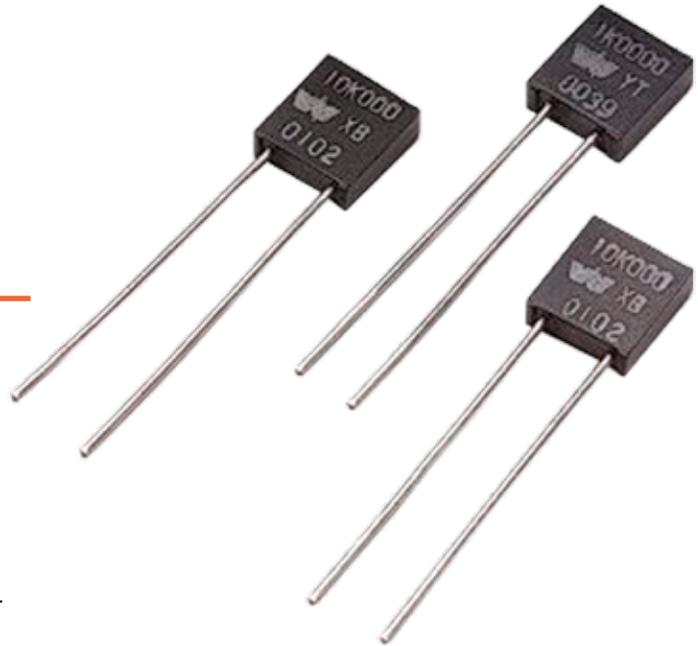


Vibration Proofing Metal Foil Resistors for Reliable Performance in Aerospace and Data Logging Applications

Circuitry for space probes, avionics and down-hole data logging must perform flawlessly under harsh conditions, including high vibration and extreme temperature changes. Even a failure of a minor component can negatively impact—or stop—the performance of the entire device. For instance, satellites have failed due to resistor malfunction.



WILBRECHT LEDCO, INC.

White Paper

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Resistors are electrical devices used to direct current flow through a circuit—thus producing a drop in voltage between two points. A vital component of most modern-day electrical networks and electronic circuits, resistors operate according to Ohm's law. The law states that the current between two points of a conductor is directly proportional to the potential difference through the two points.

The level of resistance determines the functionality of a particular resistor. During resistor design, several factors must be considered. The necessary precision of the resistance is set by the manufacturing tolerance of the selected resistor, in accordance with unique application requirements. A maximum power rating of a particular resistor must be higher than the predicted power dissipation in a particular circuit. Plus, the temperature coefficient of resistance (TCR) may be another important factor if the application calls for high precision. The TCR is the relative change of resistors' value when the temperature changes. For applications subject to large temperature changes, the TCR should be as low as possible.

Introduction to metal foil resistors

Foil resistors—introduced in the 1960's—feature a special alloy foil to serve as the primary resistance element. These resistors offer superior precision and stability compared to most alternative varieties, in part due to the low TCR. The TCR of foil resistors is inherently low, and has been improved since their introduction to allow accurate use in many demanding applications.

The resistor technology of choice to respond to the demand on precision and stability during a large range of temperature change is quite often metal foil based. Metal foil resistors have a uniquely low TCR due to the proprietary properties of the nichrome foil and the mounting on a ceramic substrate. However, this unique foil construction also presents challenges to the manufacturing process—namely, to produce a sufficiently robust connection to the nichrome foil used in the construction.

Manufacturing requirements

Industry-leading manufacturers have successfully met this challenge through a unique thin lead wire construction, and metal-foil resistors have been efficaciously used in a broad range of aerospace and data logging industries that require high precision. This successful manufacturing process consists of avoiding foil damage caused by lead vibration by using a unique two-wire lead construction. This design allows flexible stress relief between the foil and the external lead wire and minimizes potential cracking or tearing of the foil at the wire connection.

The NASA qualification standard for metal foil resistors requires both a 100G-shock test and a 20G (peak value) vibration test. To meet this standard, NASA has recognized the importance of wire terminations in metal foil resistors. Thus, in their Specification S-311-P-813—developed for the procurement of Space Level precision resistors—NASA specifically calls out (§3.3 Design and Construction) “resistor constructions using a thin metal foil element shall include a flexible intermediate conductor between the terminal lead and the foil (ex., a metal ribbon or thin wire).”

Construction processes

To ensure the foil is not damaged during the welding operation, strictly enforced control procedures are followed starting with spot-welding set-up—which consists of adjusting the weld parameters for each different lot of chips that are welded throughout the day. The control procedures are specified in the welding process and ensure that the chips are handled properly before and after welding to prevent damage. Procedures are also followed through lot archiving—which consists of performing a weld-pull test twice daily and recording the results along with the chip lot number and weld settings. Before commencing, critical spot-weld settings are checked. The solder joint on each two-wire lead is also checked before use in the welding process. Lot identity is maintained for all spot-welds, and weld strength testing is performed repeatedly during the shift.

