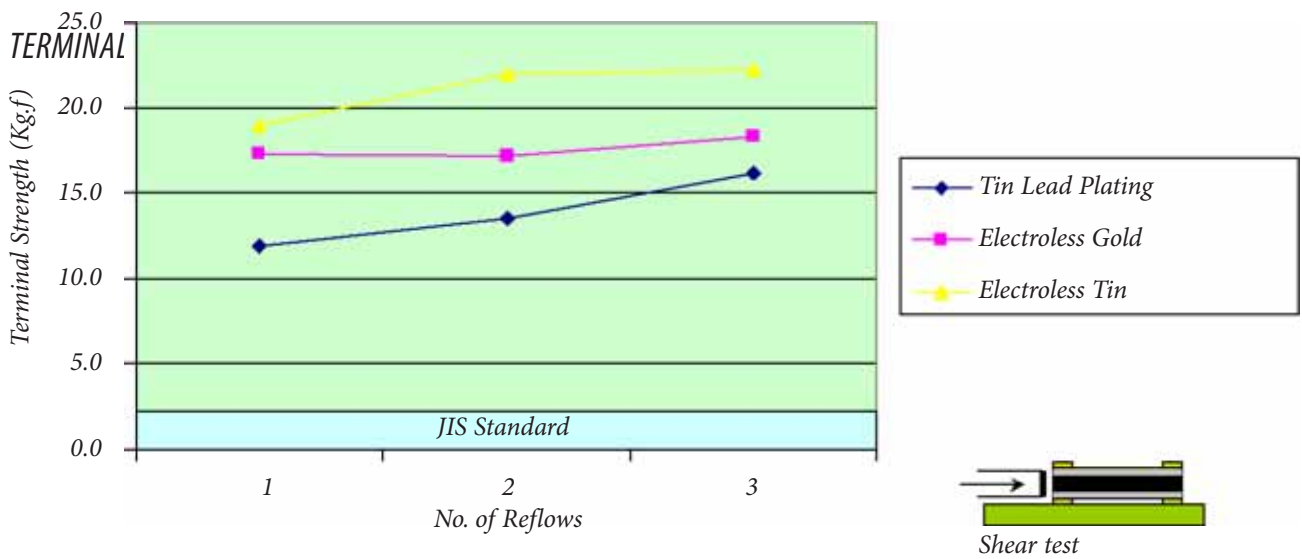
Test Results

TERMINAL STRENGTH TEST COMPARISON BETWEEN LEAD AND LEAD FREE PLATED PRODUCTS

Both tin lead and lead free plated Bourns® Multifuse® Polymer PTCs form solder joints with terminal strength values in excess of the specification of the JIS-C-6429 standard (also used in AEC-Q200 Rev B). The castellated design of the lead free plated Polymer PTCs show further improved terminal strength of the solder joints when compared to the tin lead plated products.



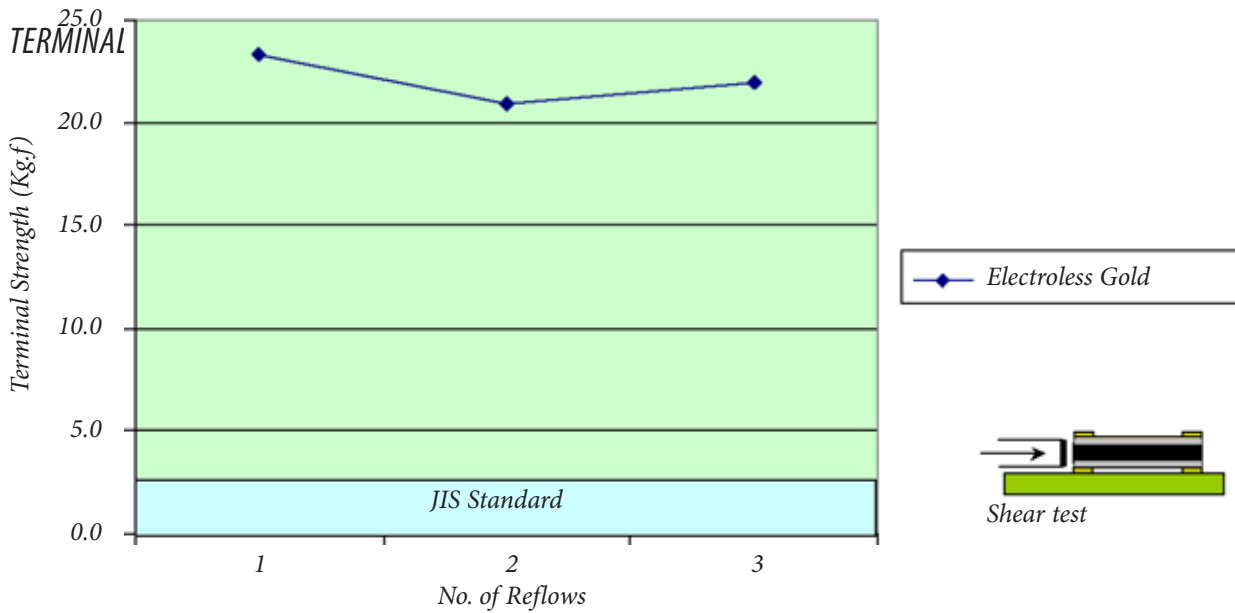
- ...> Parts reflowed using a lead free 96.5/3.5 solder paste
- ...> Parts reflowed using the recommended reflow profile



