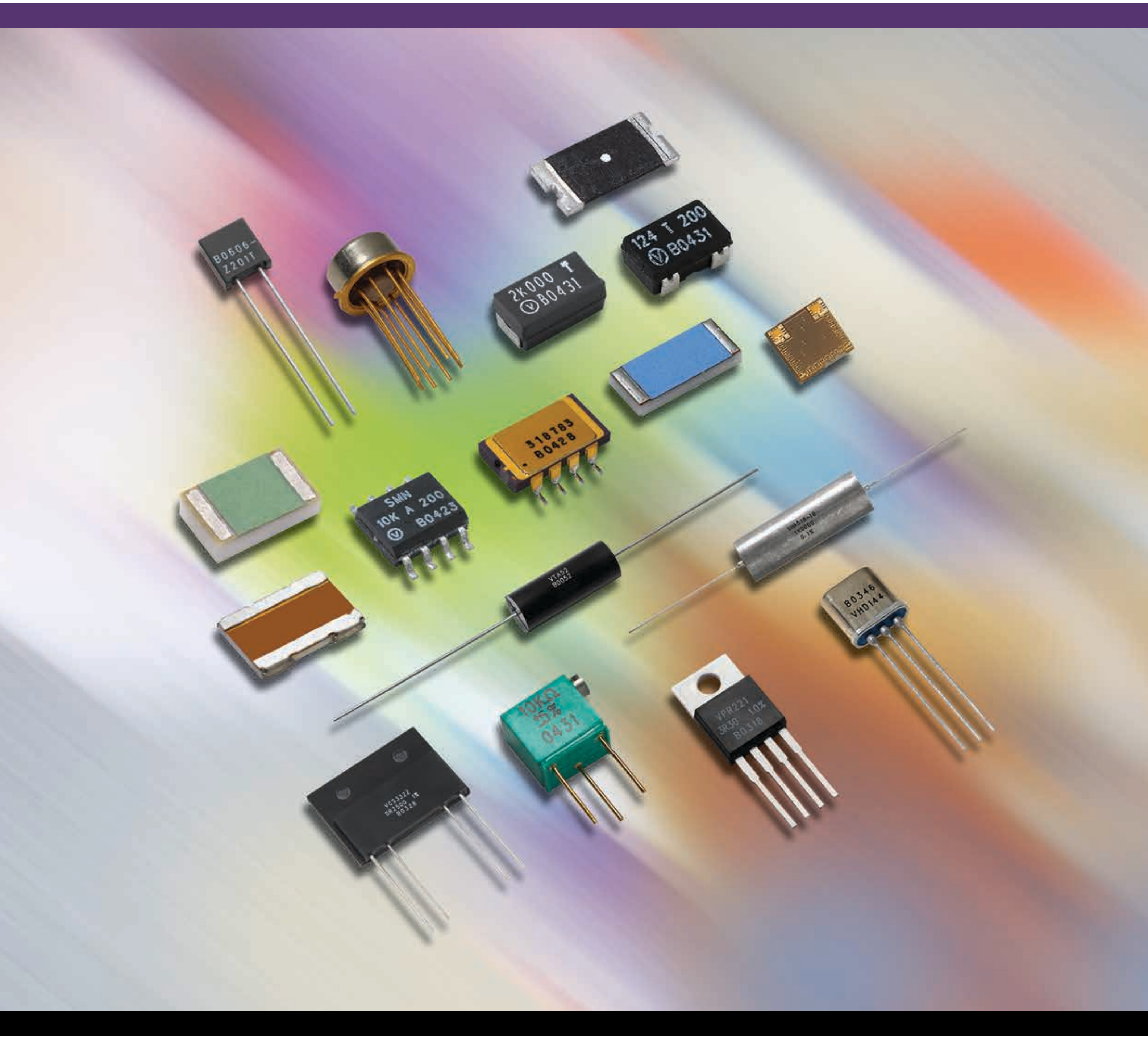
Ten Technical Reasons to Choose VFR Resistors for Your Circuit

Exerpt from the Design and Selector Guide for High-Precision Resistors



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Over fifty years after its invention by physicist Dr. Felix Zandman in 1962, Bulk Metal® Foil technology still outperforms all other resistor technologies available today for applications that require precision, stability, and reliability. VFR Bulk Metal Foil products are offered in a variety of resistor configurations and package types to meet the needs of a wide range of applications.

Introduced in 2000, Bulk Metal Foil products built on the revolutionary Z Foil Technology deliver an absolute temperature coefficient of resistance (TCR) of ±0.2 ppm/°C (–55°C to +125°C, +25°C ref.), one order of magnitude better than previous foil technologies. The lower the absolute TCR, the better a resistor can maintain its precise value despite ambient temperature variations and self-heating when power is applied.

A specific foil alloy with known and controllable properties (Ni/Cr with additives) is cemented to a special ceramic substrate, resulting in a thermo-mechanical balance of forces. A resistive pattern is then photo-etched in the foil. This process uniquely combines the important characteristics of low TCR, long-term stability, non-inductance, ESD insensitivity, low capacitance, fast thermal stabilization, and low noise in one single resistor technology.

These capabilities bring high stability and reliability to system performance without any compromise between accuracy, stability, and speed. To acquire a precision resistance value, the Bulk Metal Foil chip is trimmed by selectively removing built-in "shorting bars." To increase the resistance in known increments, selected areas are cut, producing progressively smaller increases in resistance.

In the planar foil, the parallel patterned element design reduces inductance; maximum total inductance of the resistor is 0.08 µH. Capacitance is 0.5 pF maximum. A 1 kΩ resistor has a settling time of less than 1 ns up to 100 MHz. Rise time depends on resistance value, but higher and lower values are only slightly slower than mid-range values. Absence of ringing is especially important in high-speed switching as in, for example, signal conversion. The DC resistance of a 1 kΩ Bulk Metal Foil resistor compared with its AC resistance at 100 MHz can be expressed as follows: AC resistance/DC resistance = 1.001.

