Facts at a Glance

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Authors: Yuval Hernik
Tel: +972-54-300-0191
E-mail: Yuval.Hernik@vishaypg.com

"Mind the Gap": High Precision Bulk Metal® Foil Resistors, Their Imposters and Impersonators

Counterfeit resistors have inundated the electronics market and caused confusion about the differences between actual and published specifications. In the last few months we have found cases of counterfeit foil resistors as well.

It is said that imitation is the sincerest form of flattery. But counterfeiting is a crime, and the consequences of substituting fake resistors for real Bulk Metal Foil resistors in analog circuits, systems, and programs can be very grave indeed.

That's why it is more important than ever to verify that the foil resistors you're using are in fact the high-precision devices you believe them to be.

Deceptive practices

In one type of scam, for parts that are supplied on reels, tubes, and magazines, the supplier contrives to pass incoming inspection by positioning good parts in the first five or ten positions in the container. Incoming inspections often take only the first few from each package for test. The dishonest suppliers place the suspect or inferior parts in subsequent positions to avoid detection. Some situations have been documented where the subsequent parts were just empty shells.

Another dishonest approach is where suppliers actually buy a few good parts from the original manufacturer plus a lot of parts specified as lesser performance. For example, a high-speed, low noise IC might sell for $100 while the same manufacturer sells a lesser performing part of identical configuration but different part number for $5. The dishonest supplier buys the lesser performing $5 parts and re-marks them as the better $100 parts and deceptively sells the inferior product at a very high markup. With resistors, they might buy loose tolerance parts and re-mark them as tight tolerance parts. Or they might even buy standard commercial level parts and re-mark them as high reliability military parts.

Some parts are even counterfeit in their entirety.

How can these pitfalls be avoided?

The best way to counter these fraudulent scams is to assiduously follow these supply chain control practices:

- Buy only from Vishay Foil Resistors Company (VFR) or its authorized distributors and catalog houses
- Avoid third party transactions, resellers, and disreputable suppliers without long-term fixed locations available for ready visits, verification, and auditing
- Look for the Vishay Foil Resistors Certificate of Compliance with every shipment
- Inspect complete marking on all resistor products or containers and compare with VFR data sheets, available in catalog form or online here in our Design and Selector Guide
- At incoming inspection, test beyond the first few pieces. Select inspection samples from start, middle and end of the package plus a few from randomly selected positions.
- Do not let timing pressures induce you to make risky purchasing decisions that could put your company, projects, and reputation in jeopardy

Why can't counterfeits duplicate the performance of Bulk Metal Foil resistors?

The physics of the Bulk Metal resistor are fairly simple to describe but the realization of a foil resistor requires advanced expertise in multiple disciplines such as metallurgy; high-temperature adhesives; very fine line photolithography; fine etching and chemical passivation; conductor path design to minimize inductance, capacitance, excess noise and hot spots (points of high current density); stress analysis and its thermal components; strain-relieving encapsulants or terminations; and reliability-enhancing in-process and post manufacturing operations (PMO).

In its simplest form, the foil resistor is a metal grid adhesively bonded to a special flat alumina substrate; but, in actuality, the details are much more complex:

1. The metal:

   The resistance material is a cold-rolled unique alloy of nickel-chrome (NiCr) rolled to a thickness of 100 to 200 micro-inches, maintaining its monolithic bulk metal characteristics with no micro-voids in its structure. It has an integral identity independent of any substrate or support. The composition of the metal is fine-tuned so that it has a specific linear thermal expansion coefficient (LThEC) as well as a specific inherent temperature coefficient of resistance (TCR). The unbonded alloy must have a specific positive TCR associated with a specific linear coefficient of expansion.

2. The adhesive:

   The proprietary adhesive must be applied in a uniformly thin layer and be capable of thousands of thermal shocks and temperature cycles from less than -65^0C to more than

+200^{0}C (also available down to −200^{0}C for cryogenic applications) without cracking, crazing, creeping, shifting, hardening, or relaxing its bond. This comes through many years of development with operational tests taking years of powered life tests to determine the efficacy of each refinement. Vishay Foil Resistors' documented life test data covers more than 30 years of continuous operation audited by instrument, ATE, avionics, military, and space customers.

3. The substrate:

   The specially chosen substrate must be a specific ceramic with no free ions to unite with water-vapor to form reliability-risking etchants. All epoxies and all plastics are hydroscopic; when temperature and humidity cycling pulls water-vapor through the encapsulants there can be no free ions present to form metal-destroying etchants. But, more importantly, the substrate must provide a very specific linear coefficient of expansion to counterbalance the linear coefficient of expansion of the Bulk Metal Foil resistive element.

4. The resistance grid:

   The resistance grid is etched out of the NiCr alloy after the alloy has been bonded to the substrate. The grid is configured to allow remote trimming of resistance value to within 0.0005% (5 ppm) producing finished resistors with tolerances as tight as 0.001% (10 ppm). The grid pattern is further designed to minimize inductance, capacitance, hot spots, and excess current noise.

