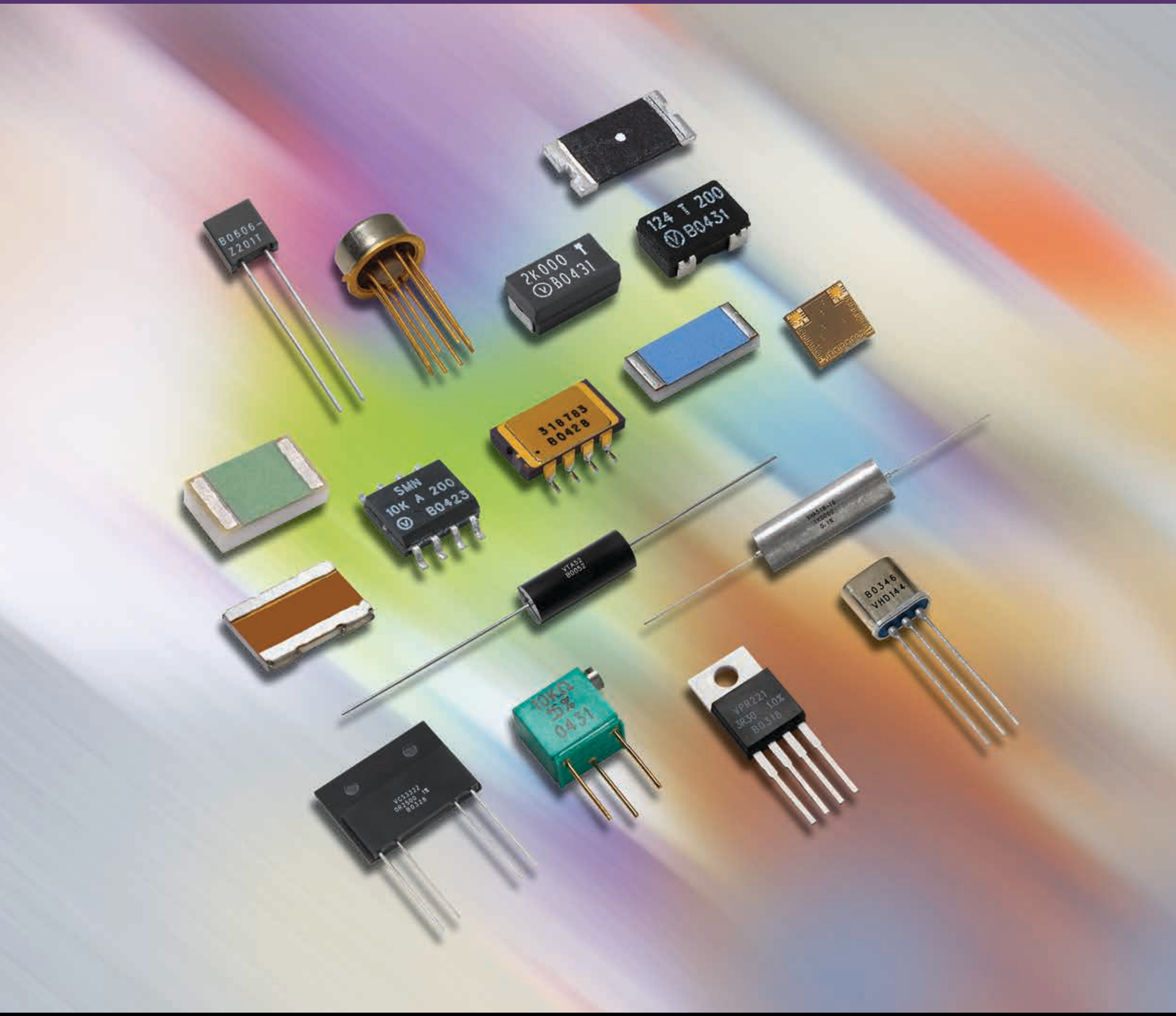
Design and Selector Guide for High-Precision Resistors

Product Overview



vishayfoilresistors.com

VISHAY FOIL RESISTORS
A VPG Brand

Bulk Metal® Foil Resistors Design and Selector Guide

Vishay Foil Resistors

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About Vishay Foil Resistors

First introduced in 1962, the Bulk Metal® Foil technology of Vishay Precision Group's (VPG) Vishay Foil Resistors (VFR) product line still out-performs all other resistor technologies available for applications that require precision, stability, and reliability. Ultra-precision Bulk Metal Foil resistors provide extremely low temperature coefficient of resistance (TCR) and exceptional long-term stability through temperature extremes. VFR products include discrete resistors and resistor networks in surface-mount and through-hole (leaded) configurations, precision trimming potentiometers, and discrete chips for use in hybrid circuits, with customized chip resistor networks and arrays available. We continue to develop, manufacture, and market new types of Bulk Metal Foil resistors, including military-established-reliability components (EEE-INST-002, DLA, CECC, ESA, ER, QPL, etc).

This Design and Selector Guide brings together the technical data you need to choose the best Bulk Metal Foil resistor for your application—including technical aspects of foil technology, selector guides, and applications sections. Selector guides are divided into sections providing the resistance range, tolerance, TCR, rated power, and load-life stability of Bulk Metal Foil products in eight categories:

- Surface-mount
- Through-hole
- Power current-sensing
- Voltage dividers and resistor networks
- Hermetically-sealed
- Trimming potentiometers
- Hybrid chips and custom designed hermetically-sealed networks (PRND)
- Avionics, military, and space (AMS)

Bulk Metal® Foil Technology Product Life Cycle

VISHAY FOIL RESISTORS
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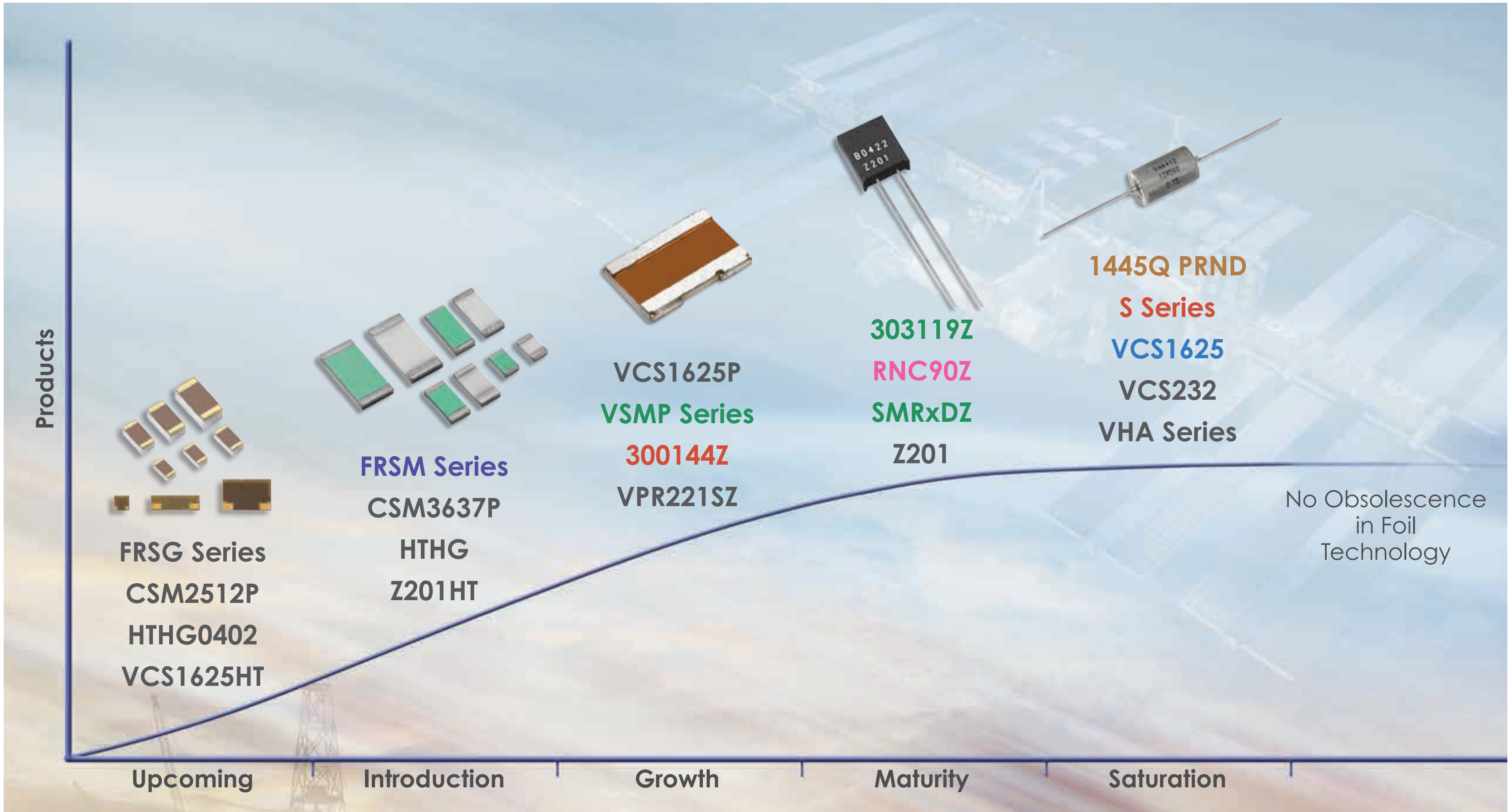


Color Key for Certificates

DLA DWG Available
DLA + EPPL European Preferred Parts List, Issue 11
DLA + EEE INST 002 test program
EEE INST 002 test program
Established Reliability (ER)
QPL

Recent and Forthcoming Product Developments

- Implementation of Z1 Foil Technology in all products
- Introduction of new products for high-temperature applications (up to 240°C)
- Smaller SMD case sizes (including 0402 and 0603)
- Current sense with higher power

Foil Technology Generations — 1962: Classic Foil I • 1982: Classic Foil II • 2000: Z Foil • 2010: Z1 Foil Technology

Ten Technical Reasons to Choose VFR Resistors for Your Circuit

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.

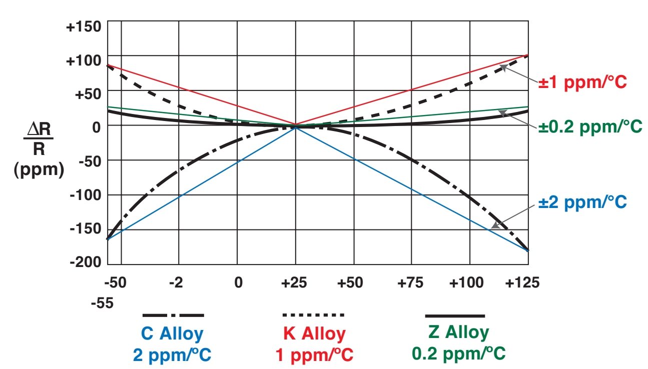


Figure 1. Typical resistance versus temperature curve and its chord slopes (TCR) of foil alloys in military range

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.

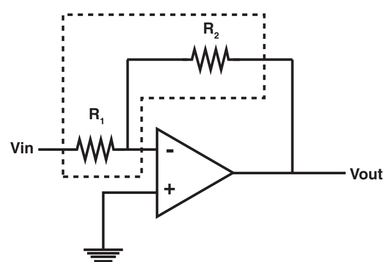


Figure 2. Typical application

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).