- ...> Parts reflowed using a lead 63/37 Sn/Pb solder paste
- ...> Parts reflowed using the recommended reflow profile

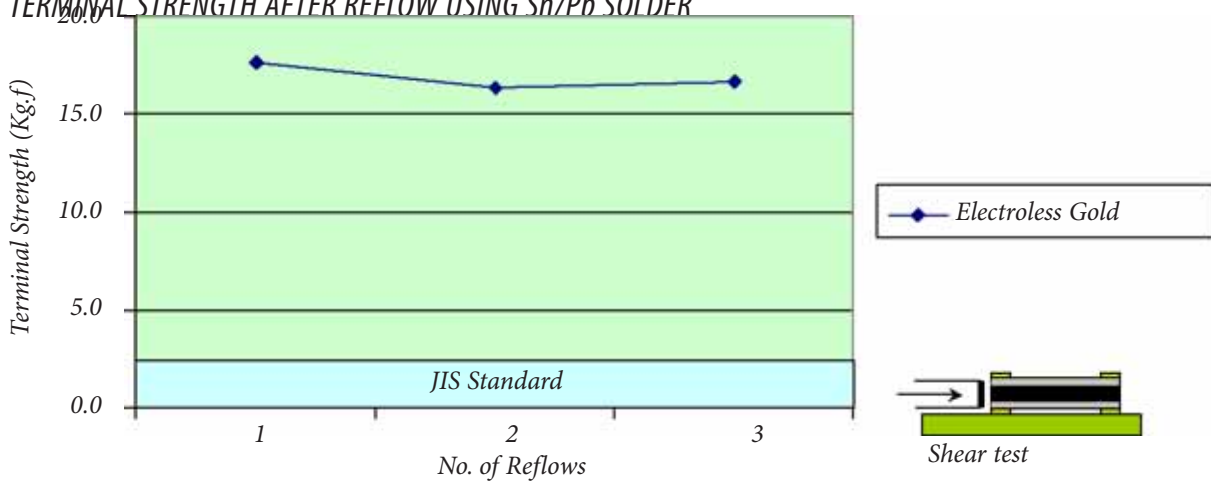
TERMINAL STRENGTH TEST OF LEAD FREE PLATED PRODUCTS AFTER STEAM AGING

The electroless gold plated Bourns® Multifuse® Polymer PTCs show no significant reduction in the terminal strength of the solder joints after being subjected to a 72-hour steam age test (85 °C, 85 % humidity).



- ...> Parts reflowed using a lead free 96.5/3.5 solder paste
- ...> Parts reflowed using the recommended reflow profile

TERMINAL STRENGTH AFTER REFLOW USING Sn/Pb SOLDER



- ...> Parts reflowed using a lead 63/37 Sn/Pb solder paste
- ...> Parts reflowed using the recommended reflow profile

TIN WHISKER GROWTH ACCELERATED TEST

Bourns® Multifuse® Polymer PTC lead free surface mount components standard metal termination finish is electroless nickel immersion gold (ENIG). However, since components may also be supplied with a 100 % tin (Sn) finish, tests must be performed to measure the propensity of the tin plating to grow whiskers.

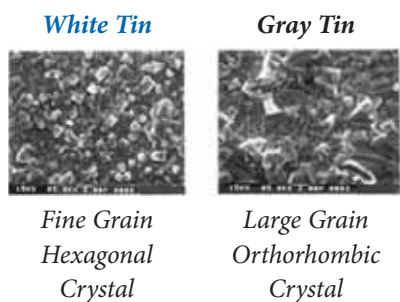
Two sets of tests were carried out to accelerate tin whisker growth:

- ...> Temperature cycle test: 500 cycles, 1 cycle= [-35 °C 7 min, 23 °C 5 min, 125 °C 7 min, 23 °C 5 min]
- ...> Temperature humidity: 85 °C , 85 % RH, 500 hours

The tests match the requirements in the SONY SS-00254 method.

