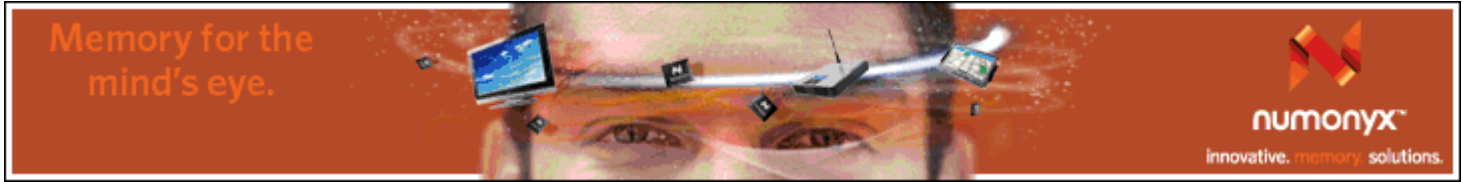




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[Engineering Essentials]

Bolster Overcurrent Protection With Chip Fuses

The accuracy, stability, and repeatability of the fusing characteristic are key to selecting the best fuse for the application.

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Chip fuses assume two roles in electronics: protecting end users from injury, and preventing damage to circuitry. These functions benefit both the owner and the vendor of a given piece of equipment.

Over the last 10 years, market demand for electronic devices serving information technology, mobile, and consumer applications has risen dramatically. Alongside the rapidly increasing demand comes the greater risk of unexpected conditions in electronic devices. Other electronic devices mostly cause these conditions, creating hazards like electrical overloads that demand protection via overcurrent devices such as chip fuses.

CHIP FUSE DESIGN PRINCIPLES

Before analyzing the electrical properties of the various chip fuses on the market, it's important first to understand the design principles underlying each technology.

Standard melting fuses may be based on a metal wire inside a capped ceramic or glass tube filled with air or sand. Chip fuses, on the other hand, employ completely different principles. Most chip fuses look like standard chip components and are built using either a single-layer or multilayer ceramic substrate. Some older designs are based on epoxy fiberglass substrates similar to printed circuit boards (PCBs).

The fusing element on top of the single-layer or inside the multilayer substrate is based on a highly conductive material such as copper, gold, or an alloy like copper-tin (Cu-Sn) or silver-palladium. These composite materials can increase the fuse's ability to withstand inrush current. However, they also tend to be less stable in their response to thermal stress, which heightens the possibility of incorrect opening after multiple inrush cycles.

Depending on the type of substrate, the fusing element may be a laser-trimmed thick-film deposit or a chemically etched metal layer to achieve the desired characteristic. Bonded gold wire may also be used. The shape and thickness are determined so the element will melt in a certain time under overload conditions, if the electrical current reaches a certain level.

To fulfill its role as the functional layer of the chip component, the fusing element must also be protected against environmental conditions. In the case of a single-layer chip fuse, the element is usually covered with a lacquer or epoxy. The fusing elements of multilayer chip fuses tend to receive inherent protection from the substrate layers. Since chip fuses can be rated for currents up to the 7- to 8-A range, they need surface-mount device (SMD) contacts with low ohmic resistance.

The fusing characteristic is the most important property of a chip fuse ([Fig. 1](#)). This defines the melting times at certain levels of electrical overcurrents. If the current reaches a certain predetermined level, the electrical power dissipated within the fuse element is sufficient to melt and vaporize the element within a known duration called the pre-arc time.

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KEY PERFORMANCE PARAMETERS

The fusing characteristic shown in [Figure 1](#) has two main regions. The first region, to the left of the blue curve, includes normal “transparent” operation within the green-shaded area as well as short overcurrent conditions up to twice the rated current of the fuse. This region defines the pulse-load capability of the chip fuse, and it depends on the properties of the fuse element. For example, a high pulse-load capability can be achieved by increasing its cross section.

The blue line defines the melting times for overload and short-circuit currents above the rated current of the fuse (IR), which is 5 A for the fuse illustrated. The energy required to melt the fuse is governed by I^2T . So as the value of the overcurrent rises, the opening time for the fuse becomes shorter.