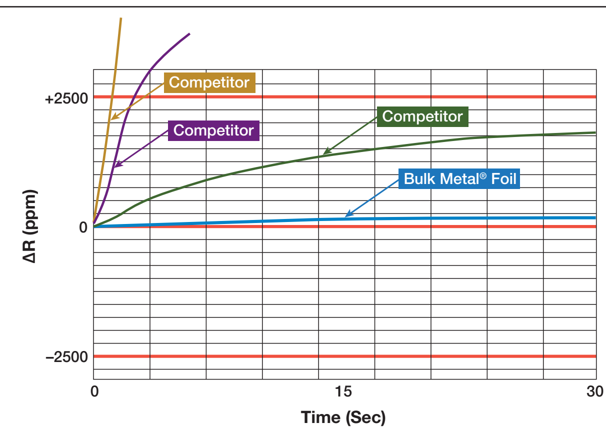
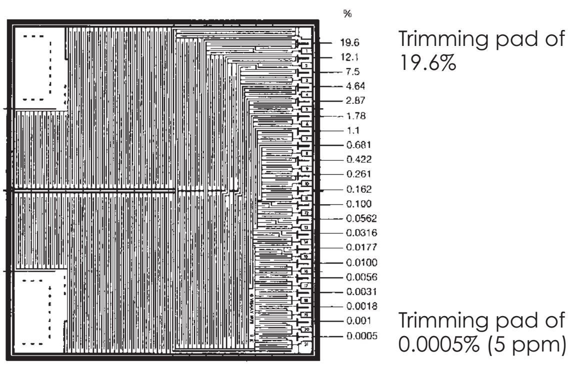


Figure 3. Thermal stabilization demonstration (1 W applied to 50 mΩ SMD 2512)

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.

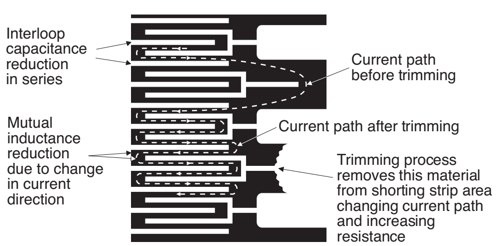
Bulk Metal Foil resistors are calibrated as accurately as 0.001% by selectively trimming various adjusting points that have been designed into the photo-etched pattern of the resistive element (see Figure 4). They provide predictable step increases in resistance to the desired tolerance level. Trimming 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.

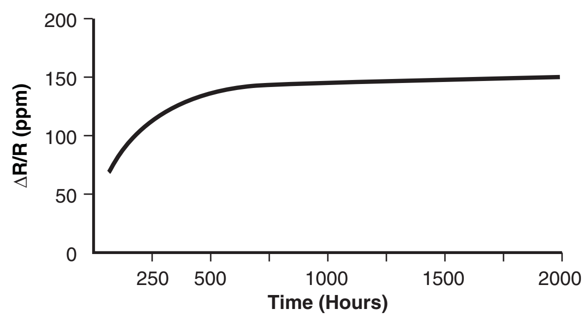


Figure 6. Relative resistance change (ΔR/R) as a function of time, load 0.3 W, +125°C ambient

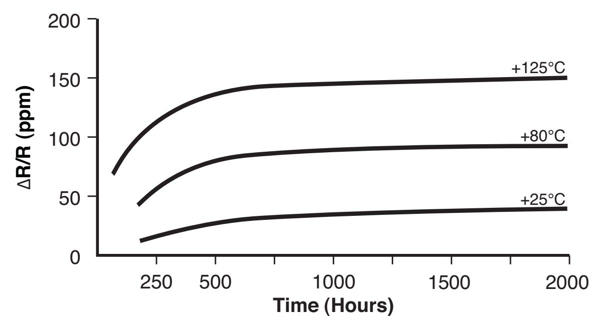


Figure 8. ΔR/R = F (time), loads 0.03 W, different ambient temperatures

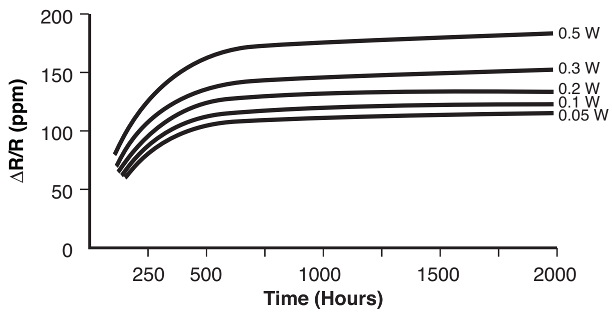


Figure 7. (ΔR/R) = F (time), loads 0.05 to 0.5 W, +125°C ambient

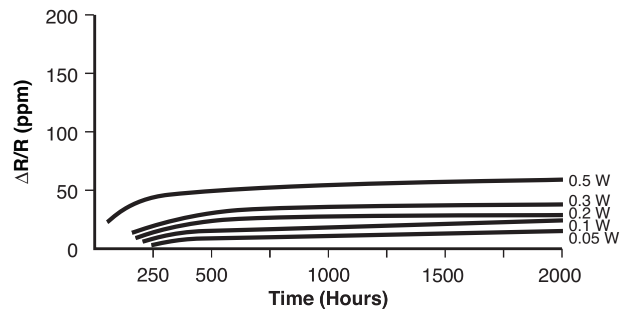


Figure 9. ΔR/R = F (time), loads 0.05 to 0.5 W, +25°C ambient

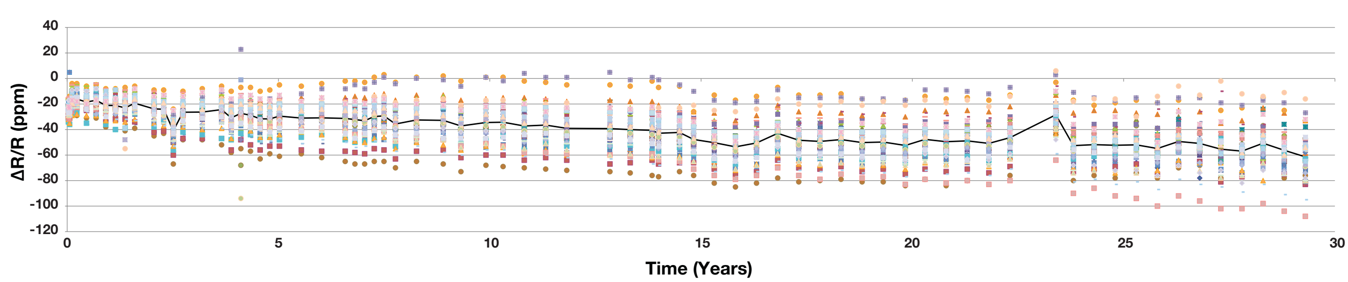


Figure 10. Long-term stability over 29 years, 0.1 W at 70°C, 50 samples (S102C, 10 kΩ)

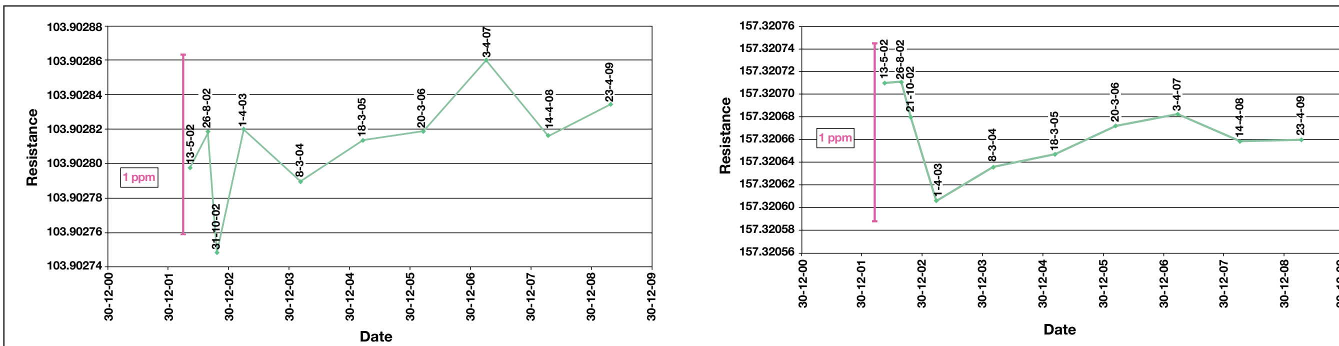
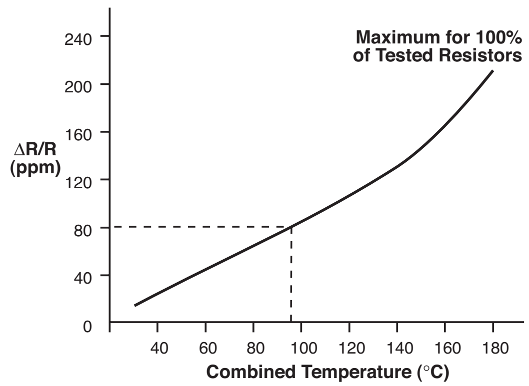


Figure 11. Shelf life test results of hermetically sealed VHP101 foil resistors over 8 years

* 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

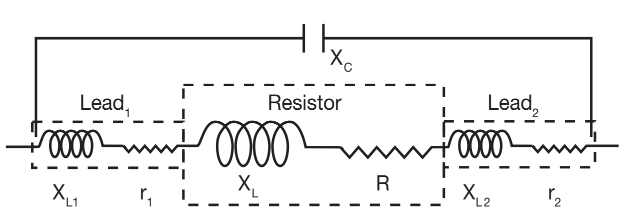


Figure 13. The equivalent circuit of a resistor

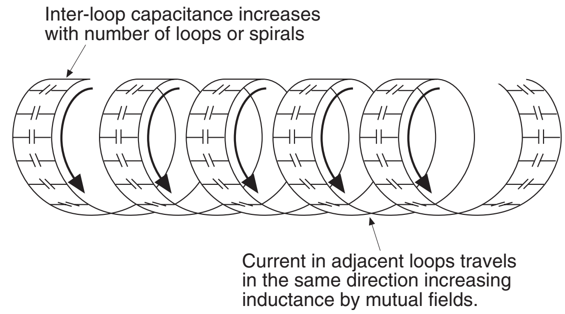


Figure 14. Capacitance and inductance in a wound or spiraled resistor

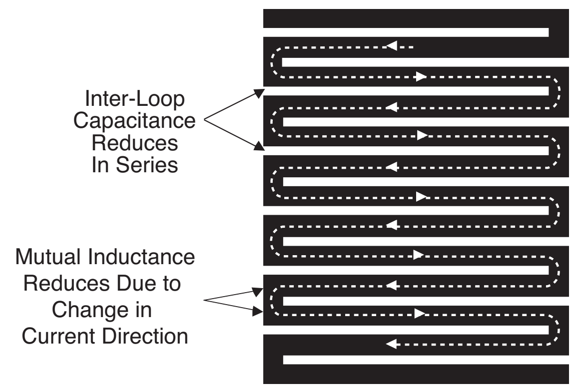


Figure 15. Bulk Metal Foil planar design

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.

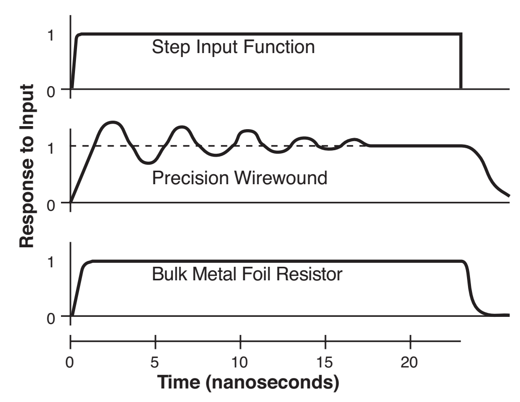


Figure 16. Comparison of a response to a pulse

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).