Foil techniques produce a combination of highly desirable and previously unattainable resistor specifications. By taking advantage of the overall stability and reliability of VFR resistors, designers can significantly reduce circuit errors and greatly improve overall circuit performance. Bulk Metal technology enables customer-oriented products designed to satisfy challenging technical requirements. Customers are invited to contact our Application Engineering Department with non-standard technical requirements and special applications (email: foil@vpgsensors.com).

Features

- Temperature coefficient of resistance (TCR) for Z Foil Technology: ±0.2 ppm/°C typical (–55°C to +125°C, +25°C ref.)
- Power coefficient of resistance for Z Foil technology (Power PCR) "ΔR due to self heating": ±5 ppm at rated power
- Load-life stability: to ±0.005% (50 ppm) at +70°C, 10,000 hours at rated power
- Resistance tolerance: to ±0.001% (10 ppm)
- Resistance range: 0.5 mΩ to 1.8 MΩ
- Electrostatic discharge (ESD): at least to 25 kV
- Non-inductive, non-capacitive design
- Rise time: 1 ns without ringing
- Thermal stabilization time <1 sec (nominal value achieved within 10 ppm of steady-state value)
- Current noise: 0.010 μV_{RMS}/volt of applied voltage (<–40 dB)
- Thermal EMF: 0.05 µV/°C
- Voltage coeffcient: <0.1 ppm/V
- Trimming operations increase resistance in precise steps but from remote locations so that the etched grid in the active area remains reliable and noise-free (see Figures 4 and 5)
- Lead (Pb) free, tin/lead and gold terminations are available

Range of Foil Resistor Products

- Surface-mount chips, molded resistors and networks
- Power resistors and current sensors
- Military established reliability (QPL, DLA, EEE-INST-002, ESA, CECC)
- Leaded (through-hole)
- Hermetically sealed
- Trimming potentiometers
- Voltage dividers and networks
- Hybrid chips (wire-bondable chips)
- High-temperature resistors (>220°C)
- Resistors for audio

Reason 1: Temperature Coefficient of Resistance (TCR)

"Why are extremely low absolute TCR resistors required?" This is a good question to ask when evaluating the performance and cost of a system, and the answers are as numerous as the systems in which the resistors are installed. The following pages discuss ten different individual technical characteristics of Bulk Metal Foil technology that are important to precision analog circuits. While each characteristic is discussed independently for clarity, many circuits require some specific combination of these characteristics and, often, all characteristics are required in the same resistive devices.

As an example, one might examine the requirements of an operational amplifier. In operational amplifiers the gain is set by the ratio of the feedback resistor to the input resistor. With differential amplifiers the common-mode rejection ratio (CMRR) is based on the ratios of a four-resistor set. In both cases, any change in the ratios of these resistors directly affects the function of the circuit. The ratios might change due to different absolute temperature coefficients experiencing differential heating (either internal or external), differential tracking through changes in ambient temperature, differential time-response to step inputs or high-frequency signals, differential Joule heating due to different power levels, different changes in resistance over design life, etc.

So it can easily be seen that it is common for many circuits to depend on many application-related stability characteristics —all at the same time in the same devices. Bulk Metal Foil technology is the ONLY resistor technology that provides the tightest envelope of ALL of these characteristics in the same resistor, with low noise also inherent.

Initial TCR

The solution to stability problems is resistors with extremely low absolute TCR to keep temperature-induced changes to a minimum. Two predictable and opposing physical phenomena within the composite structure of the resistive alloy and its substrate are the keys to the low absolute TCR capability of a Bulk Metal Foil resistor:

- Resistivity of the resistive alloy changes directly with temperature in free air (resistance of the foil increases when temperature increases)
- The coefficient of thermal expansion (CTE) of the alloy and the substrate to which the foil alloy is cemented are different, resulting in a compressive stress on the resistive alloy when temperature increases (resistance of the foil decreases due to compression caused by the temperature increases)

The two opposing effects occur simultaneously, resulting in an unusually low, predictable, repeatable, and controllable TCR. Due to the design of the Bulk Metal Foil resistor, this TCR characteristic is accomplished automatically, without selection, and regardless of the resistance value or the date of manufacture — even if years apart.

Improved TCR In Bulk Metal Z Foil Resistors to ±0.2 ppm/°C

Foil resistor technology has continued to progress over the years, with significant improvements in TCR. Figure 1 shows the typical TCR characteristics of the various foil alloys used to produce Bulk Metal Foil resistors. The original C Foil alloy exhibited a negative parabolic response to temperature with a positive chord slope on the cold side and a negative chord slope on the hot side. Next was the K Foil alloy, which produced an opposite parabolic response with temperature with a negative chord slope on the cold side and a positive chord slope on the hot side. In addition, it provided a TCR approximately one half that of the C Foil alloy.

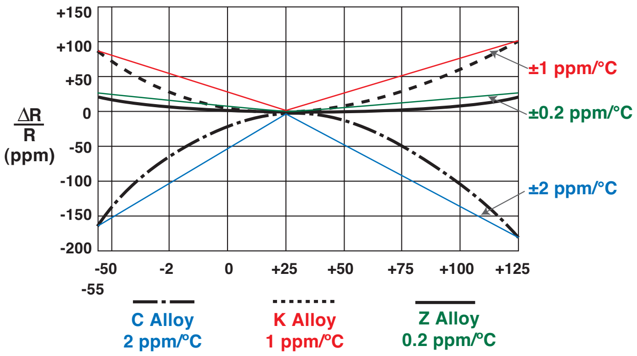


Figure 1. Typical resistance versus temperature curve and its chord slopes (TCR) of foil alloys in military range

The latest breakthroughs are the Z and Z1 Foil alloys, which have a similar parabolic response to the K Foil alloy but produce TCR characteristics an order of magnitude better than C Foil and five times better than the K Foil. Using this technology, extremely low TCR resistors have been developed that provide virtually zero response to temperature. These technological developments have resulted in a major improvement in TCR characteristics compared to what was available before, and what is available in any other resistor technology.