Typically, the fuse is expected to open within one to three seconds when it's exposed to twice its rated current. At 10 times the rated current, it should open in less than 0.1 ms. From the opposite point of view, to prevent the fuse opening when it's exposed to a normal inrush current, the maximum I^2T of the inrush pulse should be approximately less than 50% of the maximum rated I^2T for the fuse. The melting time of the fuse is related to the thermal resistance between the fuse element and the environment, which depends on the characteristics of the fuse element, substrate, sealing, and terminations, as well as the layout of the PCB. As a result, the opening time, and therefore the effectiveness of the protection that's provided, depends both on the production technology and the product's design.

If the thermal resistance between the fuse element and the environment is too low, there will be insufficient energy to melt the fuse element. This will prevent the fuse from cutting off overload currents equivalent to double the rated current below 120 seconds. [Figure 2](#) and [Figure 3](#) illustrate this case for multilayer chip fuses as well as for laser-trimmed thickfilm chip fuses.

In practice, however, the accuracy, repeatability, and stability of the fusing characteristic depend strongly on the design of the fusing element and the production technology used. Understanding the influence of these two factors holds the key to selecting the optimum chip fuse for a given application.

The stability of the fusing characteristic is closely linked to the component design. Repeatability, on the other hand, depends mostly on the stability and precision of the chip fuse production technology.

STABILITY

What does “stability” mean with respect to the fusing characteristic? The electrical resistance of the chip fuse is the parameter that determines its fusing properties. Due to the fact that the applied energy under overload conditions is proportional to the resistance value, a fuse will melt more quickly with increasing resistance. Conversely, reducing the resistance will produce a slower melting time.

Experience with thick-film resistors has shown that thermal stresses such as short-time overloads, soldering heat, and pulse stresses tend to produce a positive drift in electrical resistance. These phenomena occurring in a chip fuse will therefore change its characteristic, resulting in shorter melting times.

Continue to page 2

Fuse elements incorporating a mix of different materials, such as copper-tin alloys, are designed to achieve a high value of I^2T . Yet they're particularly sensitive to shorter opening times after successive thermal stresses because the stresses induce migration of the constituent materials.

[Figure 4](#) illustrates the ongoing migration process of Cu-Sn after pulse-load stress. Depending on the magnitude and duration of the power load, these types of fuses change their fusing characteristics to faster melting times. Techniques to preserve the stability of chip fuse resistance value will prevent such drifting of the fusing characteristic.

REPEATABILITY

During the design-in process, electronic engineers face high variations of fusing characteristics. Generically, chip fuses are resistors of low ohmic value, having resistances down to the milliohm range. As explained above, the fusing characteristic is related to the resistance value. If there's a wide variation of resistance value, there will be a corresponding wide variation of fusing characteristic.

Due to this variation in resistance value, a chip fuse may open during normal inrush current. Or, conversely, it may fail to open when necessary during an overload condition. This, of course, is the worst-case situation, which engineers must avoid. [Figure 5](#) illustrates the typical spread of fusing characteristics for printed thickfilm fuses.

SOLVING STABILITY AND PRECISENESS OF FUSING CHARACTERISTIC

Thin-film technology can meet all of the requirements in relation to the advanced stability and preciseness and narrow spread of the fusing characteristic. Thin-film sputtering technology has been used to produce highly stable and precise thin-film resistors since the end of the 1960s, and several billions of these devices are now deployed in harsh environmental conditions in all fields of electronics.

Current sputtering techniques benefit from key advantages, such as tight control over the deposit thickness, and achieve a homogenous crystalline structure in the resulting metal layer. When using thinfilm technology to create chip fuses, these attributes directly influence the stability and narrow spread of fusing parameters.

However, tight control over the geometry of the fuse element is also necessary to control the rated current of chip fuses. Structuring of the fuse element using a photolithographic process offers the ability to produce precise geometric contours and dissolve unused conductive material between the terminations.

Using photolithography, the length and width of the fusing element can be controlled with the same accuracy and precision as the thickness of the sputtered thin-film layer. [Figure 6](#) shows how the photolithographic process used to produce the Vishay MFU series thin-film chip fuses creates a fuse element with a clean and clear shape.

