SMD Fuse
for Space Applications

Introduction

Fuses for over-current circuit protection have been used in space applications for a considerable period of time. With the MGA-S and as a manufacturer of passive components, SCHURTER is not only able to provide a fuse product, which meets all requirements for this industry but is also qualified according to ESCC Generic Specification no. 4008. As a listed supplier at ESCC and as a European fuse supplier, SCHURTER offers a product that is made using thin-film technology. The standard version for industrial applications has been on the market since 1990 and has annual sales of more than one million pieces. This clearly demonstrates a stable manufacturing process together with operation at a high quality level. For the space version, where only narrow tolerances in the manufacturing process are accepted, 8000 fuses have been manufactured and passed through the screening procedure. The customer TESAT in Germany has reported no failures to date. This article gives an insight into the fuse's technical data, its design, manufacturing process and application information.

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Technical Data

For its type (Fig. 1) the fuse is very small (3.2 x 1.55 x 1.55 mm or a 1206 footprint) and is intended for use in both direct (DC) and alternating (AC) current circuits. They are capable of operation in an ambient temperature range of -55 °C to 150 °C including high vacuum environments (≤ 50 mTorr).

Fig. 1: MGA-S Fuse

- The current range extends from 140 mA to 3.5 A for continuous operation. Based on the rated current, the recommended derating curve is shown (Fig. 2). The fuse can be operated at its rated current indefinitely, this being in accordance with the IEC definition of rated current.

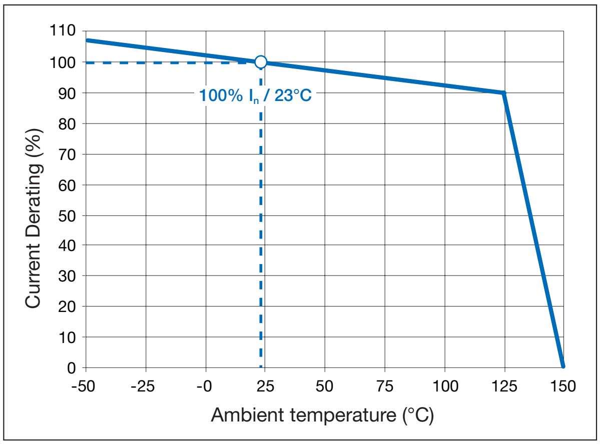

Fig. 2: Derating Curve

In contrast, one of the requirement of UL 248-14 is that a fuse must operate at its rated current (1.0 x In) for at least four hours. After this time, the fuse should be able to open and disconnect the circuit. This means, therefore, that a UL type fuse should not be operated continuously above 70% of its rated current. The previous definition of the current range which is not in use anymore was from 200 mA to 5.0 A which were in accordance with the UL definition of rated current. For the standard model MGA, the UL definition of rated current still applies.

- An important feature of a fuse is the value of its voltage drop and cold resistance. For both values the minimum and maximums are given. With the following formula, heat dissipation can be calculated:

$$P_{\text{Heat Dissipation}} = U_{\text{Voltage Drop}} * I_{\text{Operating Current}}$$

- Consistent minimum and maximum pre-arcing time limits for over-currents (Fig. 3) are also relevant for a fuse that is independent from the mode of operation (e.g. in a vacuum). The super-quick-acting characteristic ensures a rapid fuse disconnection in the event of a short circuit.

Rated Current In	1.43 x In min.	3.58 x In min.	3.58 x In min.	5.71 x In min.	5.71 x In min.	8.57 x In min.	8.57 x In min.
0.14 A - 3.5 A	4.0 h	2.0 ms	5.0 s	0.5 ms	10.0 ms	0.05 ms	2.0 ms

Fig. 3: Pre-Arcing Times

- The overload operating I^2t-value of a fuse defines the energy level of an over-current pulse that is needed for fuse interruption. This is important when inrush pulses that are well in excess of the fuse's rated current occur regularly. These forms of pulses stress the fuse and accelerate the aging process. Calculation on this can be made, but go beyond the content of this article.

- The breaking capacity / interrupt rating define the amount of current and voltage level the fuse is able to interrupt in the event of an over-current failure. A breaking capacity of 300 A @ 125 VDC defines that a fuse is able to interrupt a prospective over-current of up to 300 A at 125 VDC and a max. time constant of 1 ms. The power factor is defined as followed: (R/X) = Real Power (W) / Apparant Power (VA).