Typical TCR

Foil typical TCR is defined as the chord slopes of the relative change of resistance vs. temperature (RT) curve, and is expressed in ppm/°C (parts per million per degree centigrade). Slopes are defined from 0°C to +25°C and +25°C to +60°C (instrument range), and from –55°C to +25°C and +25°C to +125°C (military range). These specified temperatures and the defined typical TCR chord slopes apply to all resistance values, including low-value resistors. Note, however, that without four terminals and Kelvin connections in low values, an allowance for lead resistance and associated TCR may have to be made. All resistance and TCR measurements of leaded styles are made by the factory at a gage point one-half in from the standoffs. Contact the Application Engineering Department for the expected TCR increase for low-value resistors.

TCR Tracking

"Tracking" is the stability of the ratio(s) of two or more resistors. When more than one resistor shares the same substrate (see Figure 2), the TCR tracking will be much better than the TCR provided by two discrete resistors. Resistors with different technologies increase or decrease in value when temperatures change, even from the same batch. Resistance ratio tracking is influenced by heat that comes from outside (such as a rising ambient temperature or hot adjacent objects) and inside (as a result of self-heating due to power dissipation) the device. Resistors may be selected for good TCR tracking when they are all at the same temperature. However, changes due to differential internal temperatures (e.g., differential power dissipation) or different local temperatures (e.g., differential heating from neighboring components) are superimposed upon the tracking and cause additional temperature-related errors. Therefore, low absolute TCR is important for good TCR tracking in precision applications.

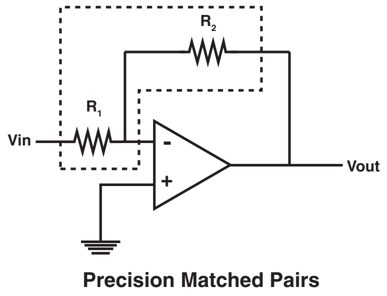


Figure 2. Typical application

The best analog design would be to use a fundamentally low-absolute-TCR resistor, since it would minimize the effect of ambient temperature and self-heating. This is impossible to accomplish with resistors with high TCR >5 ppm/°C, even with good initial TCR tracking of less than 2 ppm/°C.

Reason 2: Power Coefficient of Resistance (PCR)

The TCR of a resistor for a given temperature range is established by measuring the resistance at two different ambient temperatures: at room temperature and in a cooling chamber or oven. The ratio of relative resistance change and temperature difference gives the slope of $\Delta R/R = f(T)$ curve. This slope is usually expressed in ppm/°C. In these conditions, a uniform temperature is achieved in the measured resistance. In practice, however, the temperature rise of the resistor is also partially due to self-heating as a result of the power it is dissipating. As stipulated by the Joule effect, when current flows through a resistance, there will be an associated generation of heat. Therefore, the TCR alone does not provide the actual resistance change for a precision resistor.

Hence, another metric is introduced to incorporate this inherent characteristic—the power coefficient of resistance (PCR). PCR is expressed in parts per million per Watt (ppm/W) or in ppm at rated power. In the case of Z Foil Bulk Metal® resistors, the PCR is 5 ppm typical at rated power or 4 ppm/W typical for power resistors. For example, for a foil power resistor with a TCR of 0.2 ppm/°C and PCR of 4 ppm/W, a temperature change of 50°C (from +25°C to +75°C) at rated power of 0.5 W will produce a $\Delta R/R$ of $50 \times 0.2 + 0.5 \times 4 = 12$ ppm absolute change.

Reason 3: Thermal Stabilization

When power is applied to the resistor, self-heating occurs. Foil's low TCR and PCR capabilities help to minimize this effect. But to achieve high-precision results, a rapid response to any changes in the environment or other stimuli is necessary. When the level of power is changed, the resistance value must adjust accordingly as quickly as possible. A rapid thermal stabilization is important in applications where the steady-state value of resistance according to all internal and external factors must be achieved quickly to within a few ppm.

While most resistor technologies may take minutes for thermal stabilization to its steady-state value, a VFR resistor is capable of almost immediate stabilization, down to within a few ppm in under a second. The exact response is dependent on the ambient temperature as well as the change in power applied; the heat flow when power is applied places mechanical stresses on the element and as a result causes temperature gradients. Regardless, Bulk Metal Foil outperforms all other technologies by a large margin (see Figure 3).

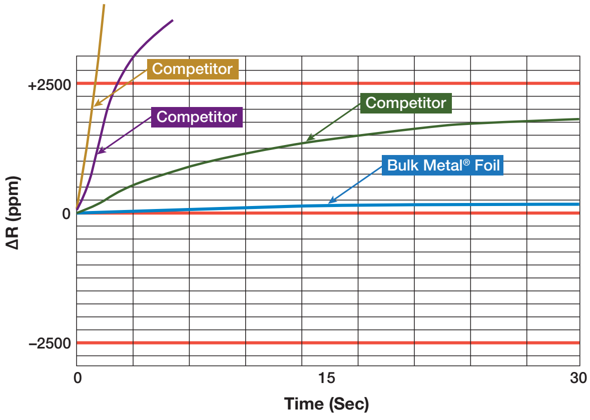
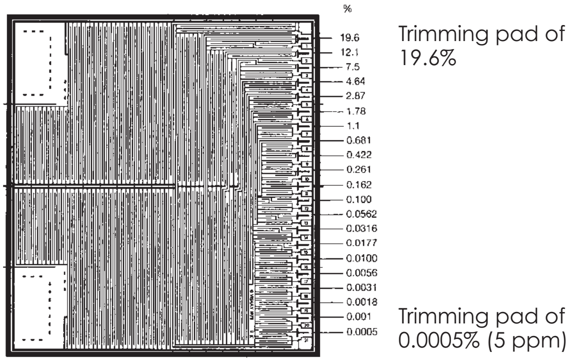


Figure 3. Thermal stabilization demonstration
(1 W applied to 50 mΩ SMD 2512)

Reason 4: Resistance Tolerance

Why do users employ tight-tolerance resistors? A system, device, or one particular circuit element must perform for a specified period of time and still perform within specification at the end of that service period. During its service life, it may have been subjected to some hostile working conditions and therefore may no longer be within the purchased tolerance. One reason for specifying a tighter purchased tolerance than the end-of-life error budget tolerance is to allow room for service shifts. Another reason is that the error budget is more economically applied to resistors than to most other components.