5. The physics of the composite structure:

   Consider the composite structure of the Bulk Metal Foil resistive element bonded to the flat ceramic substrate. The independent unbonded metal foil has a positive LThEC (linear thermal expansion coefficient), expanding in all directions with an increase in temperature. The substrate also has positive LThEC but it is less than the metal so it does not expand as much as the metal with the same increase in temperature. When the metal is bonded to the substrate, the metal wants to expand more than the substrate to which it is bonded. The net effect is that, while both are expanding, the metal experiences a compressive force as it tries to expand faster against the constraining force of the slower expansion of the substrate. When a metal is placed under compression the compressive forces drive the resistance down. All the materials in this structure are delicately balanced so that this compression-induced decrease in resistance exactly offsets the metal's inherent positive TCR. The compressive force drives the resistance down the exact amount needed to balance the metal's natural increase in resistance, yielding a net zero change in resistance with a change in temperature. Further, the stress/strain balance throughout the entire temperature and power application ranges of the foil resistors is such that it does not exceed the elastic limit (Hooke's law) for any material used and all performance criteria are repeatable and reliable.

6. Temperature Coefficient of Resistance (TCR) as a performance index.

    a. Many designers use a resistor's TCR as a shorthand index to the resistor's relative level of precision. And it is generally true that, if resistor technologies are arranged according to the best TCR's they produce, that does directly correspond to their general level of precision--- the better the TCR, the better the precision. While that indicates the general order, the degree of precision doesn't necessarily have the same TCR vs. precision proportionality for every technology. The Bulk Metal foil resistors have the lowest TCR of any resistor technology, as low as 0.2 ppm/ºC from -55ºC to +125ºC, 25ºC reference, depending on the product.
    b. It should be noted that the test method for defining TCR makes three resistance measurements, typically -55ºC, +25ºC, and +125ºC for military applications. These measurements are then used to define ΔR vs. ΔT from -55ºC to +25ºC and from +25ºC to +125ºC. It is important to note that one might erroneously assume that, because only three resistance vs temperature measurements are taken, the R vs. T curve is always linear at every point between those temperature extremes. The actual curve in other technologies could be more of a parabolic shape going through the 25ºC point, or it could be a linear approximation. As a typical example, consider a thin film resistor whose end-point measurements indicate +10 ppm/^{0}C from -55ºC to +25ºC and -10ppm/ºC from +25ºC to +125ºC. This dome-shaped curve passes through the 25ºC point of reference. But the ΔR vs. ΔT across temperature spans other than the +25 ºC reference could be much greater than the defined +/- 10ppm/ºC TCR because the curve is not linear as assumed when only the end points are measured. That is, the TCR may be much greater at different temperature spans along the curve. For example, the TCR might be +10 ppm/ºC from -55ºC to +25 ºC but, being non-linear, it would be higher from -55ºC to about -15ºC. Similarly, The TCR might be -10 ppm/ºC from +25 ºC to +125 ºC but could be -15 ppm/ºC at about +100ºC and -20 ppm/ºC at +125 ºC. So the non-linear TCR would mean greater change over different sections of the temperature range and circuit performance would change non-linearly over different temperature bands. This is why designers must be wary of resistors that claim to have a specific TCR without specifying the specific temperature over which that TCR applies. For example a thin film resistor might claim to be +/- 5 ppm/ºC without specifying that this TCR only applies to the very narrow range of +25ºC to +45ºC. On the other hand, a resistor offered at +/- 10 ppm/ºC could just as well be approximately +10ppm/ºC across the entire range of -55ºC to +25ºC to +125ºC, or approximately -10ppm/ºC across that range. In that case the TCR would be approximately +/- 10 ppm/ºC even through the smallest temperature spans around the +25 ºC reference point.
    However, the TCR of the Bulk Metal foil resistor's 0.2 ppm/ºC is extremely low and linear over the entire temperature range. Circuits using this resistor have uniform resistor-related performance over any temperature span all along the full temperature range. Moreover, with an absolute* temperature coefficient as low as 0.2 ppm/ºC, different circuits using foil resistors as reference resistors have essentially the same reference standards even when

the circuits are geo-physically separated because the resistance values do not depend upon maintaining the same temperature for all resistors.
*"absolute" TCR defines the independent TCR, as opposed to" relative" or "tracking" TCR that defines the TCR of one resistor relative to the TCR of another(e.g.: TCR of R1 minus the TCR of R2)

It is unfortunate that fraud and deception have penetrated the electronics industry to their present extent, but this is a fact we all have to live with and unremitting vigilance is our only protection.

For a thorough treatise on the unparalleled performance of Bulk Metal foil resistor technology, see Ten Technical Reasons to specify Vishay Foil Resistors for your circuit.

Further information about other Vishay Foil Resistors products is available on our website: www.vishayfoilresistors.com.
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