NEW HIGH - PRECISION FOIL RESISTORS FOR SPACE PROJECTS, WITH ZERO TEMPERATURE COEFFICIENT, VERY LOW POWER COEFFICIENT AND HIGH RELIABILITY

Hero Faierstein
Vishay Israel Ltd.
2, Ha'ofan Street, Holon 58814, Israel
Tel: 972-3-5570834, Fax 972-3-5599664
faierstein_h@vishayilh.co.il

ABSTRACT

Since its introduction on the market in 1962, **Bulk Metal® Foil Technology (BMFT)** still out - performs all other resistor technologies available today for applications that require **precision and stability.**
Foil resistors are used when high accuracy is required.
The combined effects caused by:

- variation in ambient temperature and
- self heating as a result of load (Joule effect)

influence the stability of high precision resistive components.
The relative change of resistance with ambient temperature is defined as **Temperature Coefficient of Resistance(TCR)**. A low **TCR** allows a resistor to maintain its precise value when its temperature changes due to ambient temperature variations. Although the **TCR** of foil resistors is considered extremely low, this characteristic has been further refined over the years. The latest achievement came with the development by **Vishay** of the new **"Z - alloy"**.
The **"Z-based"** foil technology provides a significant reduction of the resistive components' sensitivity to ambient temperature variations and applied power changes.
This paper explains the temperature effects on the stability of the resistors and offers some Vishay "Z-based" components as ultimate choice for accuracy in space, airborne and military projects.

PRECISION FOIL RESISTORS – CONSTRUCTION AND OPERATION PRINCIPLE

The building block used for **Bulk Metal Foil (BMF)** products is the chip resistor element. The chip consists of a homogeneous metal foil bonded by an adhesive layer on a ceramic substrate. The unique combination of materials and construction provides superior performances that are unavailable – **all in one resistor** – in other technologies.
The extremely low TCR is one of the main features of the foil technology. Two opposing physical phenomena within the chip are the key of the low TCR capability of BMF:
- Resistance of the foil in its free state (before bonding to a substrate) increases when temperature rises .
- Since foil is cemented to the much thicker ceramic substrate and since the coefficient of thermal expansion of ceramic is smaller than the thermal coefficient of expansion of the foil (typically 6 ppm/°C versus 13ppm/°C, respectively), as the temperature increases, the foil undergoes compressive stress. Resistance of the foil decreases due to compression.
The result of matching these two simultaneous effects is a low and predictable TCR (Figure 1)

Figure 1. TCR concept
Resulting Resistance vs .Temperature curve

The net temperature sensitivity of the integral resistor package could be reduced to zero if both effects were linear, equal in magnitude and of opposite sign. The reduction of the non-linear component is at the core of the latest Vishay achievement: the new **"Z – alloy".**
The **Z201** – an **Ultra Performance Aerospace and Instrumentation Resistor** – was the first in a series of ultra precision devices using the "Z based" foil technology. Its essentially Zero TCR represents an industry breakthrough.
The TCR of a resistor for a given temperature range is established by measuring the resistance at two different ambient temperatures. The ratio of relative resistance change (Δ R) and temperature difference (ΔT) gives the

slope of the ΔR/R = f(T) curve. This slope is usually expressed in parts per million per degree centigrade (ppm/°C). As shown in the illustration below (Figure 2), the resistor Z201 has nominal TCR slopes of
0.2 ppm/°C in the military temperature range:
-55°C to +125°C.
Z201 has a **ten fold TCR** improvement over standard foil resistors.

Figure 2. Z201 – Resistance Temperature Characteristic

In the working conditions described above, where external factors generate the heat, a uniform temperature is achieved in the measured resistance. But, very often, both effects of ambient temperature change and applied power change are present simultaneously.
The temperature rise of the resistor is also, depending on the application, partially due to the power it is dissipating (Joule effect). In this case the heat is generated internally. The foil becomes hotter than the ceramic. The heat flowing from the resistive layer to the substrate causes temperature gradients and additional stresses in the foil. The change of the resistance value is no longer in accordance with the R = f (T) curve.
All these factors must be taken into account when resistors having an extremely low TCR are required.
This has led to the introduction of a new figure of merit - **Wattage (Power) Coefficient of Resistance (WCR**) – - a different concept from TCR (Figure 3).
This new parameter, expressed in ppm/W, is used to describe the shift in resistance value due to change of applied power. For steady loads and changing ambient temperatures, low-TCR resistors will provide the best stability. When both ambient and power are changing, both low TCR and WCR are needed to ensure high stability.