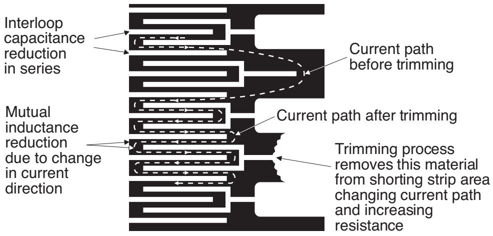
Bulk Metal Foil resistors are calibrated as accurately as 0.001% by selectively trimming various adjusting points that have been designed into the photo-etched pattern of the resistive element (see Figure 4). They provide predictable step increases in resistance to the desired tolerance level. Trimming the pattern at one of these adjusting points will force the current to seek another longer path, thus raising the resistance value of the element by a specific percentage.



NOTE: Foil shown in white, etched spaces in black.

Figure 4. VFR's S102C resistor element

The trimming operations increase resistance in precise steps but from remote locations, so that the etched grid in the active area remains reliable and noise-free (see Figure 5). In the fine adjusted areas, trimming affects the final resistance value by smaller and smaller amounts down to 0.001% and finally 0.0005% (5 ppm). This is the trimming resolution (see Figure 4).



Foil shown in black, etched spaces in white

Note
To acquire a precision resistance value, the Bulk Metal Foil chip is trimmed by selectively removing built-in "shorting bars." To increase the resistance in known increments, marked areas are cut, producing progressively smaller increases in resistance. This method reduces the effect of "hot spots" and improves the long-term stability of VFR resistors.

Figure 5. Trimming to values (conceptual illustration)

Reason 5:
Load Life Stability

Why are designers concerned about stability with applied load? Load-life stability is the characteristic most relied upon to demonstrate a resistor's long-term reliability. Military testing requirements to 10,000 h with limits on amount of shift and the number of failures results in a failure rate demonstration. Precision Bulk Metal Foil resistors have the tightest allowable limits. Whether military or not, the load-life stability of VFR resistors is unparalleled and long-term serviceability is assured.

The reason VFR resistors are so stable has to do with the materials of construction (Bulk Metal Foil and high alumina substrates). For example, the S102C and Z201 resistors are rated at 0.3 W at 125°C with an allowable ΔR of 150 ppm max after 2000 h under load and 500 ppm max after 10,000 h (see Figures 6 and 7 for the demonstrated behavior). Conversely, the ΔR is reduced by decreasing the applied power, which lowers the element temperature rise in VFR resistors. Figure 6 shows the drift due to load-life testing at rated power and Figure 7 shows the drift due to load-life testing at varied power. Reducing the ambient temperature has a marked effect on load-life results and Figure 8 shows the drift due to rated power at different ambient temperatures. The combination of lower power and ambient temperature is shown in Figure 9 for model S102C.

Our engineers have ensured the stability of our resistors through several tests and experiments. Figure 10 displays the results of our tests that have been in progress for 29 years. Fifty sample S102C 10 kΩ resistors have been in a 70°C heating chamber while under 0.1 W applied power for this entire duration. The average deviation in resistance is just 60 ppm.

Figure 11 shows the shelf life performances, documented by a customer, for hermetically sealed VHP101 Foil resistors for over eight years. The average deviation did not exceed 1 ppm.

For evaluation of load-life stability, the two parameters that must be mentioned together—power rating and ambient temperature—can be joined into one single parameter for a given style of resistor. If the steady-state temperature rise can be established, it can be added to the ambient temperature and the sum will represent the combined (load induced + ambient) temperature. For instance, the S102C VFR resistor has a temperature rise of 9°C per 0.1 W of applied power. This leads to the following example calculations:

If T = 75°C, P = 0.2W, and t = 2000 hrs.;

Then self-heating = 9°C x 2 = 18°C.

18°C rise + 75°C ambient = 93°C total ΔR.

R max = 80 ppm from the curve of Figure 12.

Figure 12 shows, for the given duration of a load-life test, how the drift increases with the level of the applied combined temperature. As explained above, the combined temperature comprises the effect of power-induced temperature rise and the ambient temperature. The curve shows maximum drift.

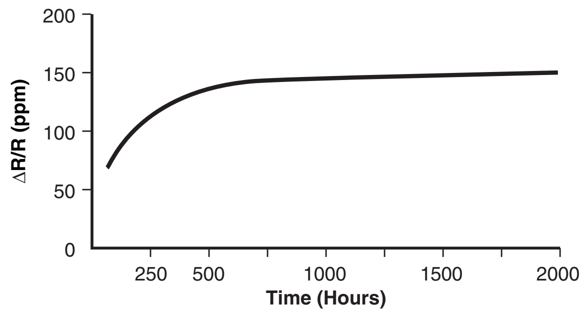


Figure 6. Relative resistance change (ΔR/R) as a function of time, load 0.3 W, +125°C ambient