- Environmental tests according to ESCC Generic Specification no. 4008, Chart F4 have shown that the fuse is able to withstand a broad range of tests such as Rapid Change of Temperature, Mechanical Shock, Damp Heat Steady State, Resistance to Soldering Heat or Thermal Vaccum. It can be said that the fuse is humidity and shock resistant. The robust design permits soldering of the fuse in either a reflow or wave soldering process.

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Fuse Design

Fig. 4 illustrates the design of the fuse. The core is a glass stick, which is sputtered with different layers of materials for the fuse-link (red) and pads (orange). Different layer thickness and the choice of different materials permit different current ratings of fuses to be

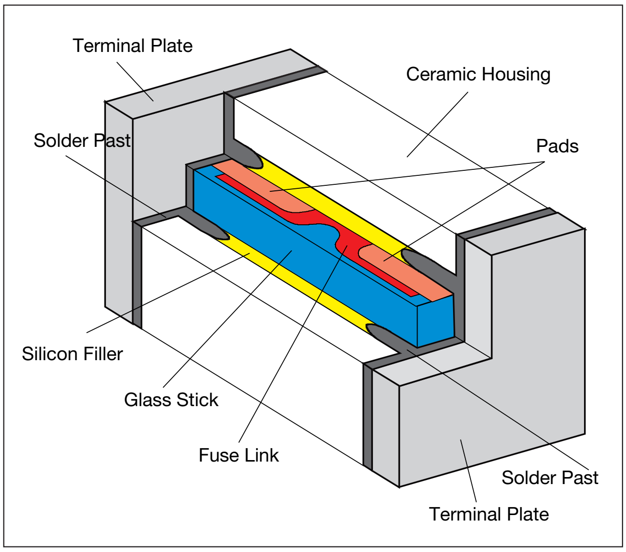

Fig. 4: Construction of the fuse

made. As an important feature of the fuse, the breaking capacity or interrupt rating is achieved with the silicon filling (yellow). The terminal plates (grey), which are soldered with a high temperature solder past (Pb content > 80%) (dark grey) to the glass stick, finalises the electrical connection to the outside. The ceramic housing construction is environmentally sealed, very robust and ideally suited for long-term operation in space. The sealing ensures that in the event of an disconnection, no arcs or gasses can escape.

Manufacturing Process

The manufacturing of thin-film technology based fuses is a complex process and contains many stages. These stages can be loosely grouped as follows:

1. Sputtering fuse links on glass stick and insertion
3. Cutting and cauterisation
4. Sputtering end metals and soldering of terminal plates
5. Seal test and conditioning
6. Final terminal plating and testing

These are described in more details in the following sections.

Sputtering Fuse Links on Glass Stick and Insertion

One of the key manufacturing process steps is the sputtering of the glass stick with different layers of materials such as copper. As shown in Fig. 5, the narrow part in the middle shows the fuse link that will melt and interrupt the circuit when an inadmissible over-current occurs. The pads on both ends connect the fuse-link to the terminal plates.

Ceramic tubes, which include fifty fuse units per tube, are placed on a board, and a wax is used to fix the tubes. Following on from this, silicon is injected into the ceramic tubes. The sputtered glass stick with the fifty units is now inserted into the tube and brought to an exactly defined position. Through the octagonal ceramic tube hole and the square glass stick, positioning is ensured and the silicon is well spread around the glass stick.

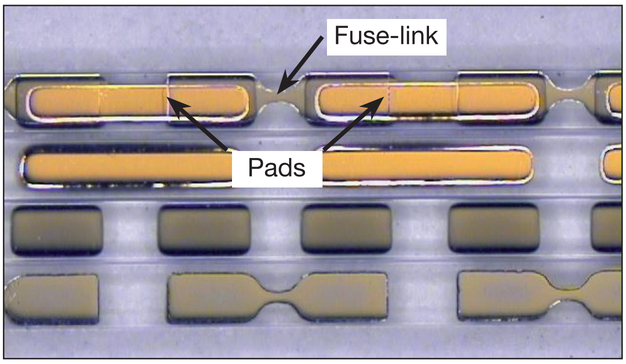

Fig. 5: Sputtering on glass stick

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Cutting and Cauterisation

After insertion, the board is now ready for cutting. An automatic cutting machine ensures that the ceramic tubes are cut (Fig. 6) at the right point. The de-waxing process separates the fuses into single pieces with flat front surfaces. Continuing on from this, the single fuse elements are cauterised (Fig. 7) or etched so as to remove some silicon and thus to provide access to the solder pads of the fuse-link.