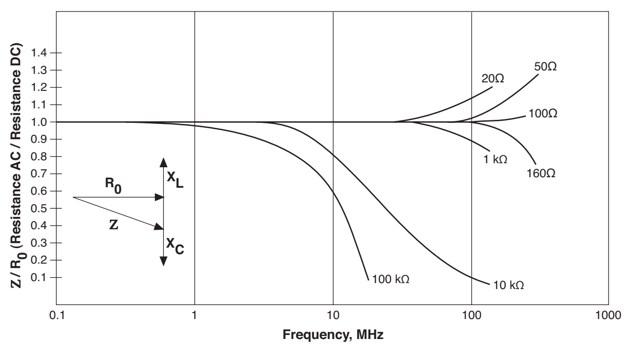


Figure 17. Effect of operation at frequency; for higher frequency, please contact the Application Engineering Department at foil@vpgsensors.com

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

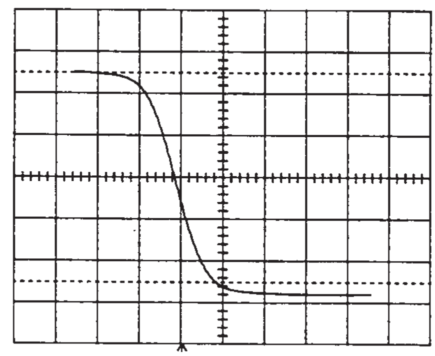


Figure 18. Segment of a fundamental curve

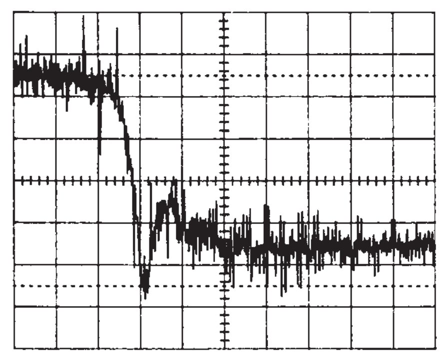


Figure 19. Signal with added resistor noise

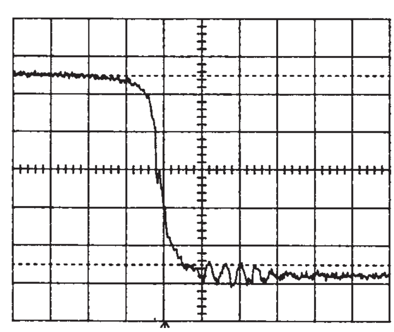


Figure 20. Signal with a Bulk Metal Foil resistor

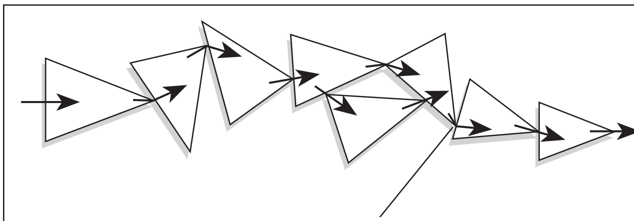


Figure 21. The current path in a particle-to-particle matrix

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.

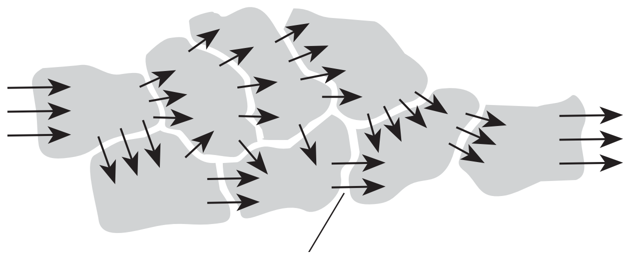


Figure 22. The current path in a resistive alloy

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)

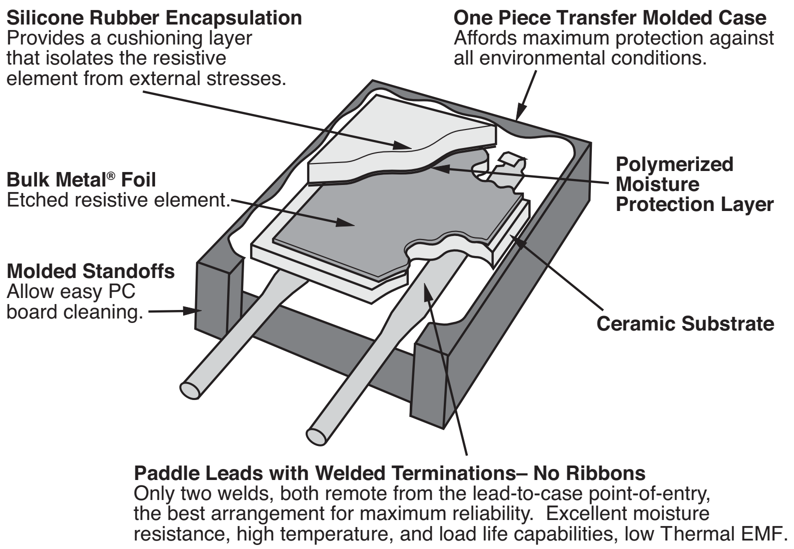
Electrostatic discharge (ESD) can be defined as a rapid transfer of charge between bodies at different electrical potentials—either by direct contact, arcing, or induction—in an attempt to become electrically neutral. The human threshold for feeling an ESD is 3000 V, so any discharge that can be felt 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

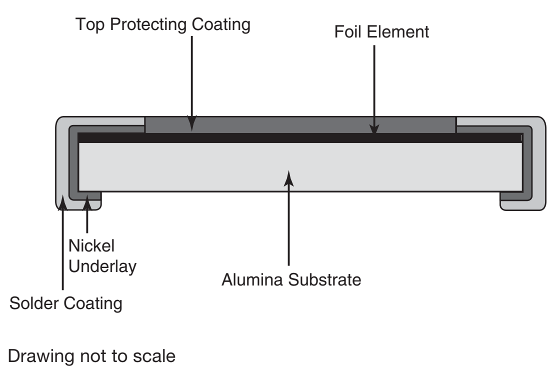


Figure 24. Surface-mount wrap-around chip foil resistor construction

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).

Post-Manufacturing Operations (PMO) Enhance the Already Superior Stability of Foil Resistors

These post-manufacturing operations (PMOs) are uniquely applicable to resistors made of resistive foil and they take the already superior stability of VFR devices one step further. They constitute an exercising of the resin that bonds the foil to the substrate, the foil, the alumina, the molding, and the contacts. The operations employed are:

- Temperature cycling/thermal shock
- Short-time overload/power shot (accelerated load life)
- Power conditioning

Temperature Cycling

Temperature cycling is initially done in the chip stage of all production and will eliminate any fallout. The cycling exercises the foil and the contacts without reducing their initial bonding strength. A small reduction in resistance is tolerable during this PMO.

Short-Time Overload (Accelerated Load Life)

Short-time overload (STO) occurs when a circuit is subjected at one point in time to a temporary, unexpected high pulse (or overload) that can result in device failure. This STO is performed on all resistors during manufacturing, with a function of eliminating any hot spots if they exist.

Power Conditioning

The standard load-life curve of a foil resistor exhibits a significant portion of its change in the first 250 h to 500 h, after which the curve begins to stabilize (see Figure 1). The power conditioning exercise applies a load for a specified amount of time to eliminate this knee in the load-life curve. Upon delivery, the resistor will be on the flat part of the curve for your convenience. The power conditioning is a function of the application and should be worked out between our Applications Engineering department and your design team.

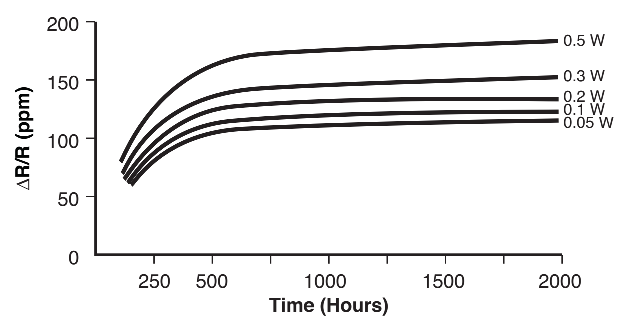


Figure 1. (ΔR/R) = F (Time), loads 0.05 to 0.5 W, +125°C ambient

Can We Use PMO on Other Resistor Technologies?

Applying these same operations to thick film, thin film, and wirewound resistors has vastly different consequences and can drive these devices out of tolerance or create an open circuit. The resistors experience too many failures to discuss here. On the other hand, these operations are an enhancement to foil resistor performance and should be considered when the level of stability required is beyond the published limits for standard products.

For further information and additional custom-designed PMO, please contact our Application Engineering department at foil@vpgsensors.com.

Surface-Mount Resistors

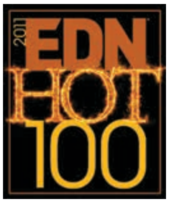
Key Benefits

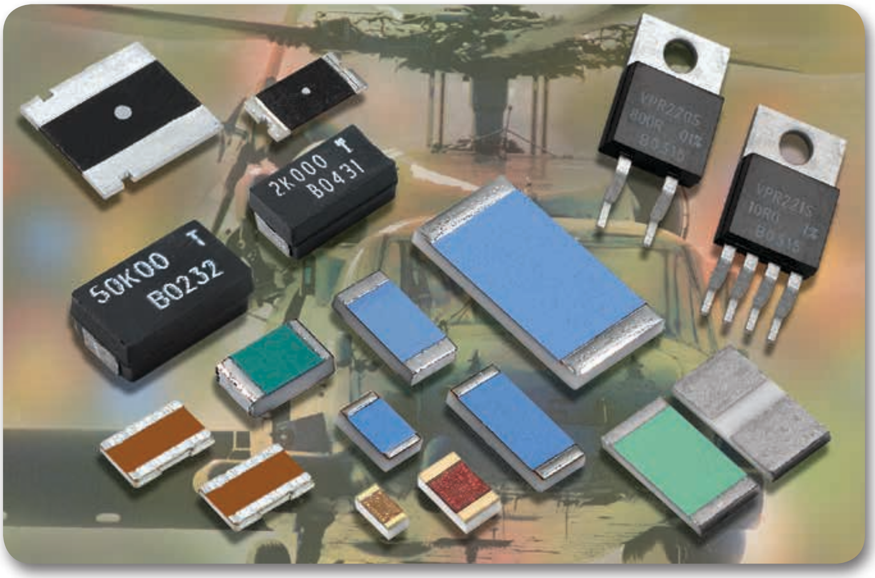
- Temperature coefficient of resistance (TCR):
  - ±0.2 ppm/°C (–55°C to +125°C, +25°C ref.) typical with Z Foil
- Resistance tolerance to ±0.01%
- Power coefficient of resistance (PCR) "ΔR due to self heating": 5 ppm at rated power with Z Foil
- Electrostatic discharge (ESD) at least to 25 kV
- Overload capability (6.25 x rated power, 5) <0.005% (50 ppm)
- Rise Time: 1 ns without ringing
- Structure and process provides low sensitivity to moisture
- Non-inductive, non-capacitive image design
- Current noise: 0.010 μVRMS/V of applied voltage (<–40 dB)
- Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
- Matched sets are available upon request
- VFR resistors are not restricted to standard values; specific "as required" values can be supplied at no extra cost or delivery (e.g. 1K2345 kΩ vs. 1 kΩ)
- Lead (Pb)-free, gold, and tin/lead terminations available
- Now available with flexible terminations
- Prototype quantities available in just five working days or sooner