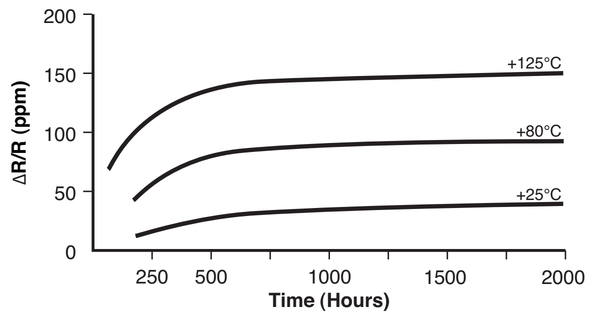


Figure 8. ΔR/R = F (time), loads 0.03 W, different ambient temperatures

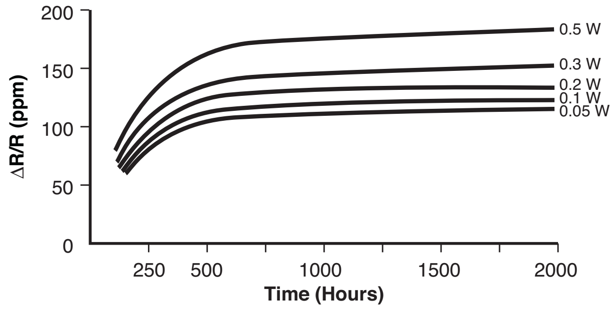


Figure 7. (ΔR/R) = F (time), loads 0.05 to 0.5 W, +125°C ambient

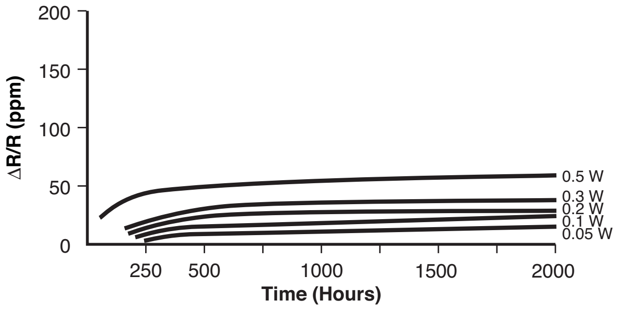


Figure 9. ΔR/R = F (time), loads 0.05 to 0.5 W, +25°C ambient

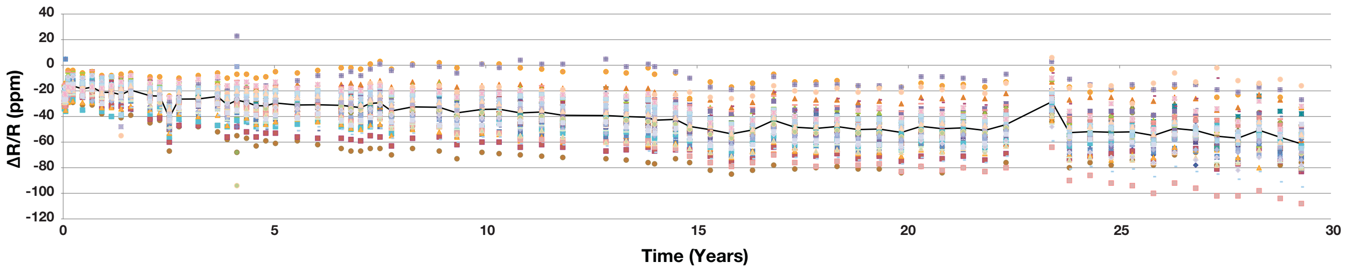


Figure 10. Long-term stability over 29 years, 0.1 W at 70°C, 50 samples (S102C, 10 kΩ)

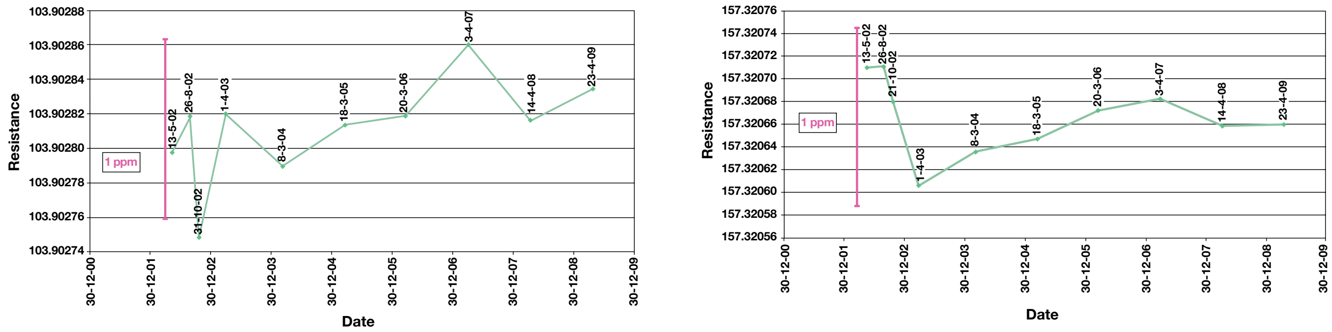
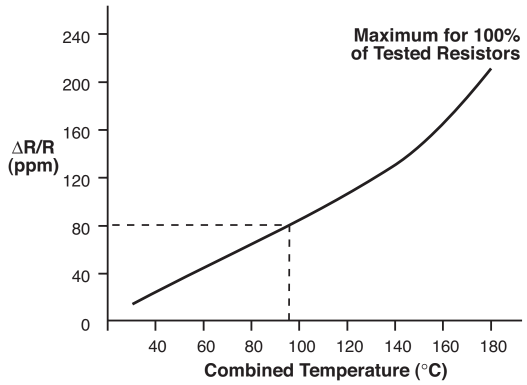


Figure 11. Shelf life test results of hermetically sealed VHP101 foil resistors over 8 years

* Combined temperature– ambient and temperature rise due to applied power.



This information is based on product taken off the line without any screen testing or power conditioning. Further drift reduction is available by factory power conditioning. Consult Application Engineering for this and other screening tests that are available.

Figure 12. Maximum resistance shifts after 2000 h of load-life test under thermal stresses*

Reason 6: High Speed and Response Time

The equivalent circuit of a resistor, as shown in Figure 13, combines a resistor in series with an inductance and in parallel with a capacitance (PLC). Resistors can perform like an R/C circuit, filter, or inductor depending on their geometry. In spiraled and wirewound resistors, this reactance is created by the loops and spaces formed by the spirals or turns of wire. Figure 14 shows how the capacitance and inductance increase as the resistance value increases due to continually increasing the number of spirals or turns.

