Overcurrent Protection with Thin Film Resistors Technology

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CHIP FUSE DESIGN PRINCIPLES

Before analysing the electrical properties of the various types of chip fuses on the market, it is 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 have the appearance of 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.

The elementary fusing element on top of the single layer or inside the multi layer substrate is based on a highly conductive material such as copper, gold, or an alloy such as copper-tin or silver-palladium. These composite materials can increase the fuse's ability to withstand inrush current but also tend to be less stable in their response to thermal stress, which increases 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 that the element will melt in a certain time under overload conditions, if the electrical current reaches a certain level.

To fulfil 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 7 A to 8 A, SMD contacts with low ohmic resistance are required.

FUNCTIONALITY OF CHIP FUSES

Chip fuses have two roles in electronic products: to protect end users from injury and to prevent damage to electronic circuitry. These functions hold benefits for both the owner and the vendor of a given piece of equipment. Over the last ten years market demand for electronic devices serving information technology, mobile and consumer applications has increased dramatically. Alongside this rapidly increasing demand, the risk of unexpected conditions in electronic devices has also grown. These unexpected conditions are mostly caused by other electronic devices, creating hazards including electrical overloads that demand protection using overcurrent devices such as chip fuses.

The fusing characteristic, as shown in figure 1, is the most important property of a chip fuse. 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 vaporise the element within a known duration called the pre-arc time.

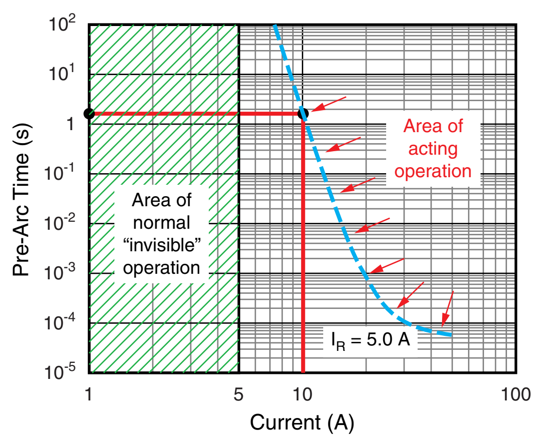

Fig. 1 - Fusing Characteristic

KEY PERFORMANCE PARAMETERS

Referring to the fusing characteristic shown in figure 1, there are two main regions. The first region, to the left of the dashed curve, includes normal 'transparent' operation within the 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 is dependent upon the properties of the fuse element: e.g. a high pulse-load capability can be achieved by increasing its cross section.

The dashed line defines the melting times for overload and short-circuit currents above the rated current of the fuse (I_R), which is 5 A for the fuse illustrated. The energy required to melt the fuse is governed by I^2t; hence as the value of the

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overcurrent increases, the opening time for the fuse becomes shorter. Typically, the fuse is expected to open within 1.0 s to 3.0 s when exposed to twice its rated current. At 10 times rated current, it should open in less than 0.1 ms. From the opposite point of view, to prevent the fuse opening when 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 is dependent upon the characteristics of the fuse element, substrate, sealing and terminations, and also the layout of the printed circuit board. Hence the opening time - and therefore the effectiveness of the protection provided - depends both on the production technology and the design of the product. 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 s. Figures 2 and 3 illustrate this case for multilayer chip fuses and laser-trimmed thick film chip fuses.

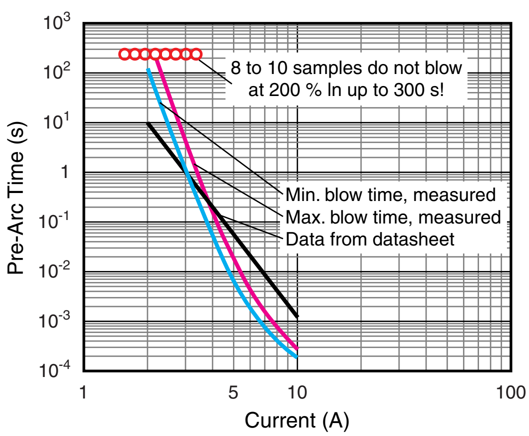


Fig. 2 - Multilayer Chip Fuse

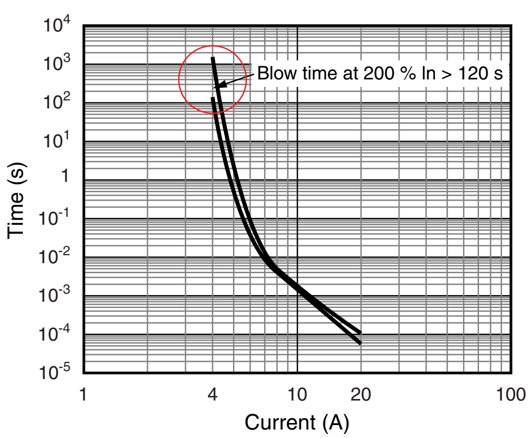


Fig. 3 - Thick Film Chip Fuse (trimmed)

STABILITY AND REPEATABILITY

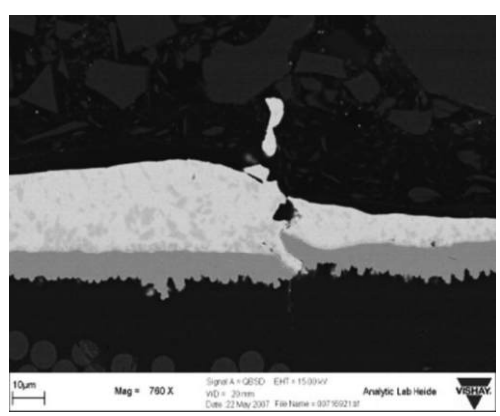
In practice, however, the accuracy, repeatability and stability of the fusing characteristic depend strongly on the design of the fusing element and the production technology used. Understanding the influence of these two factors holds the key to selecting the optimum chip fuse for a given application.