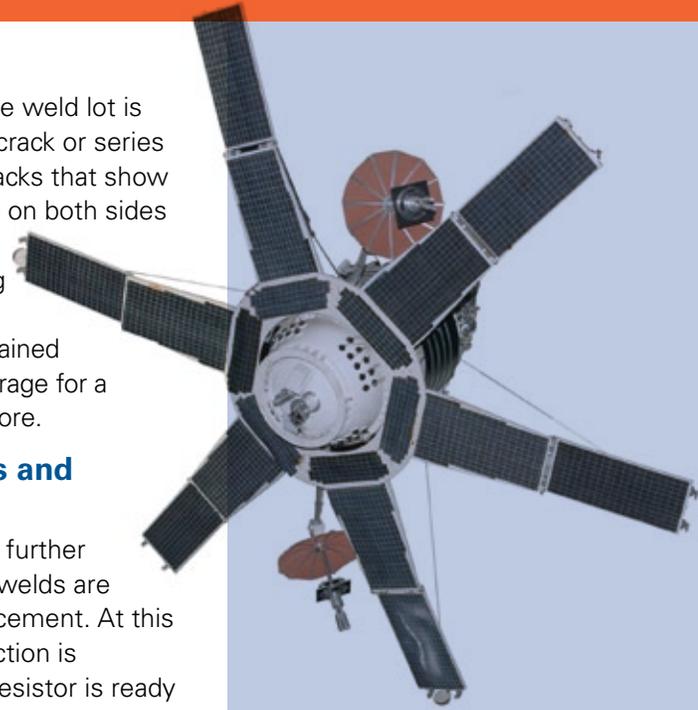
Further, if the particular order of resistors requires lead dissolve tests—including all resistors manufactured to the S311-P-813 specification and additional orders in which the customer requests the tests—to verify that welding pressure has not cracked the foil, multiple parts are selected twice each shift for analysis.

Following NASA requirements, lead dissolve is accomplished by placing a beaker of welded assemblies and nitric acid into an ultrasonic cleaner for one-minute intervals until the lead is completely dissolved from the foil pad. The weld area of the pad is then visually inspected at 100 times magnification for cracks using both back and reflective lighting. If any of the samples shows a crack of more than 25 percent of the weld

circumference, the entire weld lot is rejected. However, any crack or series of small, straight line cracks that show welding has taken place on both sides of the crack are acceptable. Once testing is completed, the lead dissolve samples are retained for records in secure storage for a period of five years or more.

Protective coatings and calibration

After acceptance and to further protect the foil, all spot-welds are given an epoxy re-enforcement. At this point, the initial construction is completed and the foil resistor is ready for resistance calibration. The calibration procedure refines the resistance to the exact specified value and tolerance, determined by an application. Next, a moisture barrier and RTV buffer coat are applied for additional protection against the elements, followed by the external transfer molded epoxy for the final layer of protection.

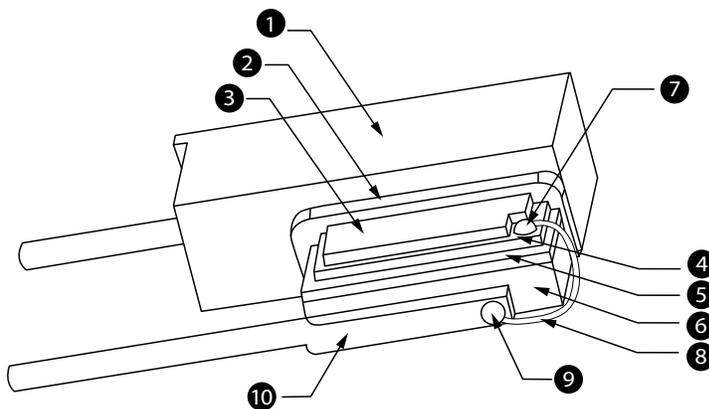




Upon completion of the calibration and molding processes, the resistors undergo a preparatory screening process, after which they are subjected to the Group A & B testing, as specified in S-311-P-813. Additionally, Group C testing is performed monthly, quarterly and semi-annually as required in this specification.

This two-wire lead construction is used in all Wilbrecht Ledco foil resistor products, which are built in its Huron, SD, facility to NASA S-311-P-813 or DSCC RNC90 specifications, as well as in the commercial product range.

Wilbrecht Ledco is the only NASA 311 qualified foil resistors manufacturer to use this manufacturing process.



- ① Transfer Molded Epoxy
- ② Moisture Barrier/Buffer Coating
- ③ Protective Coating
- ④ NiCr Foil (Etched Resistive Element)
- ⑤ Bonding Layer
- ⑥ Alumina Substrate
- ⑦ Epoxy Strengthened Weld Joint
- ⑧ Secondary Lead (For Mechanical Stress Relief)
- ⑨ High Temperature Solder
- ⑩ Through Hole Lead



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