Certain assembly techniques attempt to mitigate the inductance in wirewound resistors, but all have only limited effect. On the other hand, in planar resistors such as the Bulk Metal Foil resistors, the geometry of the lines of the resistor patterns is intentionally designed to counteract this reactance. Figure 15 shows a typical serpentine pattern of a planar resistor. Opposing current directions in adjacent lines reduce mutual inductance while geometry-related inter-line capacitances in series reduce overall capacitance. Both inductance and capacitance produce reactance proportional to the operating frequency, which changes the effective resistance and the phase between the current and voltage in the circuit.

Both inductive and capacitive reactance distort input signals, particularly in pulse applications. Figure 16 shows the current response to a voltage pulse comparing a fast Bulk Metal Foil resistor to a slower wirewound resistor. Here a pulse width of one nanosecond would have been completely missed by the wirewound resistor, while the VFR resistor achieves full replication in the time allotted.

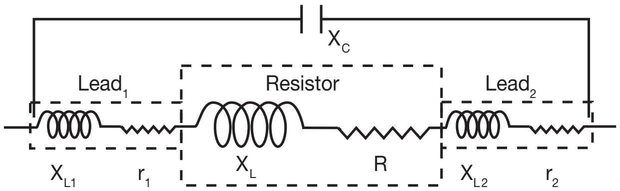
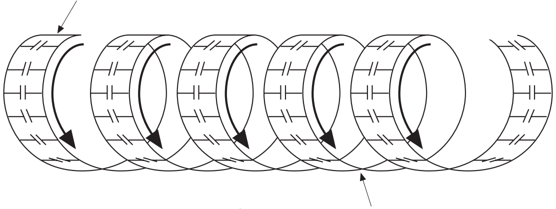


Figure 13. The equivalent circuit of a resistor

Inter-loop capacitance increases with number of loops or spirals



Current in adjacent loops travels in the same direction increasing inductance by mutual fields.

Figure 14. Capacitance and inductance in a wound or spiraled resistor

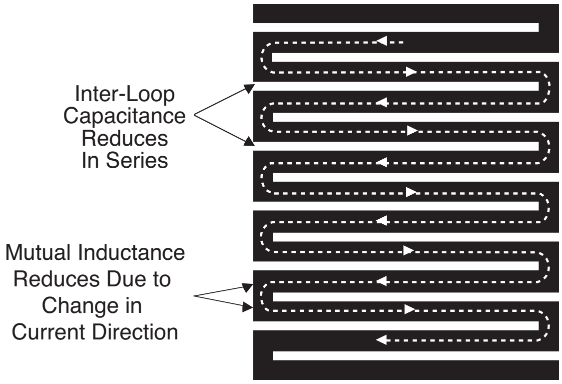


Figure 15. Bulk Metal Foil planar design

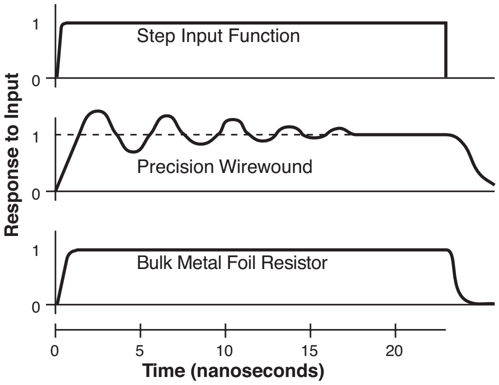


Figure 16. Comparison of a response to a pulse

In frequency applications, these reactive distortions also cause changes in apparent resistance (impedance) with changes in frequency. Figure 17 shows a family of curves relating the AC resistance to the DC resistance in Bulk Metal Foil resistors. Very good response is seen in the 100 Ω range out to 100 MHz, and all values have a good response out to 1 MHz. The performance curves for other resistor technologies can be expected to show considerably more distortion (particularly wirewound devices).

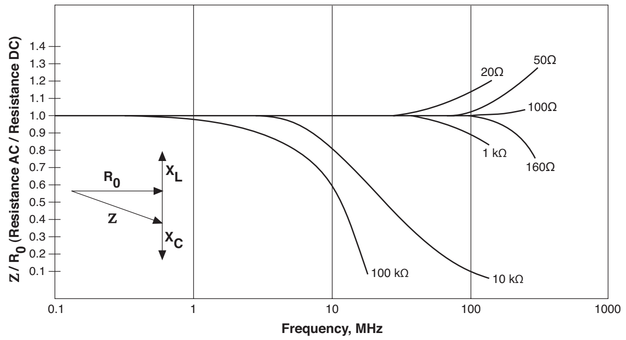


Figure 17. Effect of operation at frequency; for higher frequency, please contact the Application Engineering Department at foil@vpgsensors.com

Reason 7:
Noise: "Hear the Difference"

As sound reproduction requirements become more demanding, the selection of circuit components becomes more exacting and the resistors in the signal path are critical. Measurement instrumentation based on low-level signal inputs and high gain amplification cannot tolerate microvolt-level background noise when the signal being measured is itself in the microvolt range. Although audio circuitry, where signal purity is of the utmost concern, is the most obvious use of noise-free components, other industries and technologies are equally concerned with this characteristic.

Resistors, depending on construction, can be a source of noise. This unintended signal addition is measurable and independent of the presence of a fundamental signal. Figures 18-20 illustrate the effects of resistor noise on a fundamental signal. Resistors made of conductive particles in a non-conductive binder are the most likely to generate noise. In carbon composition and thick film resistors, conduction takes place at points of contact between the conductive particles within the binder matrix. Where these point-to-point contacts are made constitutes a high-resistance conduction site, which is the source for noise. These sites are sensitive to any distortion resulting from expansion mismatch, moisture swelling, mechanical strain, and voltage input levels. The response to these outside influences is an unwanted signal as the current finds its way through the matrix. Figure 21 illustrates this current path.