Applications

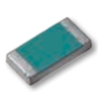
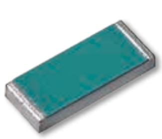
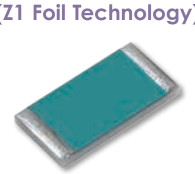
- Military and aerospace: DLA Drawings, EPPL, ESA, and EEE-INST-002 are available
- Commercial aviation
- Aircraft and missile guidance systems
- Medical
- Automatic test equipment (ATE)
- Electron beam applications
- Measurement systems
- Current sensing
- High-precision amplifiers
- Weighing systems

FRSH and VCS1625P Bulk Metal Foil Chip Resistors Selected for EDN's Annual "Hot 100 Products





Our goal is to find solutions for challenging applications. For any questions, please contact foil@vpgsensors.com

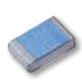
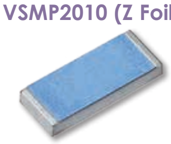
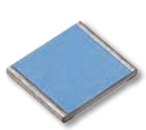
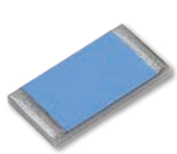
Model	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Surface-Mount							
FRSM0603 (Z1 Foil Technology) 	Y4021	New Z1 Foil Technology, ultra high-precision wrap-around chip resistor for improved load life stability and high temperature applications up to +175°C	100Ω to 4 kΩ	±0.01%	±0.2 ppm/°C	0.1W	±0.0025%
FRSM0805 (Z1 Foil Technology) 	Y4022		5Ω to 8 kΩ	±0.01%	±0.2 ppm/°C	0.2W	±0.0025%
FRSM1206 (Z1 Foil Technology) 	Y4023		5Ω to 25 kΩ	±0.01%	±0.2 ppm/°C	0.3W	±0.0025%
FRSM1506 (Z1 Foil Technology) 	Y4024		5Ω to 30 kΩ	±0.01%	±0.2 ppm/°C	0.3W	±0.0025%
FRSM2010 (Z1 Foil Technology) 	Y4025		5Ω to 70 kΩ	±0.01%	±0.2 ppm/°C	0.5W	±0.0025%
FRSM2512 (Z1 Foil Technology) 	Y4027		5Ω to 125 kΩ	±0.01%	±0.2 ppm/°C	0.75W	±0.0025%

Uncalibrated chips are available for FRSM product family.

* Tighter performances and higher or lower value resistances are available for all models upon request.

Surface-Mount Resistors

VISHAY FOIL RESISTORS
A VPG Brand

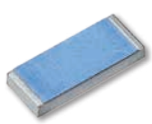
Model	Global Model	Product Description	Resistance Range *	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Surface-Mount							
VSMP0603 (Z Foil) 	Y1636	Ultra high-precision wrap-around chip resistor	100Ω to 5 kΩ	±0.01%	±0.2 ppm/°C	0.1W	±0.005%
VSMP0805 (Z Foil) 	Y1624	Ultra high-precision wrap-around chip resistor DLA 07024	5Ω to 8 kΩ	±0.01%	±0.2 ppm/°C	0.2W	±0.005%
VSMP1206 (Z Foil) 	Y1625	Ultra high-precision wrap-around chip resistor DLA 07025	5Ω to 25 kΩ	±0.01%	±0.2 ppm/°C	0.3W	±0.005%
VSMP1506 (Z Foil) 	Y1626	Ultra high-precision wrap-around chip resistor DLA 03010	5Ω to 30 kΩ	±0.01%	±0.2 ppm/°C	0.3W	±0.005%
VSMP2010 (Z Foil) 	Y1627	Ultra high-precision wrap-around chip resistor DLA 06001	5Ω to 70 kΩ	±0.01%	±0.2 ppm/°C	0.5W	±0.005%
VSMP2018 (Z Foil) 	Y1637	Ultra high-precision wrap-around chip resistor DLA 9300	5Ω to 20 kΩ**	±0.01%	±0.2 ppm/°C	0.75W	±0.005%
VSMP2512 (Z Foil) 	Y1628	Ultra high-precision wrap-around chip resistor DLA 06002	10Ω to 125 kΩ	±0.01%	±0.2 ppm/°C	0.75W	±0.005%

Uncalibrated chips are available for VSMP product family.

* Tighter performances and higher or lower value resistances are available for all models upon request.

** Higher values from 20 kΩ to 150 kΩ can be supplied upon special request

Surface-Mount Resistors

Model	Global Model	Product Description	Resistance Range *	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Surface-Mount							
VSM0805 	Y1172	High-precision wrap-around chip resistor DLA 07024	5Ω to 8 kΩ	±0.01%	±2 ppm/°C	0.1W	±0.005%
VSM1206 	Y1496	High-precision wrap-around chip resistor DLA 07025	5Ω to 25 kΩ	±0.01%	±2 ppm/°C	0.15W	±0.005%
VSM1506 	Y1455	High-precision wrap-around chip resistor DLA 03010	5Ω to 30 kΩ	±0.01%	±2 ppm/°C	0.2W	±0.005%
VSM2010 	Y1611	High-precision wrap-around chip resistor DLA 06001	5Ω to 70 kΩ	±0.01%	±2 ppm/°C	0.3W	±0.005%
VSM2512 	Y1612	High-precision wrap-around chip resistor DLA 06002	10Ω to 125 kΩ	±0.01%	±2 ppm/°C	0.4W	±0.005%
Flex-1 	Y2014 **New**	Surface mount with flexible terminations system and load-life stability of 0.005%	5Ω to 33 KΩ	±0.01%	±0.2 ppm/°C	0.25W	±0.005%
SMR1DZ (Z Foil) 6.0 mm x 3.2 mm 	Y1745	Ultra high-precision molded resistor with flexible terminations DLA 06020	5Ω to 33 kΩ	±0.01%	±0.2 ppm/°C	0.25W	±0.005%
SMR1D 6.0 mm x 3.2 mm 	Y1121	High-precision molded resistor with flexible terminations DLA 06020	5Ω to 33 kΩ	±0.01%	±2 ppm/°C	0.25W	±0.005%

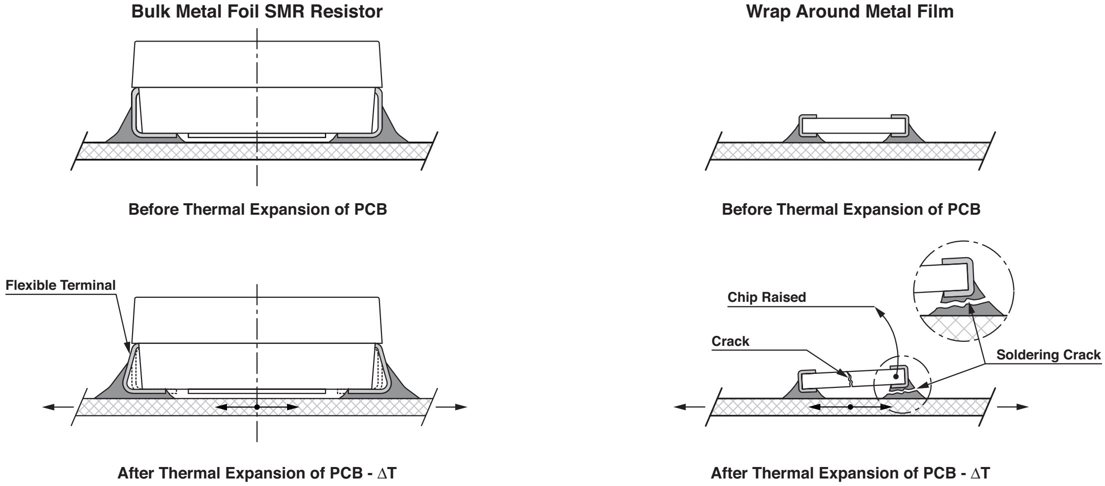
Uncalibrated chips are available for VSM product family.

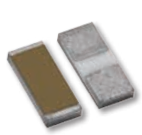
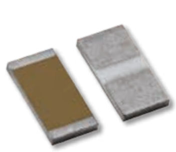
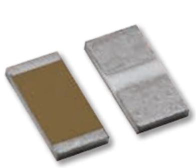
* Tighter performances and higher or lower value resistances are available for all models upon request.

Model	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Surface-Mount							
Flex-2 	Y2015 **New**	Surface mount with flexible terminations system and load-life stability of 0.005%	5Ω to 80 kΩ	±0.01%	±0.2 ppm/°C	0.6W	±0.005%
SMR3DZ (Z Foil) 7.3 mm x 4.3 mm 	Y1746	Ultra high-precision molded resistor with flexible terminations DLA 06021	5Ω to 80 kΩ	±0.01%	±0.2 ppm/°C	0.6W	±0.005%
SMR3D 7.3 mm x 4.3 mm 	Y1169	High-precision molded resistor with flexible terminations DLA 06021	5Ω to 80 kΩ	±0.01%	±2 ppm/°C	0.6W	±0.005%
SMR3P (Z Foil) 7.3 mm x 4.3 mm 	Y1168	Ultra high-precision industrial grade molded surface-mount resistor	100Ω to 15 kΩ	±0.01%	±0.5 ppm/°C **Maximum**	0.6W	±0.005%

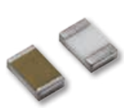
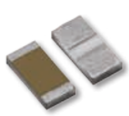
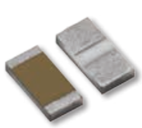
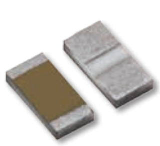
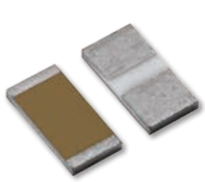
* Tighter performances and higher or lower value resistances are available for all models upon request.

SMRxDZ Flexible Termination - Thermal Expansion Effect



Model	Global Model	Product Description	Resistance Range *	Best Tolerance	TCR (−55°C to +125°C, +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Surface-Mount, High Temperature Applications							
FRST0603 	Y4013 **New**	Z1 Foil Technology, ultra high-precision surface-mount chip resistor for high temperature applications	100Ω to 4 KΩ*	±0.01%	±2.5 ppm/°C	0.1W	±0.0025%
FRST0805 	Y4014 **New**		5Ω to 8 kΩ	±0.01%	±2.5 ppm/°C	0.2W	±0.0025%
FRST1206 	Y4015 **New**		5Ω to 25 kΩ	±0.01%	±2.5 ppm/°C	0.3W	±0.0025%
FRST1506 	Y4016 **New**		5Ω to 30 kΩ	±0.01%	±2.5 ppm/°C	0.3W	±0.0025%
FRST2010 	Y4017 **New**		5Ω to 70 kΩ	±0.01%	±2.5 ppm/°C	0.5W	±0.0025%
FRST2512 	Y4018 **New**		5Ω to 125 KΩ	±0.01%	±2.5 ppm/°C	0.75W	±0.0025%

* For 0603 values between 4K and 5K, please contact us.