The stability of the fusing characteristic is closely linked to the component design, whereas its repeatability depends mostly on the stability and precision of the chip fuse production technology.

STABILITY

It is first necessary to understand the meaning of the term stability in relation 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. Although fuse elements incorporating a mix of different materials, such as copper-tin alloys, are designed to achieve a high value of I^2t, they are particularly sensitive to shortening of the opening time after successive thermal stresses. This is because the stresses induce migration of the constituent materials, as shown in picture 1, which 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.



Pic. 1 - Sn-Dot Technology after Pulse Stress

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REPEATABILITY

During the design-in process, electronic engineers are faced with 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 is a wide variation of resistance value there will be a corresponding wide variation of fusing characteristic. Due to this variation it can happen that a chip fuse will open during normal inrush current or, conversely, may fail to open when necessary during an overload condition. This, of course, is the worst case situation, which engineers must avoid. Figure 4 illustrates the typical spread of fusing characteristics for printed thick-film fuses.

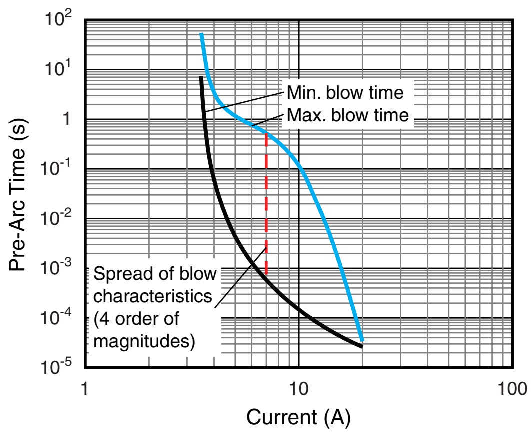


Fig. 4 - Thick-film Chip Fuse (printed)

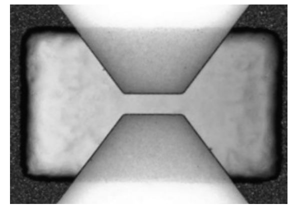
SOLVING STABILITY AND REPEATABILITY CHALLENGES

Thin film technology can meet all the requirements in relation to advanced stability and precise repeatability 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 thin film technology to create chip fuses, these attributes directly influence the stability and repeatability 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 to 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.

Picture 2 shows how the photolithographic process used to produce the Vishay MFU series thin film chip fuses creates a fuse element having a clean and clear shape.



Pic. 2 - Shape of an MFU Fuse Element

Combining thin film sputtering technology together with photolithography allows component manufacturers to achieve tight tolerances on fuse element geometries at the same time as ensuring a homogeneous crystalline structure of the fuse element. This delivers the twin benefits of minimising stress-induced deviations in the resistance value as well as promoting repeatability in manufacturing. Figure 5 illustrates the resulting close correlation between minimum and maximum blow times for MFU-series chip fuses produced using this combination of techniques.

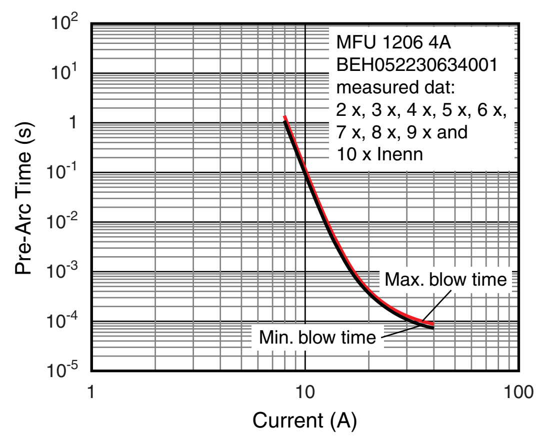


Fig. 5 - MFU Fusing Characteristic (minimum and maximum)

FINISHING

As a further advantage of adopting identical production processes as those used to build thin film resistors, finishing processes including sealing, marking, and plating of low ohmic terminations are followed by automatic optical inspection and resistance measurement performed on every chip fuse produced. Only chip fuses meeting the high quality requirements and tight resistance tolerances that Vishay has established for thin film resistors are laid into paper tape. The packing process assures that these thin film chip fuses will exhibit the expected performance in the field, as and when necessary, to protect both the end user and the equipment vendor from the consequences of dangerous overload conditions.

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SUMMARY

Thin film technology is an established technology for high-grade passive components, which has been proved 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 repeatability 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.

ABOUT VISHAY INTERTECHNOLOGY, INC.

Vishay Intertechnology, Inc., a Fortune 1000 Company listed on the NYSE (VSH), is one of the world's largest manufacturers of discrete semiconductors (diodes, rectifiers, transistors, and optoelectronics and selected ICs) and passive electronic components (resistors, capacitors, inductors, sensors, and transducers). These components are used in virtually all types of electronic devices and equipment, in the industrial, computing, automotive, consumer, telecommunications, military, aerospace, and medical markets. Its product innovations, successful acquisition strategy, and ability to provide "one-stop shop" service have made Vishay a global industry leader. Vishay can be found on the internet at www.vishay.com.

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