SHAPE OF AN MFU FUSE ELEMENT

By combining thin-film sputtering technology with photolithography, component manufacturers can achieve tight tolerances on fuse element geometries. At the same time, they can ensure a homogeneous crystalline structure of the fuse element.

This delivers the twin benefits of minimizing stress-induced deviations in the resistance value as well as promoting repeatability in manufacturing. [Figure 7](#) illustrates the resulting close correlation between minimum and maximum blow times for MFU series chip fuses produced using this combination of techniques.

SUMMARY

Thin-film technology is an established technology for high-grade passive components, and it has been proven and refined over decades. Its advantages in terms of accuracy, repeatability, and stability are appreciated in mass production for billions of thin-film resistors every year.

Chip fuses produced in thin-film technology now deliver similarly predictable properties in terms of the stability and narrow spread of the fusing characteristic. With this proven technology embodied in next-generation safety devices for overcurrent protection, power electronics designers can achieve higher levels of safety and performance in new product designs.

fig 1

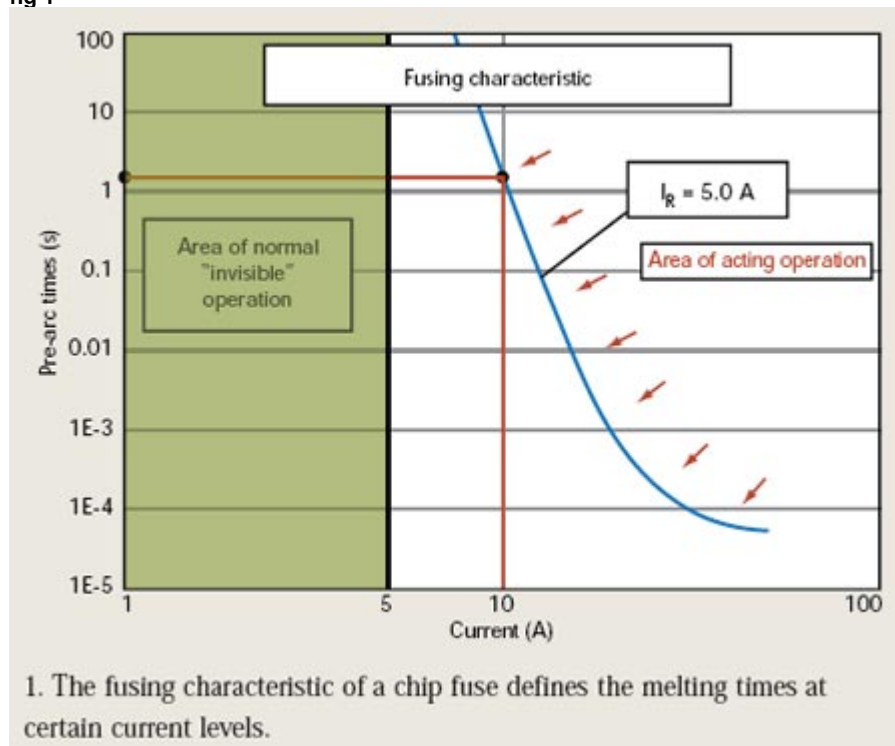


fig 2

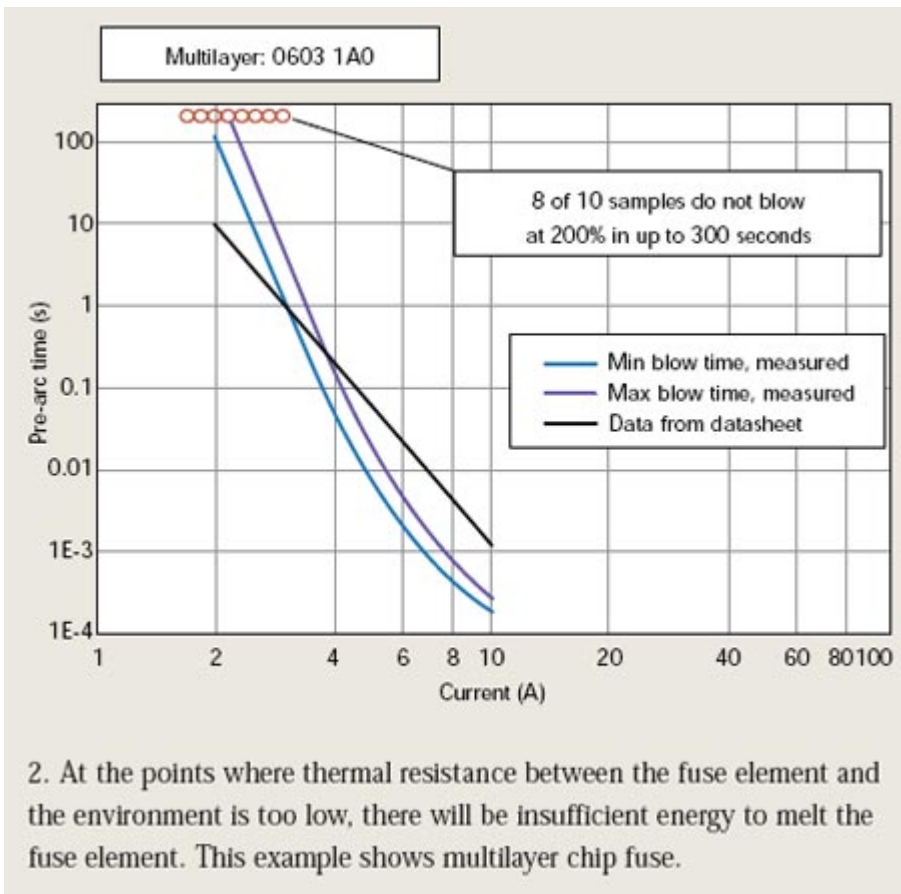


fig 3

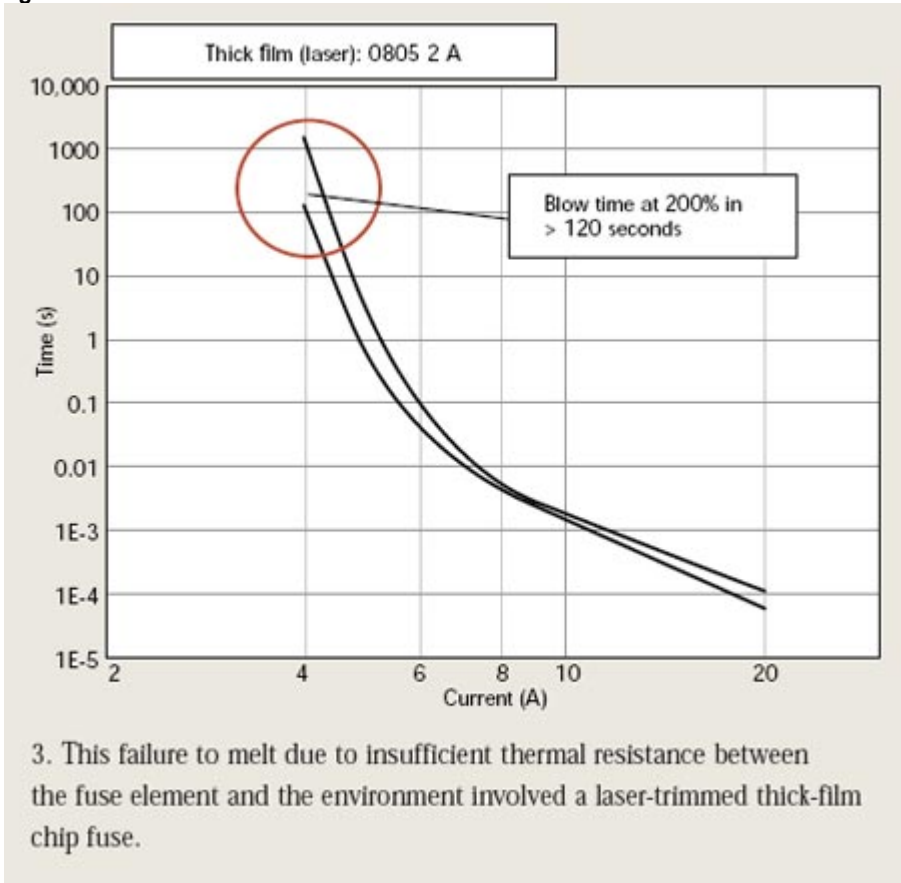
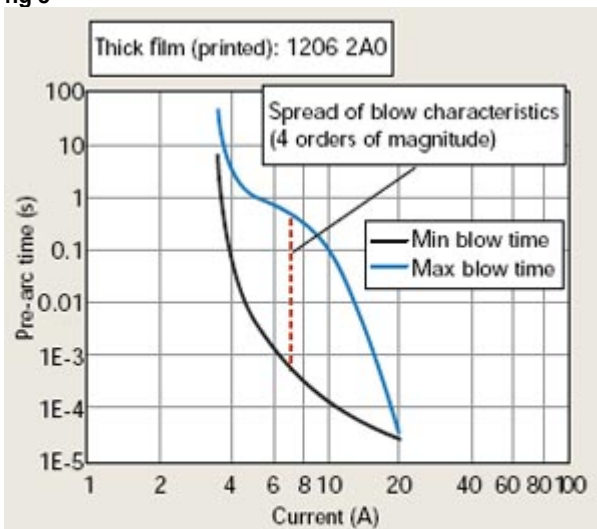