Model	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +200°C, +25°C ref.) Typical	Rated Power at +70°C**	Load Life 2000 Hours, +200°C at Working Power - Typical**	Long Term Stability at +225°C for 2000 hours, No Power - Typical
Surface-Mount, High Temperature Applications								
FRSH0603 	Y4061	Z1 Foil Technology, ultra high-precision surface-mount wrap-around resistor with extended pads for **high power/ high temperature applications up to +225°C**	100Ω to 4 kΩ*	±0.02%	±2.5 ppm/°C	0.12W	±0.05%	±0.05%
FRSH0805 	Y4062		5Ω to 8 kΩ	±0.02%	±2.5 ppm/°C	0.3W	±0.05%	±0.05%
FRSH 1206 	Y4063		5Ω to 25 kΩ	±0.02%	±2.5 ppm/°C	0.5W	±0.05%	±0.05%
FRSH1506 	Y4064		5Ω to 30 kΩ	±0.02%	±2.5 ppm/°C	0.6W	±0.05%	±0.05%
FRSH2010 	Y4065		5Ω to 70 kΩ	±0.02%	±2.5 ppm/°C	0.8W	±0.05%	±0.05%
FRSH2512 	Y4066		5Ω to 125 kΩ	±0.02%	±2.5 ppm/°C	1.2W	±0.05%	±0.05%

* For 0603 values between 4k and 5k, please contact us
** Tighter performances and higher or lower value resistances are available for all models upon request.
*** For further information, please refer to FRSH datasheet.

Model	Global Model	Product Description	Resistance Range	Best Tolerance	TCR (–55°C to +220°C, +25°C ref.) Typical	Rated Power at +220°C*	Long Term Stability at + 240°C for 2000 Hours, No Power - Typical
Surface-Mount, High Temperature Applications							
HTHG5x5 	Y0780 **New**	Z1 Foil Technology, high temperature hybrid chip **up to +240°C**, connection method: gold wire bonding	5Ω to 10 kΩ	±0.02%	±2.5 ppm/°C	0.025W	±0.05%
HTHG15x5 	Y0781 **New**		5Ω to 30 kΩ	±0.02%	±2.5 ppm/°C	0.05W	±0.05%
HTHG15x10 	Y0782 **New**		30Ω to 80 kΩ	±0.02%	±2.5 ppm/°C	0.075W	±0.05%
HTHG0603 	Y0794 **New**	Z1 Foil Technology, high temperature chip **up to +240°C**, connection method: gold wire bonding	100Ω to 5 kΩ	±0.02%	±2.5 ppm/°C	0.0125W	±0.05%
HTHG0805 	Y0795 **New**		5Ω to 8 kΩ	±0.02%	±2.5 ppm/°C	0.02W	±0.1%
HTHG1206 	Y0796 **New**		5Ω to 25 kΩ	±0.02%	±2.5 ppm/°C	0.033W	±0.05%
HTHG1506 	Y0797 **New**		5Ω to 30 kΩ	±0.02%	±2.5 ppm/°C	0.04W	±0.1%
HTHG2010 	Y0798 **New**		5Ω to 70 kΩ	±0.02%	±2.5 ppm/°C	0.1W	±0.05%
HTHG2512 	Y0799 **New**		5Ω to 100 kΩ	±0.02%	±2.5 ppm/°C	0.15W	±0.05%

* For further information, please refer to the HTHG datasheet at www.vishaypg.com/doc?63221

Surface-Mount Resistors

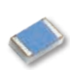
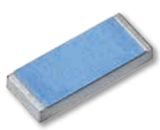
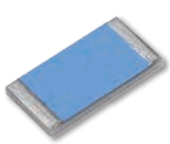
VISHAY FOIL RESISTORS A VPG Brand

Selector Guides

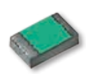
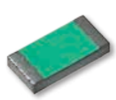
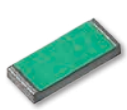
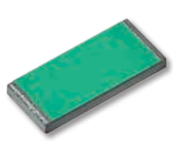
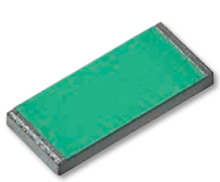
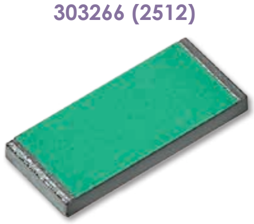
Model	Global Model	Product Description	Resistance Range	Best Tolerance	TCR (–55°C to +220°C, +25°C ref.) Typical	Rated Power at +220°C*	Long Term Stability at +240°C for 2000 Hours, No Power - Typical
Surface-Mount, High Temperature Applications							
HTHA0603 	Y0774 **New**	Z1 Foil Technology, high temperature chip, **up to +240°C**, connection method: aluminum wire bonding**	100Ω to 5 kΩ	±0.02%	±2.5 ppm/°C	0.0125W	±0.05%
HTHA0805 	Y0775 **New**		5Ω to 8 kΩ	±0.02%	±2.5 ppm/°C	0.02W	±0.05%
HTHA1206 	Y0776 **New**		5Ω to 25 kΩ	±0.02%	±2.5 ppm/°C	0.033W	±0.05%
HTHA1506 	Y0777 **New**		5Ω to 30 kΩ	±0.02%	±2.5 ppm/°C	0.04W	±0.05%
HTHA2010 	Y0778 **New**		5Ω to 70 kΩ	±0.02%	±2.5 ppm/°C	0.1W	±0.05%
HTHA2512 	Y0779 **New**		5Ω to 125 kΩ	±0.02%	±2.5 ppm/°C	0.15W	±0.05%

* For further information, please refer to HTHA datasheet.

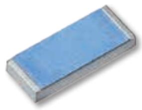
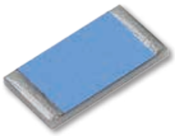
** For other mounting options: flip chip (facing down) mounted by electrical conductive-epoxy or reflow soldering, please contact the application engineering department: foil@vpgsensors.com

Model	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Surface-Mount							
FRFC0805 	Y4072 New	Z1 Foil Technology, ultra high-precision flip chip resistor	5Ω to 8 KΩ	±0.01%	±0.2 ppm/°C	0.2W	± 0.0025 %
FRFC1206 	Y4073 New		5Ω to 20 KΩ	±0.01%	±0.2 ppm/°C	0.4W	± 0.0025 %
VFCP0805 	Y1629	Z Foil, ultra high-precision flip-chip resistor	5Ω to 8 kΩ	±0.01%	±0.2 ppm/°C	0.1W	±0.005%
VFCP1206 	Y1630		5Ω to 25 kΩ	±0.01%	±0.2 ppm/°C	0.25W	±0.005%
VFCP1506 	Y1631		5Ω to 30 kΩ	±0.01%	±0.2 ppm/°C	0.3W	±0.005%
VFCP2010 	Y1632		5Ω to 70 kΩ	±0.01%	±0.2 ppm/°C	0.4W	±0.005%
VFCP2512 	Y1633		5Ω to 125 kΩ	±0.01%	±0.2 ppm/°C	0.6W	±0.005%
VPR220S 	Y1122	Precision foil power resistors, TO-220 configuration, 2-terminal connection	5Ω to 10 kΩ	±0.01%	±2 ppm/°C	8W on heat sink 1.5W in free air	+0.005% at +25°C
VPR220SZ 	Y1623	Z1 Foil Technology, ultra high-precision surface-mount power current sense resistor	5Ω to 10 kΩ	±0.01%	±0.2 ppm/°C	8W on heat sink 1.5W in free air	+0.005% at +25°C

* Tighter performances and higher or lower value resistances are available for all models upon request.

Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Surface-Mount, Military and Space Applications						
303261 (0603) 	FRSM Z1 Foil Technology configuration screen/ test flow in compliance with EEE-INST-002 (Tables 2A and 3A, Film/Foil, Level 1) and MIL-PRF-55342 **New**	100Ω to 2 kΩ	±0.02%	±0.2 ppm/°C	0.05W	±0.02%
303262 (0805) 		10Ω to 5 kΩ	±0.02%	±0.2 ppm/°C	0.1W	±0.02%
303263 (1206) 		10Ω to 14 kΩ	±0.02%	±0.2 ppm/°C	0.15W	±0.02%
303264 (1506) 		10Ω to 16 kΩ	±0.02%	±0.2 ppm/°C	0.2W	±0.02%
303265 (2010) 		10Ω to 35 kΩ	±0.02%	±0.2 ppm/°C	0.3W	±0.02%
303266 (2512) 		10Ω to 75 kΩ	±0.02%	±0.2 ppm/°C	0.4W	±0.02%

Surface-Mount Resistors

Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Surface-Mount, Military and Space Applications						
303134 (0805) 	Ultra high-precision surface-mount chip resistors, VSMP Z Foil Technology configuration, screen/test flow in compliance with EEE-INST-002 and MIL-PRF-55342	10Ω to 5 kΩ	±0.02%	±0.2 ppm/°C	0.1W	±0.03% maximum
303135 (1206) 		10Ω to 14 kΩ	±0.02%	±0.2 ppm/°C	0.15W	±0.03% maximum
303136 (1506) 		10Ω to 16 kΩ	±0.02%	±0.2 ppm/°C	0.2W	±0.03% maximum
303137 (2010) 		10Ω to 35 kΩ	±0.02%	±0.2 ppm/°C	0.3W	±0.03% maximum
303138 (2512) 		10Ω to 75 kΩ	±0.02%	±0.2 ppm/°C	0.4W	±0.03% maximum
303139 	Molded surface-mount, space-and-military-grade resistors SMRxDZ, screen/test flow in compliance with EEE-INST-002, Level 1 and MIL-PRF-55182	5Ω to 14 kΩ	±0.02%	±0.2 ppm/°C	0.25W	±0.005%
303140 		5Ω to 40 kΩ	±0.02%	±0.2 ppm/°C	0.6W	±0.005%

Selector Guides

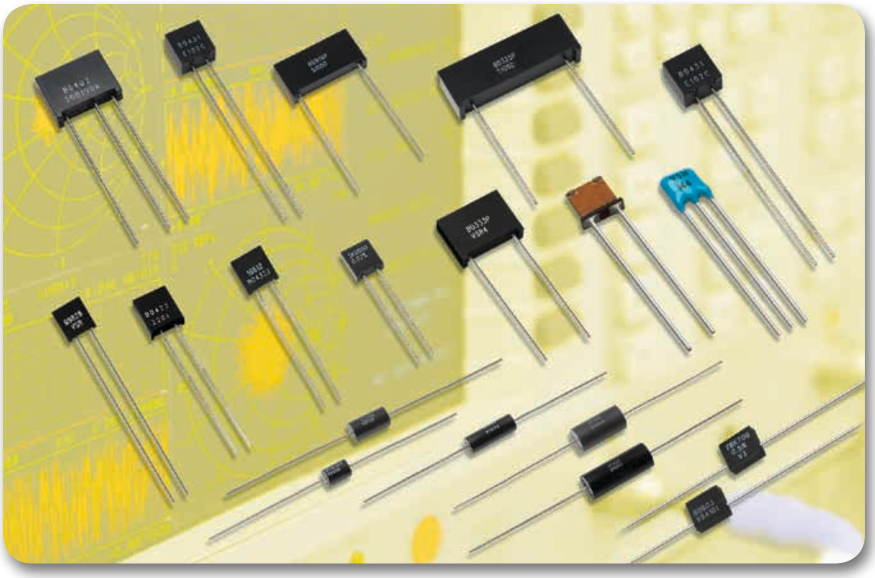
Through-Hole Resistors

Key Benefits

- Absolute Temperature Coefficient of Resistance (TCR):
  - ±0.2 ppm/°C (–55°C to +125°C, +25°C ref.) typical with Z Foil
- TCR tracking: to 0.1 ppm/°C
- Power coefficient of resistance (PCR,) "ΔR due to self heating": 5 ppm at rated power with Z Foil
- Resistance tolerance: absolute and match to ±0.005% (50 ppm)
- Electrostatic discharge (ESD) at least to 25 kV
- Load-life stability: to ±0.005% at +70°C for 10,000 at rated power
- Current noise: 0.010 μVRMS/V of applied voltage (<–40 dB)
- VFR resistors are not restricted to standard values; specific "as required" values can be supplied at no extra cost or delivery (e.g. 1.2345 kΩ vs. 1 kΩ). Prototype quantities available in just five working days or sooner
- Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
- Rise time: 1 ns, without ringing