Resistors made of metal alloys, such as Bulk Metal Foil resistors, are the least likely to be noise sources. Here, the conduction

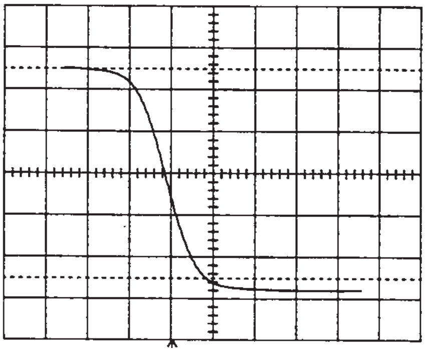


Figure 18. Segment of a fundamental curve

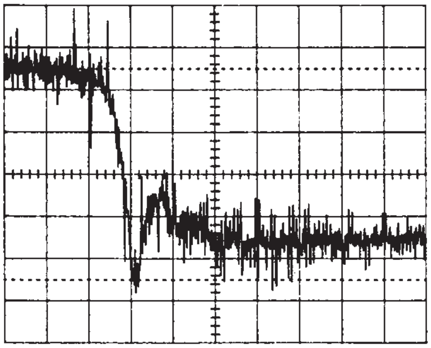


Figure 19. Signal with added resistor noise

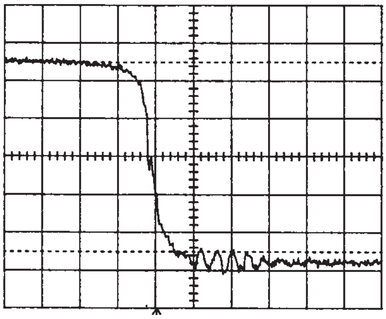
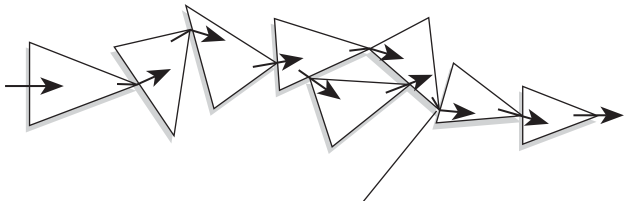


Figure 20. Signal with a Bulk Metal Foil resistor



Noise generation is maximum when current flow is through point to point contacts as shown in a particle to particle matrix

Figure 21. The current path in a particle-to-particle matrix

is across the inter-granular boundaries of the alloy. The inter-granular current path from one or more metal crystals to another involves multiple and long current paths through the boundaries, reducing the chance for noise generation. Figure 22 illustrates this current path.

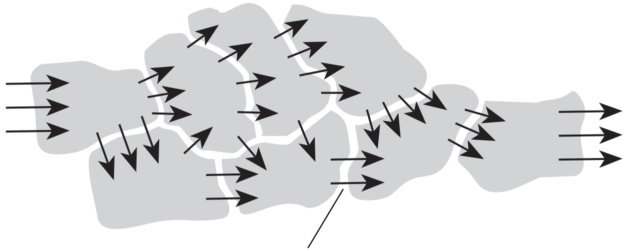


Figure 22. The current path in a resistive alloy

In addition, the photolithography and fabrication techniques employed in the manufacture of Bulk Metal Foil resistors result in more uniform current paths than are found in some other resistor constructions. Spiraled resistors, for example, have more geometric variations that contribute to insertion of noise signals. Bulk Metal Foil resistors have the lowest noise of any resistor technology, with the noise level being essentially immeasurable. Signal purity can be a function of the selection of resistor technology for pre-amp and amplifier applications. VFR resistors offer the best performance for low-noise audio applications.

Reason 8:
Thermal EMF

When a junction is formed by two dissimilar metals and is heated, a voltage is generated due to the different levels of molecular activity within these metals. This electromotive force, induced by temperature, is called thermal EMF and is usually measured in microvolts. A useful purpose of this thermal EMF is for the measurement of temperature using a thermocouple and microvolt meter.

In resistors, thermal EMF is considered a parasitic effect interfering with pure resistance (especially at low values when DC voltage is applied). It is often caused by the dissimilarity of the materials used in the resistor construction, especially at the junction of the resistor element and the lead materials. The thermal EMF performance of a resistor can be degraded by external temperature differences between the two junctions, dissymmetry of power distribution within the element, and the dissimilarity of the molecular activity of the metals involved.

One of the key features of the VFR resistor is its low thermal EMF design. The flattened paddle leads (in through-hole designs) make intimate contact with the chip, thereby maximizing heat transfer and minimizing temperature variations. The resistor element is designed to uniformly dissipate power without creating hot spots and the lead material is compatible with the element material. These design factors result in a very low thermal EMF resistor. Figures 23 and 24 display the various design characteristics that give these resistors an extremely low thermal EMF.

Reason 9:
Electrostatic Discharge (ESD)

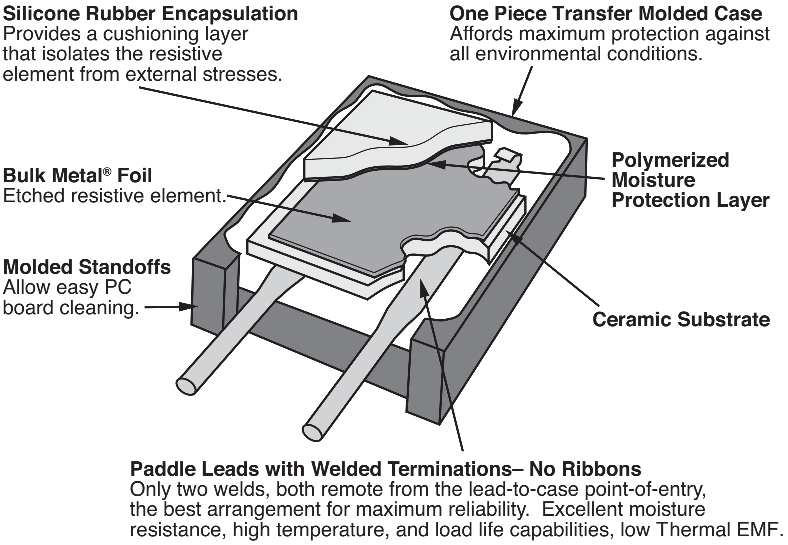
Electrostatic discharge (ESD) can be defined as a rapid transfer of charge between bodies at different electrical potentials—either by direct contact, arcing, or induction—in an attempt to become electrically neutral. The human threshold for feeling an ESD is 3000 V, so any discharge that can be felt is above this voltage level. Because the duration of this high-voltage spike is less than a microsecond long, the net energy is small compared to the size of the human body over which it is spread. From the human body's point of view, ESD does no harm. But when the discharge is across a small electronic device, the relative energy density is so great that many components can be damaged by ESD at levels as low as 3000 V or even 500 V.

