



ISABELLENHÜTTE

The Difficult Path to Zero Gravity

From Earth to Space and Back

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When Georg Simon Ohm discovered that there was a linear relationship between electric potential and electric power in certain conductors in spring of 1826, he never imagined that the law named Ohm's law in his honour would one day become the basis for modern electronics. While the development of microelectronics led to a decreased interest in the "resistor" component, some resistor types have by now become true high-tech components produced only by very few manufacturers. Precision is crucial, especially in the case of measuring resistors for accurate current measurement.

The needs hardest to meet are those of space technology, and resistors to be used in space also have to comply with immense requirements that can only be met by very few companies on this planet. For example, only a single company in Europe produces current measuring resistors qualified for use in space: Isabellenhütte Heusler GmbH & Co. KG, located in Dillenburg in Hesse.

Current Measurement in Space

While the most prominent use for Dillenburg-manufactured precision resistors under zero gravity may be in the European space laboratory Columbus, a module of the international space station ISS, they have also been used in many different satellites such as those orbiting Earth as part of the ultra-precise Galileo satellite navigation system for over 12 years.

They are basically used for the same purposes as on Earth: Current flowing through the precision resistor causes a potential drop across the resistor. Current values can then be determined with the help of Ohm's law. This method is used by companies like Astrium/ESA or Thales Alenia Space (formerly ETCA Alcatel) to monitor local voltage supply in satellites. DC/DC transformers supplying the voltage necessary for each respective unit according to the point of load method also use Isabellenhütte precision resistors for current monitoring.

Most resistors used in space are manufactured by Isabellenhütte using ISA-PLAN technology. In the case of SMx line precision resistors integrated in the Columbus space laboratory, this method led to a high continuous power of 3 W and a high pulse resistance while also meeting space-related requirements (see box).

((Box))

Space application components requirements

- Exact compliance with basic component specifications (in this case: high-precision and pulse resistance resistor)
- Extreme temperature stability with extremely low temperature drift
- Very high vibration and shock resistance
- Resistance to space radiation
- Can be used in vacuum
- Operational reliability over many years

((End of Box))

ISA-PLAN Technology

As far as the precise measurement of currents is concerned, resistors are not only required to conform exactly to the nominal resistance value and have a small temperature coefficient. They also need a low thermoelectric potential, high long-term stability, an inductive value as low as possible and a high load capacity (also for pulsed operations).

ISA-PLAN resistors meet these exact requirements even in space. These components are made from acid-etched homogenous precision resistor alloys such as Manganin[®], Zeranin[®] and Isohm[®] which are galvanically isolated and installed on a metal substrate with good thermo-conductive properties. These materials have a low temperature coefficient of less than 10 ppm/K while also being perfectly thermo-electrically adapted to copper so that thermoelectric potentials are reduced to a value close to zero. For example, the resistor material manganin has a thermal power against copper of less than 1 $\mu\text{V/K}$, which is negligible and leads to very good long-term stability of less than 0.5% even under full load.

Optimised current density distribution in resistors prevents the formation of hot spots.

With ISA-PLAN resistors, heat can be easily transferred to a substrate with a high heat capacity to ensure excellent pulse resistance.

Isabellenhütte uses this technology to build space-capable precision resistors at nominal resistance values between 20 $\mu\Omega$ and 100 Ω . The planar build offers an especially low-inductive structure and an easy way to use four conductor connections to ensure temperature coefficients of 10 ppm/K even at nominal values below 10 m Ω with the high reproducibility required by space applications.

Becoming Space-Capable

To be added to the EPPL (European Preferred Parts List) list of suppliers for space applications, a company not only needs to produce superior products, it also has to use certain procedures for their manufacture, pass several audits and qualification tests and implement test and quality assurance measures.

Isabellenhütte passed the ESA (European Space Agency) ESCC qualification (ESCC: European Space Components Coordination), which is a prerequisite for this, a long time ago. During a period of nearly two years, internal processes were closely analysed and thoroughly evaluated. At the same time, there was a component and general manufacturing process evaluation. Only after these measures were completed, the actual component qualification tests could commence.

Lead-Free? No, thank you!

Because complete devices including components such as Isabellenhütte resistors need to be space-capable, focus has to lie on the complete system. Vacuum, extreme vibration stress and centrifugal forces at launch pose particular challenges for these systems. Leaded soldering metals create substantially more vibration-resistant joints, which is the reason why no lead-free soldering metals can be used for space applications.

The reason for this effect is the fact that leaded metals help to avoid dangerous whiskers while also making the joint more flexible.

While Isabellenhütte continues supplying components for terrestrial applications with lead-free contacting in accordance with RoHS regulations, lead and tin contacting (PbSn 60/40) is still used for space application components.

For this very reason, space component tests were conducted completely separately from tests meant for customers from the automotive and other sectors to eliminate any confusion completely.

Ready for Space?

ESCC tests include various basic tests divided into different levels. For level three, ten components are chosen and examined according to their electric and mechanic properties. Properties evaluated include ease of installation, solderability, isolation resistance, electric strength and temperature coefficient. There must not be any failures.

Level 2 tests are conducted with 25 single components as “operating lifetime” tests over a period of 1000 hours during which the components are subjected to predefined load cycles. The resistors have to work under nominal load for the first 1.5 hours, before nominal load is switched off for half an hour. This cycle is repeated for a total of 500 times: $500 \times (1.5 \text{ h} + 0.5 \text{ h}) = 1000 \text{ h}$.

After the end of preset periods, measurements of electric parameters are conducted. In the example shown in figure 2, engineers determined resistance changes from the nominal and initial values after 250 h, 500 h and 1000 h.

Level 1 component tests include vibration tests, contacting resistance tests, tests to determine resistance to heat caused by soldering, tests under changing climates (air moisture and dryness in a climatic exposure test cabinet) and consistence tests, in addition to the tests from levels 2 and 3 – a standard procedure for space applications.

In Space and on Earth

Space-capable resistors have to comply with specific quality and resistance requirements, but from a procedural point of view they basically constitute standard components with product-immanent elements of space capability. These special tests “only” prove or confirm that components are actually suitable for use in space and specially adapted methods such as adaptation to the use of leaded soldering metals are only meant as a kind of fine tuning.

Because of this, terrestrial versions of space-capable components can very well be used in frequency converters, control cabinet units or cars, where lower temperature ranges and vibration resistances (using lead-free RoHS compliant soldering metals) are required. After all, these applications also call for components that guarantee proper functionality during a very long operating time.

Where developers decide to use space-capable components’ terrestrial versions, such as the Isabellenhütte SMV/SMR or SMS/SMT/SMP precision resistors, they will benefit from the very high basic quality and immense experience the manufacturer was able to gain during the ESCC qualification process.

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