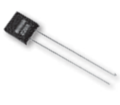
Applications

- Military
- Medical
- Electron beam applications
- Industrial
- Down-hole
- Commercial and military avionics
- Audio
- Weigh scales
- Instrumentation amplifiers
- Laboratory
- Measurement systems
- Aerospace
- Automatic test equipment (ATE)



Our goal is to find solutions for challenging applications. For any questions, please contact foil@vpgsensors.com

Through-Hole Resistors

Type	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Through-Hole, Z Foil							
Burden-Z (A) 	Y2025 Y2026	High precision bulk metal foil resistor	1Ω to 500Ω	±0.005%	±0.2 ppm/°C	0.6W at +70°C 0.3W at + 120°C	±0.005%
Burden-K (L) 	Y2023 Y2024		1Ω to 500Ω	±0.005%	±1 ppm/°C	0.6W at +70°C 0.3W at + 120°C	±0.005%
Burden-C (J) 	Y2021 Y2022		1Ω to 500Ω	±0.005%	±2 ppm/°C	0.6W at +70°C 0.3W at + 120°C	±0.005%
RTD-K (L) 	Y2010 Y2011	Handy resistor simulates RTD temperature outputs	10Ω to 5 KΩ	±0.005%	±2 ppm/°C	0.6W at +70°C	±0.005%
RTD-C (J) 	Y2012 Y2013		10Ω to 5 KΩ	±0.005%	±1 ppm/°C	0.6W at +70°C	±0.005%
Z201, Z201L 	Y1453 Y1454	Ultra high-precision Z Foil resistor	10Ω to 100 kΩ	±0.005%	±0.2 ppm/°C	0.6W at +70°C 0.3W at +125°C	±0.005%
Z202 	Y1073	Ultra high-precision **miniature** resistor	5Ω to 30 kΩ	±0.01%	±0.2 ppm/°C	0.25W at +70°C 0.125W at +125°C	±0.01%
Z203, Z203L 	Y1445 Y1446	Z1 Foil Technology, ultra high-precision resistor **for metrology and laboratory applications**	10Ω to 100 kΩ	±0.005%	**±0.5 ppm/°C maximum (+25°C to +125°C)**	0.6W at +70°C 0.3W at +125°C	±0.005%

* Tighter performances and higher or lower value resistances are available for all models upon request.

Through-Hole Resistors

VISHAY FOIL RESISTORS
A VPG Brand

Type	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Through-Hole, Z Foil							
Z201 HT 	Y1620 Y1621	Through-hole foil resistor for high temperature applications up to +200°C	10Ω to 100 KΩ	± 0.01 %	±0.2 ppm/°C ±1 ppm/°C (–55°C to +200°C, +25°C ref.)	0.4 W	to ±0.1% after 1,000 hrs of rated power at 200°C
Z204 	Y1441	Ultra high-precision Z Foil resistor	10Ω to 200 kΩ	±0.005%	±0.2 ppm/°C	1W at +70°C 0.5W at +125°C	±0.005%
Z205 	Y1443	Ultra high-precision Z Foil resistor	10Ω to 300 kΩ	±0.005%	±0.2 ppm/°C	1.5W at +70°C 0.75W at +125°C	±0.005%
Z206 	Y1447	Ultra high-precision Z Foil resistor	10Ω to 600 kΩ	±0.005%	±0.2 ppm/°C	2W at +70°C up to 400 K 1W at +125°C over to 400 K	±0.005%
AUR 	Y4700 Y4701 Y4702 Y4703	Through-hole Z Foil, low profile coated for audio applications with low harmonic distortion, and noise stabilization	5Ω to 120 KΩ	±0.01%	±0.2 ppm/°C	0.3W	±0.01%
VAR  **Noise-Free Style**	Y0706	Ultra high-precision, high resolution Z Foil **audio** resistor (no molded jacket)	10Ω to 100 kΩ	±0.01%	±0.05 ppm/°C (0°C to +60°C, +25°C ref.)	0.4W at +70°C 0.2W at +125°C	±0.005%

* Tighter performances and higher or lower value resistances are available for all models upon request.

Type	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Through-Hole, Z Foil							
VSA101 	Y0098	Ultra high-precision axial Z Foil resistor	5Ω to 100 kΩ	±0.005%	±0.2 ppm/°C	0.6W at +70°C 0.3W at +125°C	±0.005%
E102Z, E102JZ 	Y1183 Y1182	Ultra high-performance high ohmic value, small size	100 kΩ to 200 kΩ	±0.005%	±0.2 ppm/°C	0.6W at +70°C 0.3W at +125°C	±0.005%
VPR220Z (Z Foil) 	Y1622	Z Foil precision foil power resistors, TO-220 configuration, 2-terminal connection	5Ω to 10 kΩ	±0.01%	±0.2 ppm/°C	8W on heat sink 1.5W in free air at +25°C	±0.005%
VSC1Z, VSH1Z (Z Foil) 	Y0904 Y0876	High-precision **low profile conformally coated resistors, also used for audio application**	5Ω to 60 kΩ	±0.01%	±0.2 ppm/°C	0.3W at +70°C	±0.01%
VSC2Z, VSH2Z (Z Foil) 	Y0905 Y0937		60Ω to 120 kΩ	±0.01%	±0.2 ppm/°C	0.3W at +70°C	±0.01%

* Tighter performances and higher or lower value resistances are available for all models upon request.

Through-Hole Resistors

Type	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Through-Hole							
S102C 	Y0007	S-Series high-precision resistor DLA 89039 (S102C)	1Ω to 150 kΩ	±0.005%	±2 ppm/°C	**Up to 100 K:** 0.6W at +70°C 0.3W at +125°C **Over 100 K:** 0.4W at +70°C 0.2W at +125°C	±0.005%
S104D **S104F** 	Y0011 Y5011	S-Series high-precision resistor	1Ω to 500 kΩ	±0.005%	±2 ppm/°C	**Up to 200 K:** 1W at +70°C 0.5W at +125°C **Over 200 K:** 0.6W at +70°C 0.3W at +125°C	±0.005%
S105D **S105F** 	Y0012 Y4012	S-Series high-precision resistor	1Ω to 750 kΩ	±0.005%	±2 ppm/°C	**Up to 300 K:** 1.5W at +70°C 0.75W at +125°C **Over 300 K:** 0.8W at +70°C 0.4W at +125°C	±0.005%
S106D 	Y0013	S-Series high-precision resistor	0.5Ω to 1 MΩ	±0.005%	±2 ppm/°C	**Up to 400 K:** 2W at +70°C 1W at +125°C **Over 400 K:** 1W at +70°C 0.5W at +125°C	±0.005%
S102K **S102L** 	Y0062 Y0786	S-Series high-precision resistor, DLA 97009 (S102K)	1Ω to 100 kΩ	±0.005%	±1 ppm/°C	**Up to 100 K:** 0.6W at +70°C 0.3W at +125°C **Over 100 K:** 0.4W at +70°C 0.2W at +125°C	±0.005%
S104K 	Y0101	S-Series high-precision resistor	1Ω to 300 kΩ	±0.005%	±1 ppm/°C	**Up to 200 K:** 1W at +70°C 0.5W at +125°C **Over 200 K:** 0.6W at +70°C 0.3W at +125°C	±0.005%
S105K 	Y0102	S-Series high-precision resistor	1Ω to 500 kΩ	±0.005%	±1 ppm/°C	**Up to 300 K:** 1.5W at +70°C 0.75W at +125°C **Over 300 K:** 0.8W at +70°C 0.4W at +125°C	±0.005%

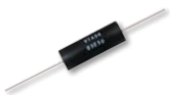
Uncalibrated S102 chip on strip resistors are available.

* Tighter performances and higher or lower value resistances are available for all models upon request.

Type	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Through-Hole							
S106K 	Y0103	S-Series high-precision resistor, DLA 97009 (S102K)	0.5Ω to 600 kΩ	±0.005%	±1 ppm/°C	**Up to 400 K:** 2W at +70°C 1W at +125°C **Over 400 K:** 1W at +70°C 0.5W at +125°C	±0.005%
E102C, E102J 	Y1186 Y1184	High-performance resistor, high ohmic value, small size	150 kΩ to 300 kΩ	±0.005%	±2 ppm/°C	0.6W at +70°C 0.3W at +125°C	±0.005%
VPR220 	Y0925	Precision foil power resistors, TO-220 configuration, 2-terminal connection	5Ω to 10 kΩ	±0.01%	±2 ppm/°C	8W at +25°C on heat sink 1.5W in free air	±0.005%
VSR, VSRJ 	Y0075 Y0789	VSR Series industrial precision resistors	1Ω to 150 kΩ	±0.01%	±4 ppm/°C	**Up to 100 K:** 3W at +70°C 0.2W at +125°C **Over 100 K:** 0.25W at +70°C 0.15W at +125°C	±0.005%
VSR4 	Y0020		1Ω to 500 kΩ	± 0.005%	±4 ppm/°C	**Up to 200 K:** 0.5W at +70°C 0.4W at +125°C **Over 200 K:** 0.25W at +70°C 0.2W at +125°C	±0.005%
VSR5 	Y0021		1Ω to 750 kΩ	± 0.005%	±4 ppm/°C	**Up to 300 KΩ:** 0.75W at +70°C 0.6W at +125°C **Over 300 KΩ:** 0.4W at +70°C 0.3W at +125°C	±0.005%
VSR6 	Y0022		0.5Ω to 1 MΩ	± 0.005%	±4 ppm/°C	**Up to 400 K:** 1.0W at +70°C 0.8W at +125°C **Over 400 KΩ:** 0.5W at +70°C 0.4W at +125°C	±0.005%
VRM 6.35mm x 25.4mm 	Y0073	Industrial **miniature** precision resistor	5Ω to 50 kΩ	±0.01%	±8 ppm/°C	0.25W at +70°C 0.125W at +125°C	±0.005%

* Tighter performances and higher or lower value resistances are available for all models upon request.

Through-Hole Resistors

Type*	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) max	Rated Power	Load Life Stability, 2000 Hours +25°C at Rated Power
Through-Hole							
VTA52Z 	Y0090 New		5Ω to 500 KΩ	± 0.01 %	± 0.2 ppm/°C	1W at +70°C 0.5W at +125°C	±0.005%
VTA53Z 	Y0091 New		5Ω to 300 KΩ	± 0.01 %	± 0.2 ppm/°C	0.66W at +70°C 0.33W at +125°C	±0.005%
VTA54Z 	Y0092 New		5Ω to 300 KΩ	± 0.01 %	± 0.2 ppm/°C	0.5W at +70°C 0.25W at +125°C	±0.005%
VTA55Z 	Y0093 New		5Ω to 150 KΩ	± 0.01 %	± 0.2 ppm/°C	0.3W at +70°C 0.15W at +125°C	±0.005%
VTA56Z 	Y0094 New	Tubular axial-lead resistors, meets or exceeds MIL-R-39005 requirements	5Ω to 150 KΩ	± 0.01 %	± 0.2 ppm/°C	0.25W at +70°C 0.125W at +125°C	±0.005%
VTA57Z 	Y0095 New		5Ω to 100 KΩ	± 0.01 %	± 0.2 ppm/°C	0.25W at +70°C 0.125W at +125°C	±0.005%
VMTA55Z 	Y0096		5Ω to 30 KΩ	± 0.01 %	± 0.2 ppm/°C	0.2W at +70°C 0.1W at +125°C	±0.005%
VMTB60Z 	Y0097		5Ω to 60 KΩ	± 0.01 %	± 0.2 ppm/°C	0.25W at +70°C 0.125W at +125°C	±0.005%
VTA52 	Y0028		5Ω to 500 kΩ	±0.01%	±8 ppm/°C	1W at +70°C 0.5W at +125°C	±0.05%

* Tighter performances and higher or lower value resistances are available for all models upon request.