Microscopic and scanning electron microscopic inspections following the tests showed no significant growth of tin whiskers in any Sn finished Bourns® Multifuse® Polymer PTC surface mount components.

Bourns® Multifuse® Polymer PTC components are plated with a white immersion tin process. This process has gained widespread acceptance as a coating. Some of the advantages of white tin include superior solderability, long shelf life and reworkability. The coating can withstand multiple heat cycles and can be used with all of the leading industry solder profiles. Immersion white tin is formulated to create a fine, dense grain structure that is stable and works to suppress the growth of an intermetallic layer. This distinguishes it from traditional tins, which have a porous structure that is unstable and insufficient to suppress the intermetallic layer. This fine grain structure allows immersion white tin to resist the dendritic growth or "tin whiskers" that can be a problem for other tins. A component coated with immersion white tin will have a solderable shelf life of more than one year. Bourns® PTCs are manufactured with an annealed process step



designed to prevent tin whisker growth.

SOLDERABILITY

To evaluate the durability and reliability of any electronic component termination finish, solderability and steam age tests are conducted on the component. Bourns® Multifuse® Polymer PTC Components with the ENIG finish and with the 100 % Sn finish have undergone extensive solderability testing. All of Bourns® Multifuse® Polymer PTC lead free surface mount components have been found to be compliant with the Joint Industry Standard, J-STD-002A. The title of the standard is Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires. The EIA soldering Technology Committee (STC) and the Component and Wire Solderability Specification Task Group of IPC developed the joint industry standard to establish procedures to assess the solderability of electronic components.

The tests outlined in the standard evaluate the resistance of the surface finish of the termination to dissolution of metallization; determination is made to verify that the metallized terminations will remain intact throughout the assembly soldering process. Compliance to the standard also indicates that subsequent storage will have no adverse effect on the ability of the components to solder to an interconnecting substrate. Steam age testing enables evaluation of the storage life capability of the components. Steam aging is used to accelerate the degradation of the metal surfaces in a similar manner to natural aging. The degradation mechanisms of surface oxidations and intermetallic growth are both enhanced by the heat and humidity of steam. The standard outlines a number of steam aging categories for a range of component leads and terminations. In this regard two categories apply to Bourns® Multifuse® Polymer PTC lead free surface mount components:

Category 2 Typical Coating Durability for Non-Tin and Non-Tin Lead Finishes.




This category is intended for surfaces finished with other than Sn or Sn/Pb coatings, which will be soldered after an extended time from the time of testing. Bourns® standard Multifuse® Polymer PTC surface mount products have an ENIG coated terminal so they fall into this category. These parts have been tested and have been found to comply with the tests and procedures outlined for the category.

Category 3 Typical Coating Durability Default for Tin and Tin Lead Finishes.

A category intended for surfaces finished with Sn or Sn/Pb coatings, which will be soldered after an extended storage from the time of testing. The Bourns® Multifuse® Polymer PTC devices with the optional Sn finish fall into this category; all products with the optional Sn finish meet or exceed the requirements of the category.

ADDITIONAL TESTING

In addition to the solderability tests, the components have been fully tested to our own internal qualification tests and the independent agency tests outlined below. Bourns® Multifuse® Polymer PTC surface mount components with a Sn finish have also been subjected to a tin whisker accelerated growth test procedure. They have been subjected to temperature cycling tests and constant temperature/humidity test procedures and in each case complied with or exceeded the existing industry standards.

UL	CSA	TÜV
file number E 174545S	file number CA 110338	file number R2057213
		

Conclusion

Bourns continues to demonstrate its environmental consciousness to the greater community by developing more environmentally friendly products. This document highlights the lead free construction of the new surface mount Bourns® Multifuse® Polymer PTCs and their ability to be assembled with both lead and lead free solder pastes and reflow profiles. The tests completed ensure the components meet the guidelines for suppliers transitioning to lead free components as outlined in the EMS Forum on Lead Free PCB Assembly. In general this document highlights the continued dedication of Bourns to produce robust and reliable components without compromising either performance or reliability.

References

This document was made with reference to the following documents:

- *Sony SS-00254*
- *EMS Forum – Guidelines for Suppliers Transitioning to Lead Free Components, Rev 1.0*
- *IBM Server & Storage Systems Environmental Requirements for Purchasing Electronic Components (including restriction on hazardous materials RoHS)*
- *Directive 2002/95/EC of the European Parliament and of the Council of January 27, 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment*

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