Figure 3. TCR vs. WCR- improved current sensor

HIGH PRECISION FOIL RESISTORS FOR SPACE PROJECTS

The demand for precision resistors with high stability has led to the development of solutions that are tailor-made to such customer specifications as variation in ambient temperature, load changes over time, limits of allowable resistance change, and the time it takes to reach these limits after a given change in load.
The following show some breakthrough resistive components resulting from these developments.
The "Z based" resistors offer the same form and fit function as do existing devices, while establishing a greatly improved standard for accuracy in fixed- resistor applications.

Vishay Established Reliability RNC90Z
- Qualified to MIL – PRF – 55182/9
- Life failure rate "R"
"Z-based" foil technology- TCR breakthrough (Figure 4):
± 2 ppm/°C maximum, over the extended range of :
-55°C to +175°C.
The **RNC90Z** is a direct replacement for the existing RNC90Y.

Figure 4. Comparison of RNC90Y to RNC90Z – Temperature Coefficient of Resistance

Vishay Power Current Sense resistors–"Z-based" foil technology - offer the best approach to power-circuit applications when a combination of accuracy, very low TCR, high resistance stability under transient power conditions, and fast response time are required.

Figure 5.1 Rapid stabilization

Figure 5.2

Figure 5.3 Temperature Coefficient of Resistance (TCR)

These products achieve optimum performance when mounted on a cooled heat sink. Hermetically sealed current sense types VHP4Z and VPR247Z provide the maximum protection against environmental stresses .

The benefit of hermeticity ensures also the exceptional long term stability under power. Molded types VFP4Z, VCS331Z, VCS332Z belong to the same series and provide, as well, the improved characteristics required by typical applications (Figure 5).

IMPROVED PERFORMANCES:

Low TCR: 2 ppm/°C
Low WCR: 4 ppm/W
Rapid ΔR Stabilization

All of these devices, utilizing the "Z –based" technology, are provided with a 4 terminal **Kelvin connection**. This is a must for current sensing when the R-value is less than 100 ohms.
Kelvin connection is employed under various circumstances including measurement of low values. Here we are concerned with sensing of large currents with a small signal (as IR drop through the resistor). The equivalent circuit is shown in Figure 6. By placing the voltage probes within the resistor, the IR drop through the element is measured without the attendant TCR and IR drop through the leads.

Figure 6 .Kelvin Connection

Vishay manufactures products that add a new dimension of performance to Bulk Metal Foil Technology. Small package sizes, tight resistance matches, close tracking and high stability are all achieved when foil chip resistors are bonded into a ceramic DIP of metal enclosure and hermetically sealed.
Two network types have been qualified (**QPL**) to MIL-PRF-83401, Characteristic C, Schematic A

Vishay model 1445Q – 14 pin DIP package
Vishay model 1446Q – 16 pin DIP package

- Hermetically sealed for maximum environmental protection
- Gold ball wire bonding
- Qualified resistance range: 100 Ω through 10 KΩ (Other values are available non QPL)
- Power rating is 0.1W per resistor

SCHEMATIC

For model 1445Q: N=7
For model 1446Q: N=8

INTERNAL LAYOUT (1446Q)

SUMMARY

Designers working with specifications for stability of just several ppm/°C should take into account the resistor behaviour when heated by an outside source, as opposed to self-heating while dissipating its own power. Quantifying this difference within the resistor's specifications can contribute significantly to the stability of the device. Designers now can guarantee a high degree of stability and accuracy in fixed - resistor applications using solutions based on Vishay's revolutionary "Z-based" foil technology. This technology really opens new options for tailor-made to customer specifications requiring high stability designs.
Airborne gyro navigation control, electron beam circuitry, fire control radar display systems, deflection amplifier circuits, constant current power supplies, feedback, gain setting, voltage division, current sensing designs are the most demanding typical applications where the improved Bulk Metal Foil resistors are the ultimate choice .
The high reliability and remarkable performances of Vishay Bulk Metal Foil components extend the useful life of end equipment and make them the most recommendable for space and airborne projects.

IMPROVED PERFORMANCE TESTING

Improved performance (meaning increased time stability with load and other stresses) is available through factory conducted "Improved Performance Testing". The test routine is usually tailored to the user's stability objectives and a product that has been screened can be brought down to a low potential load life shift.
Various screening test routines are available and all anticipated stresses must be taken into account before settling on one specific test routine.

Back to Contents