Type*	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) max	Rated Power	Load Life Stability, 2000 Hours +25°C at Rated Power
Through-Hole							
VTA53 	Y0029	Tubular axial-lead resistors, meets or exceeds MIL-R-39005 requirements	5Ω to 300 kΩ	±0.01%	±8 ppm/°C	0.66W at +70°C 0.33W at +125°C	±0.05%
VTA54 	Y0054		5Ω to 300 kΩ	±0.01%	±8 ppm/°C	0.5W at +70°C 0.25W at +125°C	±0.05%
VTA55 	Y0058		5Ω to 150 kΩ	±0.01%	±8 ppm/°C	0.3W at +70°C 0.15W at +125°C	±0.05%
VTA56 	Y0060		5Ω to 150 kΩ	±0.01%	±8 ppm/°C	0.25W at +70°C 0.125W at +125°C	±0.05%
VMTA55 	Y0014		5Ω to 30 kΩ	±0.01%	±8 ppm/°C	0.2W at +70°C 0.1W at +125°C	±0.05%
VMTB60 	Y0015		5Ω to 60 kΩ	±0.01%	±8 ppm/°C	0.25W at +70°C 0.125W at +125°C	±0.05%
VSC1, VSH1 	Y0902 Y0875	Conformally coated precision resistors	5Ω to 60 kΩ	±0.01%	±5 ppm/°C	0.3W at +70°C	±0.05%
VSC2, VSH2, VSH4 	Y0903 Y0934 Y1452		60Ω to 240 kΩ	±0.01%	±5 ppm/°C	0.3W at +70°C	±0.05%

* Tighter performances and higher or lower value resistances are available for all models upon request.

Type	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power	Load Life Stability, 2000 Hours +125°C at Rated Power
Through-Hole, Military and Space Applications							
RNC90Z (RNC90S) 	Y1189 Y1506 Y0089 Y1508	Military established reliability QPL	30.1Ω to 121 kΩ	±0.005%	±2 ppm/°C (–55°C to +175°C) maximum	0.6W at +70°C 0.3W at +125°C	0.05% maximum
RNC90Y (RNC90T) 			4.99Ω to 121 kΩ	±0.005%	±5 ppm/°C (–55°C to +125°C) maximum ±10 ppm/°C (125°C to +175°C) maximum	0.6W at +70°C 0.3W at +125°C	0.05% maximum
Z555 	Y1288	Z Foil Technology produced in QPL product line	4.99Ω to 121 kΩ	±0.005%	3 ppm/°C maximum	0.6W at +70°C 0.3W at +125°C	0.015% maximum
S555 	Y0088	Foil technology produced in QPL product line	1Ω to 150 kΩ	±0.005%	5 ppm/°C	0.6W at +70°C 0.3W at +125°C	±0.015% maximum
303143, 303143L 	303143 303143L	Ultra high-precision fixed resistor Z Foil Z201, screen/test flow as modified from S-311-P813 proposed by NASA	10Ω to 100 kΩ	±0.005%	3 ppm/°C maximum	0.6W at +70°C 0.3W at +125°C	±0.005%
RS92N, RS92NA, AN 	Y1442 Y1687 Y1688	CECC-qualified high-precision foil resistor for space applications	80.6Ω to 120 kΩ	±0.01%	±2 ppm/°C	0.5W at +70°C	±0.005%

Power Current-Sensing Resistors

Key Benefits

- Temperature Coefficient of Resistance (TCR):
  - ±0.2 ppm/°C (-55°C to +125°C, +25°C ref.) typical with Z Foil
- Power coefficient (PCR), "ΔR due to self heating": 4 ppm/W or 5 ppm/W at rated power
- Absolute resistance tolerance: ±0.01%
- Power rating: up to 10 W on heat sink
- Current noise: 0.010 µVRMS/V of applied voltage (<–40 dB)
- Four-terminal (Kelvin) connections for high accuracy
- VFR resistors are not restricted to standard values; specific "as required" values can be supplied at no extra cost or delivery (e.g. 1.2345 kΩ vs. 1 kΩ)
- Load-life stability: to ±0.005% at +25°C, for 2000 h, at rated power
- Rise time: 1 ns without ringing
- Thermal stabilization time <1 s (nominal value
- achieved within 10 ppm of steady-state value)
- Prototype quantities available in just five working days or sooner

Applications

- Military
- Medical
- Aerospace
- Force balance scales
- Electron beam applications
- Switching power supplies
- Electron microscopes
- Gyro navigation controls
- Pressure sensors
- Switching power supplies
- Motor speed controls
- Down-hole (high temperature)
- Weigh scales

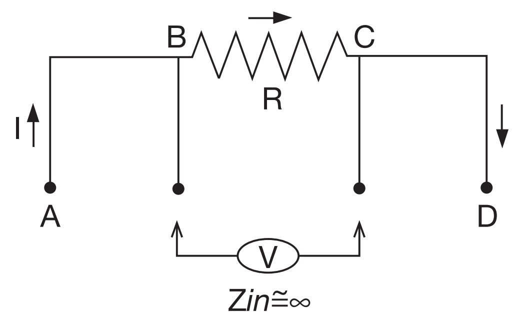
Our goal is to find solutions for challenging applications. For any questions, please contact foil@vpgsensors.com

Power Current-Sensing Resistors

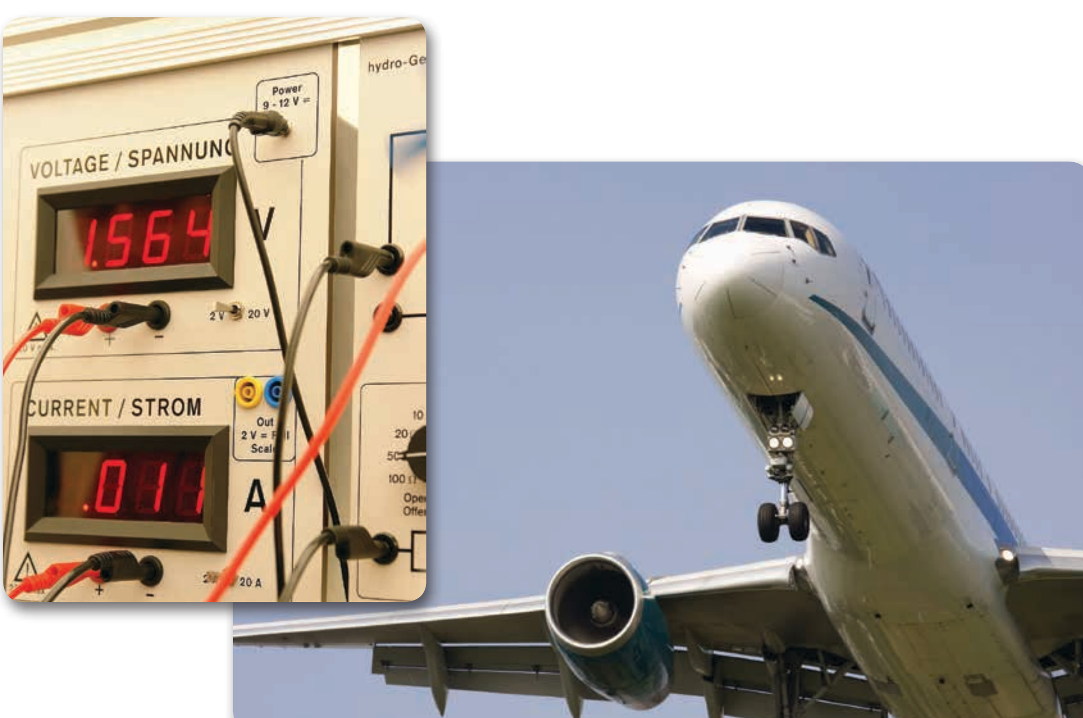
VFR power current-sensing resistors were developed with a low absolute TCR and Kelvin connections to meet today's demand for new and stable resistive products. These resistors are most often used to monitor a current that is directly proportional to some physical characteristic (such as pressure, weight, etc.) being measured by an analog sensor. The resistor converts the current to a voltage that is representative of the physical characteristic and feeds that voltage into control circuits, instrumentation, or other indicators. Deviations induced in the resistor, not representative of the monitored characteristic, can be caused by high absolute TCR response to both ambient temperature and self heating, and can feed erroneous signals into the system. Resistance is usually kept low to reduce the self-heating (Joule effect) portion of the error, while minimizing the stresses that cause long-term resistance changes. It is critical for this resistor to reach thermal equilibrium quickly in circuits that require fast response or where the current changes quickly. Thermal EMF is another important consideration in low-ohmic current sensing resistors used mostly in DC circuits (there is no effect in AC circuitry). VFR resistors are able to minimize this effect through the use of appropriate materials between the resistive layer and the terminations.

Kelvin Connections

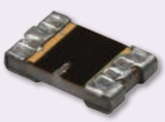
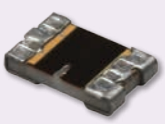
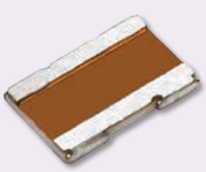
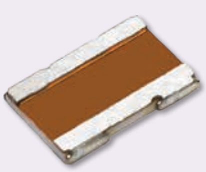
Four-terminal connections, or Kelvin connections, are required in these low-ohmic-value resistors to measure a precise voltage drop across the resistive element. The four-terminal configuration eliminates the forward voltage drop error voltage that would be present in the voltage sense leads if a standard two-terminal resistor were used. In current sense resistors, the contact resistance and the termination resistance may be greater than that of the resistive element itself, so lead connection errors can be significant if only two terminal connections are used.



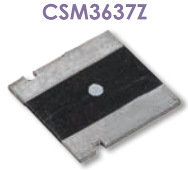
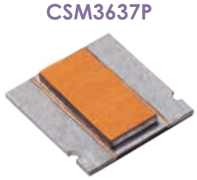
The four-terminal device separates the current leads from the voltage-sensing leads. This configuration eliminates the effect of the lead wire resistance from points A to B and C to D. Overall, Bulk Metal Foil technology provides performance capabilities far greater than any other resistor technology can supply in a product of comparable size.