fig 4



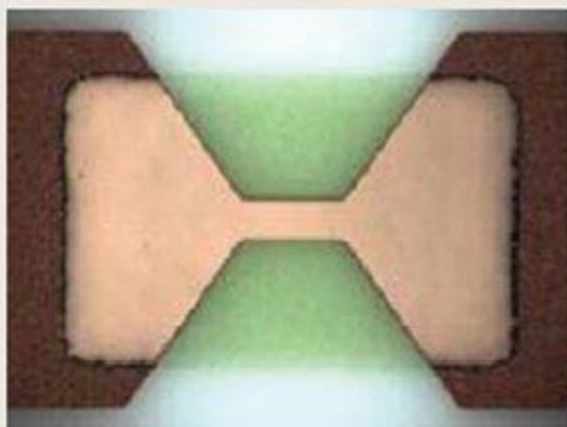
4. Copper-tin (Cu-Sn) alloys are particularly sensitive to shorter opening times after successive thermal stresses, which induce migration of the constituent materials.

fig 5



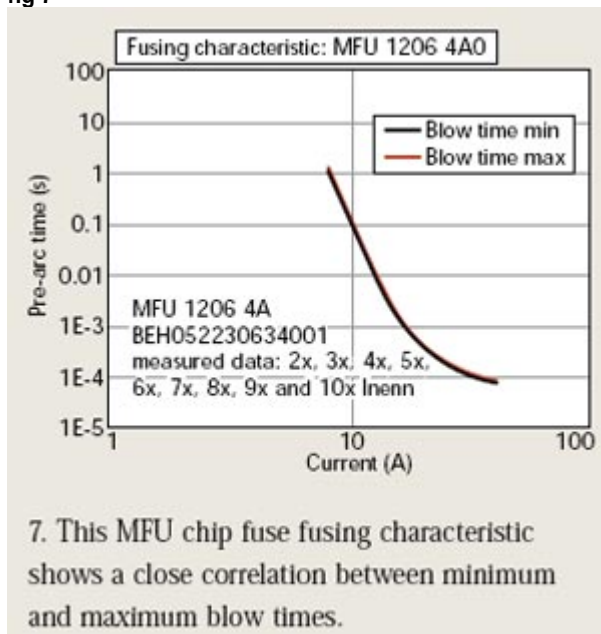
5. This kind of spread is typical of fusing characteristics for printed thick-film fuses.

fig 6



6. The photolithographic process used to produce the Vishay MFU series thin-film chip fuses creates a fuse element with a clean and clear shape.

fig 7



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