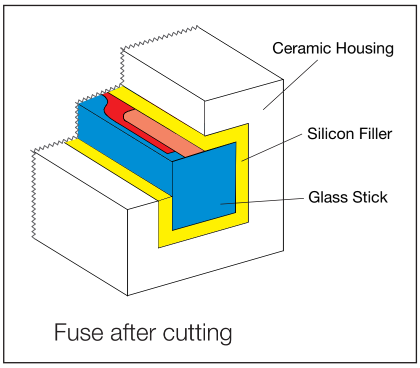

Fig. 6: Cutting

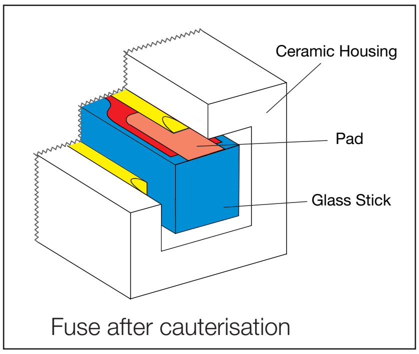

Fig. 7: Cauterisation

Sputtering of End Metals and Soldering of Terminal Plates

The fuses are placed on another board where the front surfaces face upwards. The board is now inserted into the sputter machine where, among other materials, copper is applied to the forward surfaces making them solderable. Using a high temperature solder, which means a solder paste having Pb content > 80%, copper terminal plates are soldered to the fuse ends (see Fig. 4).

Seal Test and Conditioning

The finished single fuses are put in a chamber (Fig. 8) called a “bomb” where with high pressure and an acid solvent tests whether the fuses are sealed. The test lasts 72 hours with cyclic tests up to 1500 PSI.

The conditioning process lasts a total of 84 hours and the temperature is increased to 150 °C. This ensures that the acid solvent shows those fuses that have not been sealed and where the electrical characteristic of the fuse has changed. These can be then be separated out with a cold resistance measurement. The fuses are only placed into stock if the test has shown them to be sealed.

Fig. 8: Fuse are filled in the “bomb”

Final Terminal Plating and Tests

This final process step is completed after receipt of a customer’s order. The terminals of the fuse-links are still a copper based surface (Fig. 9). Using a galvanising process, an SnPb layer is applied to the surface. The fuses are finally tested 100% both visually and electrically (cold resistance) before forwarding on to a further screening process.

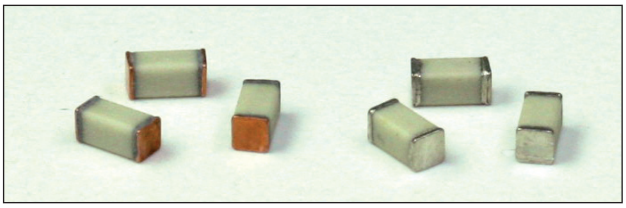

Fig. 9: Before and after tin-plating

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Screening Process

Following the final test after production, cold resistance and voltage drop are measured for each individual fuse.

The „Burn-In“ is a combination of a current and temperature test (Fig. 10 + 11) carried out for every fuse under the following conditions:

- Duration: min. 168 hours
- Current: 95.7% of rated current
- Ambient temperature: 80 °C
- Continual monitoring of current during the entire test