ESD damage is generally divided into three categories:

- Parametric failure—the ESD event alters the resistance of the component causing it to shift from its required tolerance. This failure does not directly pertain to functionality; thus a parametric failure may be present even if the device is still functional.
- Catastrophic damage—the ESD event causes the device to immediately stop functioning. This may occur after one or a number of ESD pulses, and may have many causes, such as human body discharge or the mere presence of an electrostatic field.
- Latent damage—the ESD event causes moderate damage to the device, which is not noticeable, as the device appears to be functioning correctly. However, the load life of the device is dramatically reduced, as further degradation caused by operating stresses may cause the device to fail during service. This defect is of greatest concern as it is very difficult to detect by visual inspection or re-measurement.

In resistors, ESD sensitivity is a function of their size. The smaller the resistor, the less space there is to spread the energy pulsed through it from the ESD. This energy concentration in a small area of a resistor's active element causes it to heat up, which could lead to irreversible damage. With the growing trend of miniaturization, electronic devices, including resistors, are becoming smaller and smaller, causing them to be more prone to ESD damage.

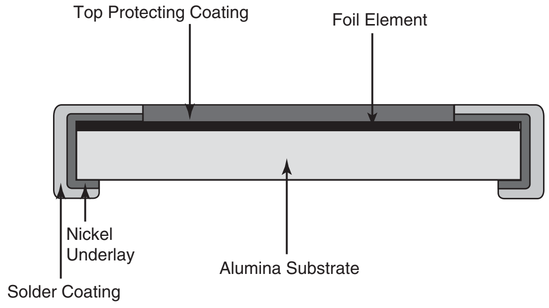
Thus, the superiority of Bulk Metal Foil precision resistors over thin film resistors, when subjected to ESD is attributed mainly to their greater thickness. Foil is 100 times thicker than thin film, and therefore the heat capacity of the resistive foil layer is much higher compared to the thin film layer. Thin film is created through particle deposition processes (evaporation or sputtering), while



The combination of ruggedized leads and molded case, plus the highly efficient heat transfer characteristics of the unique assembly and the ceramic substrate results in a high reliability resistor with excellent moisture resistance, high temperature, and load life capabilities. These also afford a very low Thermal EMF.

Flattened "paddles" are wrapped around the resistance element structure and welded directly to the resistance alloy—thus there is only one weld per lead. The closely related thermal characteristics of the selected materials, combined with the unique "paddle" lead design, produce a resistor with extremely low Thermal EMF.

Figure 23. Ruggedized construction



Drawing not to scale

Figure 24. Surface-mount wrap-around chip foil resistor construction

foil is a bulk alloy with a crystalline structure created through hot and cold rolling of the melt.

Tests performed have indicated that foil chip resistors can withstand ESD events at least to 25 kV (data available), while thin and thick film chip resistors have been seen to undergo catastrophic failures at electric potentials as low as 3000 V (parametric failures at even much less). If the application is likely to confront the resistor with ESD pulses of significant magnitude, the best resistor choice is Bulk Metal Foil.

Reason 10: Non-Measurable Voltage Coefficient

As mentioned earlier in our section on resistor noise, resistors can change value due to applied voltage. The term used to describe the rate of change of resistance with changing voltage is known as voltage coefficient. Resistors of different constructions have noticeably different voltage coefficients. In the extreme case, the effect in a carbon composition resistor is so noticeable that the resistance value varies greatly as a function of the applied voltage. Bulk Metal Foil resistor elements are insensitive to voltage variation and the designer can count on VFR resistors having the same resistance under varying circuit voltage level conditions. The inherent bulk property of the metal alloy provides a non-measurable voltage coefficient.

How Much Performance?

Naturally, not every engineer needs an entire high-performance package for their circuitry. Resistors with much poorer specifications can be used satisfactorily in many applications, so the question of need is divided into four basic categories:

1. Existing applications that can be upgraded by relying on the total performance package of Bulk Metal Foil resistors.
2. Existing applications that require one or more, but not necessarily all, of the performance parameters to be "industry best."
3. State-of-the-art circuitry that can only be developed now because of the availability of improved specifications for precision resistors.
4. Purposeful pre-planned use of precision resistors to allow for future upgrading (e.g., cost savings can be realized by having the circuit accuracy maintained by the resistors rather than by the active devices, which would greatly increase costs for only slightly better levels of performance).

In category two, for example, the need for a single parameter must be weighed against the economics of the whole package. It could cost less to use a resistor with superior overall performance specifications, because the need for compensating circuitry (and the cost of the associated components plus their assembly) may be eliminated. Cost savings may also be achieved by concentrating precision in the resistors rather than in the active devices, because active devices have greater cost per marginal performance improvement than the resistors do.

Another question that might be posed is, "Would utilizing a higher-performance resistor in order to upgrade equipment performance enhance market acceptance of the equipment?"

Conclusion

All-In-One Resistor

The ten reasons to specify foil resistors are inherent in the design and are not a function of manufacturing variables or a selection process. This combination of parameters is not available in any other resistor technology. VFR resistors combine performance characteristics resulting in unmatched performance and high reliability, satisfying the needs of today's expanding requirements.

Special Order

Consider VFR resistors for all of your low TCR needs. Special orders may be placed for low-TCR, low-value resistors and tight TCR tracking of individual resistors and network combinations. Contact the Application Engineering Department to discuss your requirements for these and any other TCR applications (email: foil@vpgsensors.com).