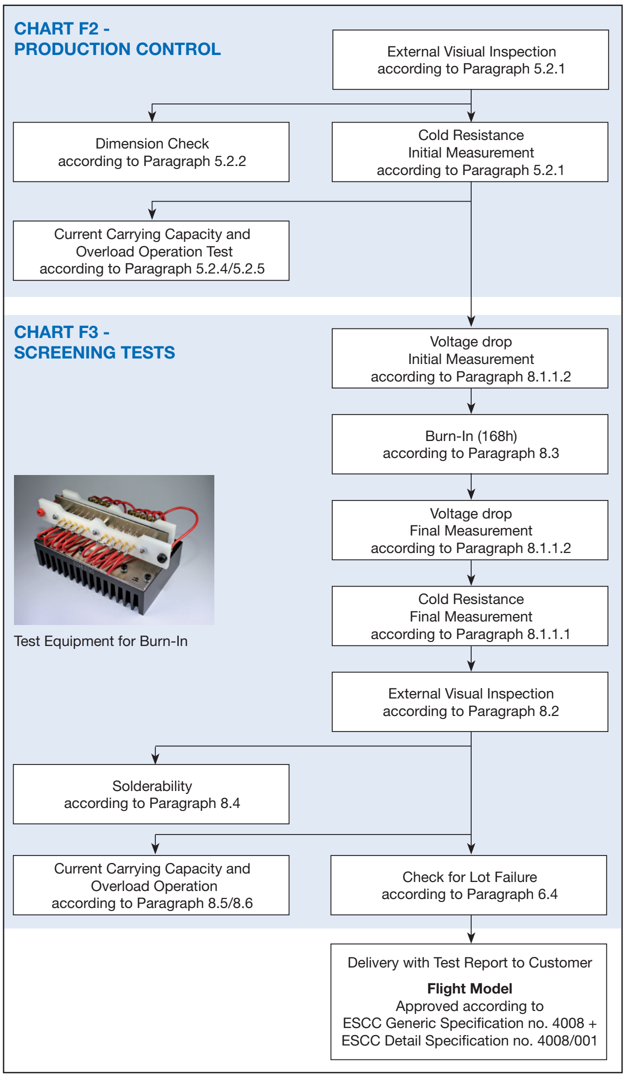

Fig. 10: Procedure for the screening process

After „Burn-In“, cold resistance and voltage drop are measured again for each fuse. The two sets of values are permitted to show a maximum deviation of 10%; otherwise the fuse has failed the test. Should there be 5% or more from a production series that lies outside this tolerance, the entire production lot is disposed off and a new series of fuses is produced.

Every fuse undergoes a strict visual check so as to exclude material faults.

Additional test fuses are manufactured with each production lot, which have also been subjected to Burn-In and relevant tests. Time-current characteristics and solderability tests are carried out to ascertain that these properties are still fulfilled. Depending on customer requirements further qualification tests can be carried out.

As a result of this extensive procedure, an absolute minimum failure rate is achieved as well as a complete guarantee of the electrical properties. A detailed test report is made for each order and supplied with the fuses. The test report and the sequence with which the fuses are placed into the blister tape correspond with each other. This permits retraceability of each single fuse back to the screening process.

Fig. 11: Burn-in equipment with fuses

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Applications

Satellites are very often equipped with a multitude of electronic modules, for a variety of functions, which are fed from a central supply unit. An example of this is the transmitting unit that is manufactured among other items by TESAT in Germany. This module amplifies the data signals that are transmitted via the antenna back to earth. The existence of numerous channels leads to a multiple redundant system. With an over-current caused by a fault in a channel, the fuse interrupts the supply in a secure and controlled manner. In a case such as this, the system switches over to another channel. The disconnected fuse thus ensures that no unnecessary current flows in the defective channel.

Should an application require a higher rated current than a single fuse can cover, a parallel switching (Fig. 12) of two or more fuses is possible. As a result of current/temperature equalisation between the fuses, simultaneous disconnection is ensured. It is to be noted that the fuses have to have the same rated current values, that they are from the same production series and that they do not influence each other with their operating temperature.

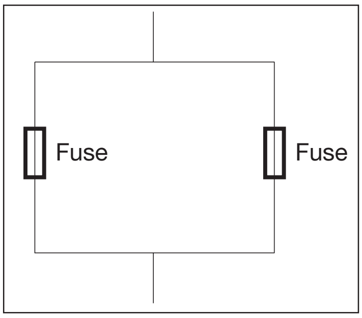

Fig. 12: Parallel circuit of fuses

In future, further R&D efforts will be made to increase current ratings by putting two or more fuses in parallel in one unit. This will also allow meeting the demand for higher current application, since satellite technology gets more sophisticated and therefore power consumption will increase.

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Author:
Thomas Hubmann
Product Manager for Fuses
SCHURTER AG, Switzerland