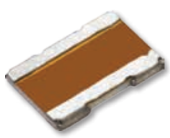
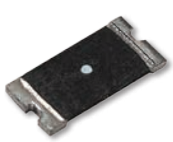
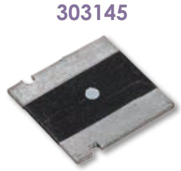
Power Current-Sensing Resistors

Product	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, 25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Surface-Mount, Z- Foil							
VCS1610Z (Z Foil) 	Y1119	High-precision, current sensing chip resistor (4-terminal)	0.3Ω to 10Ω	±0.5%	±0.2 ppm/°C	0.25W	±0.015%
VCS1610 	Y1120	High-precision, current sensing chip resistor (4-terminal)	0.1Ω to 10Ω	±0.5%	±2 ppm/°C	0.25W	±0.015%
Led1625 	Y2019 New	Ultra high-precision bulk metal foil resistors rating to 8W, TCR of ±0.2 ppm/°C, and stability of ±0.005%	0.3Ω to 10Ω	±0.02%	±0.2 ppm/°C	1W	±0.015%
VCS1625ZP (Z Foil) 	Y1606	Ultra high-precision Z Foil surface-mount current sensing for higher power	0.3Ω to 10Ω	±0.2%	±0.2 ppm/°C	1W	±0.015%
VCS1625Z (Z Foil)** 	Y1607	Ultra high-precision surface-mount current sense resistor DLA 08003	0.3Ω to 10Ω	±0.2%	±0.2 ppm/°C	0.5W maximum current 5 A	±0.015%
VCS1625P 	Y0856 New	High-precision Z Foil surface mount current sensing for high power	0.01Ω to 10Ω	±0.1%	±2 ppm/°C	1W	±0.015%
VCS1625 	Y0850	High-precision current sensing chip resistor (4-terminal) DLA 08003	0.01Ω to 10Ω	±0.1%	±2 ppm/°C	0.5W maximum current 5 A	±0.015%

Power Current-Sensing Resistors

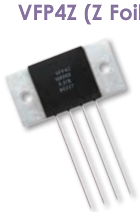
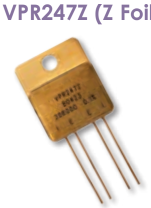
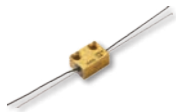
Product	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, 25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
Surface-Mount							
CSM2512, CSM3637 	Y1487 Y1488	High-precision metal strip resistor	1 mΩ to 200 mΩ	±0.1%	±15 ppm/°C maximum	Up to 3W Maximum current 38A	±0.2%
CSM2512S, CSM3637S (Improved Stability) 	Y4487	Ultra high-precision current-sense resistor	10 mΩ to 100 mΩ	±0.1%	±15 ppm/°C maximum	1W	±0.05%
	Y1472		10 mΩ to 100 mΩ	±0.2%	±15 ppm/°C maximum	2W	±0.05%
CSM3637Z 	Y1473	Ultra high- precision, current sensing, power surface-mount, metal strip resistor	3 mΩ to 50 mΩ	±0.1%	±5 ppm/°C **maximum**	3W (3 mΩ to 10 mΩ) 2W (>10 mΩ to 50 mΩ)	±0.2%
CSM3637P 	Y1474	High-precision, current sensing, power surface-mount, metal strip resistor with improved power	3 mΩ to 200 mΩ	±0.1 %	±15 ppm/°C	5W (3 mΩ <10 mΩ) 4W (10 mΩ to 100 mΩ)	± 0.2 %
Led221 	Y2019	Ultra high-precision bulk metal foil resistors rating to 8W, TCR of ±0.2 ppm/°C, and stability of ±0.005%	0.3Ω to 10Ω	±0.02%	±0.2 ppm/°C	1W	±0.015%
VPR221SZ (Z Foil) 	Y2123	Ultra high-precision surface-mount power current sense resistor	0.5Ω to 500Ω	±0.01%		8W on heat sink 1.5W in free air	±0.005% at +25°C
VPR221S 	Y1123	Precision foil power resistors, TO-220 configuration, 4-terminal connection	0.5Ω to 500Ω	±0.01%	±2 ppm/°C	8W on heat sink 1.5W in free air	±0.005%

Power Current-Sensing Resistors

Product	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, 25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power
Surface-Mount, Military and Space Applications							
303119 		VCS1625 configuration, screen/test flow in compliance with EEE-INST-002 and MIL-PRF-55342	0.01Ω to 10Ω	±0.5%	±2 ppm/°C	0.5W maximum current 5 A	±0.05%
303119Z 		VCS1625Z configuration, screen/test flow in compliance with EEE-INST-002 and MIL-PRF-55342	0.3Ω to 10Ω	±0.5%	±0.2 ppm/°C	0.5W maximum current 5 A	±0.05%
303144 		CSM2512 and CSM3637 with screen/test flow in compliance with EEE-INST-002, MIL-PRF-55342, and MIL-PRF-49465	3 mΩ to 200 mΩ	±0.5%	±20 ppm/°C	1W maximum current 18 A	±1%
303145 			2 mΩ to 200 mΩ	±0.5%	±20 ppm/°C	3W maximum current 38 A	±1%

Power Current-Sensing Resistors

VISHAY FOIL RESISTORS
A VPG Brand

Type	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power at +25°C	Load Life Stability 2000 Hours, +25°C Under Power
Through-Hole, Z Foil							
VCS331Z, VCS332Z (Z Foil) 	Y1481 Y1467	Ultra high-precision power current sense resistor	0.25Ω to 500Ω	±0.01%	±0.2	3W in free air 10W on heat sink	±0.01% in free air ±0.005% on heat sink
VHP4Z (Z Foil) 	Y1479	Ultra high-precision hermetically-sealed power current sense resistor	0.25Ω to 500Ω	±0.01%	±0.2	3W in free air 10W on heat sink	±0.01% in free air ±0.005% on heat sink
VFP4Z (Z Foil) 	Y1468	Ultra high-precision power current sense resistor	0.25Ω to 500Ω	±0.01%	±0.2	3W in free air 10W on heat sink	±0.01% in free air ±0.005% on heat sink
VPR247Z (Z Foil) 	Y1480	Ultra high-precision hermetically-sealed power current sense resistor	0.25Ω to 500Ω	±0.01%	±0.2	3W in free air 10W on heat sink	±0.01% in free air ±0.005% on heat sink
VPR5Z 	Y0118	Ultra high-precision current-sensing resistor (direct replacement for certain wirewounds)	5Ω to 100 kΩ	±0.01%	±0.2 ppm/°C	5W	±0.01% at +70°C
VPR7Z 	Y0119		5Ω to 100 kΩ	±0.01%	±0.2 ppm/°C	7W	±0.01% at +70°C

* Tighter performances and higher or lower value resistances are available for all models upon request.

Power Current-Sensing Resistors

Type	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power at +25°C	Load Life Stability 2000 Hours, +25°C Under Power
Through-Hole, Z Foil							
VCS232Z (Z Foil) 	Y1608	Ultra high-precision power current sense resistor	0.25Ω to 500Ω	±0.02%	±0.2 ppm/°C	2W maximum current 3 A	±0.005%
VPR221Z (Z Foil) 	Y1690	Ultra high-precision power resistors in TO-220 configuration, 4-lead Kelvin connected device	0.5Ω to 500Ω	±0.01%	±0.2 ppm/°C	8W on heat sink 1.5W in free air	±0.005%

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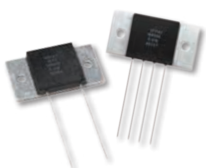
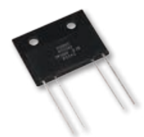
Power Current-Sensing Resistors

VISHAY FOIL RESISTORS
A VPG Brand

Product	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, 25°C ref.) Typical	Rated Power at +25°C	Load Life Stability 2000 Hours, +25°C Under Power
Through-Hole							
VFP3, VFP4 	Y0733 Y0734	Molded power high-precision current sensing resistors	0.05Ω to 80 kΩ	±0.01%	±2 ppm/°C	3W in free air 10W on heat sink	±0.005%
VHP3, VHP4, VPR247 	Y0065 Y0066 Y0830	Hermetically-sealed and molded power high-precision current sensing resistors	0.05Ω to 80 kΩ	±0.01%	±2 ppm/°C	3W in free air 10W on heat sink	±0.01%
VPR5 	Y0026	Current sensing resistor (direct replacement for certain wirewounds)	1Ω to 100 kΩ	±0.01%	±5 ppm/°C above 10Ω ±10 ppm/°C below 10Ω	5W	±0.01% at +70°C
VPR7 	Y0027		1Ω to 100 kΩ	±0.01%	±5 ppm/°C above 10Ω ±10 ppm/°C below 10Ω	7W	±0.01% at +70°C
VCS101, VCS103, VCS401 	Y0930 Y0940 Y0945	High-precision, low-value, current sense, shunt resistors, 4-lead Kelvin device	0.005Ω to 0.25Ω	±0.1%	±15 ppm/°C max. (0°C to +60°C)	To 1.5W in free air maximum current 15A	±0.5%
VCS201, VCS202 	Y0955 Y0941	High-precision current sensing resistors, conformally coated	0.005Ω to 0.2Ω	±0.1%	±15 ppm/°C	To 2W in free air maximum current to 15A	±0.02%
VCS232 	Y0942	High-precision power current sense resistor	0.2Ω to 500Ω	±0.02%	±2 ppm/°C	To 2W in free air maximum current to 3A	±0.01%

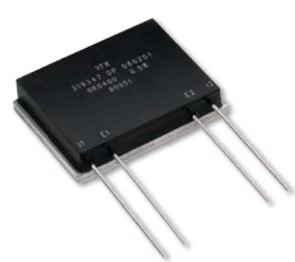
* Tighter performances and higher or lower value resistances are available for all models upon request.

Power Current-Sensing Resistors

Product	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, 25°C ref.) Typical	Rated Power at +25°C	Load Life Stability 2000 Hours, +25°C Under Power
Through-Hole							
VCS301, VCS302 	Y0959 Y0943	High-precision current sensing resistors (4-terminal)	0.005Ω to 0.25Ω	±0.5%	to ±3 ppm/°C max. (0°C to +60°C)	10W on heat sink 3W in free air maximum current 15A	±0.02%
VCS331, VCS332 	Y0960 Y0944	Precision power current sensor	0.25Ω to 500Ω	±0.1%	to ±1 ppm/°C max. (0°C to +60°C)	10W on heat sink 3W in free air maximum current 5A	±0.01%
VPR221 	Y0926	High-precision power resistors in TO-220 configuration, 4-lead Kelvin connected device	0.5Ω to 500Ω	±0.01%	±2 ppm/°C	8W on heat sink 1.5W in free air maximum current 3A	±0.005%

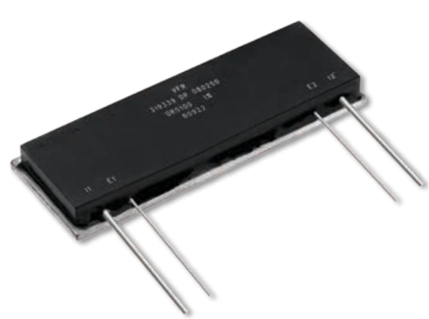
* Tighter performances and higher or lower value resistances are available for all models upon request.

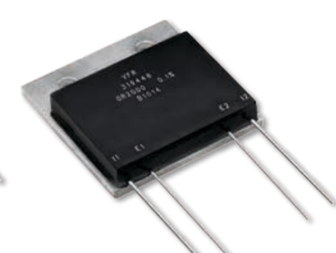
New Generation of Power Current-Sensing Resistors



VFR has introduced a new generation of power current-sensing resistors that are available as custom-tailored products. For precise current measuring, these new resistors combine very low noise with an absolute TCR of <±0.2 ppm/°C (0°C to +60°C, or +20°C to +70°C), power TCR of <1 ppm/W, absolute tolerance of ±0.01%, and a load-life stability of ±0.005% for 2000 h in free air.

The resistors feature a power rating of 20 W in free air (60 W on heat sink) over a resistance range from 0.5 mΩ to 500 Ω. The maximum current for resistance values of 10 mΩ and up is 22 A. Higher current values are available per customer requirements if needed. Thermal resistance (element to heat sink) for the resistors is 2°C/W typical.





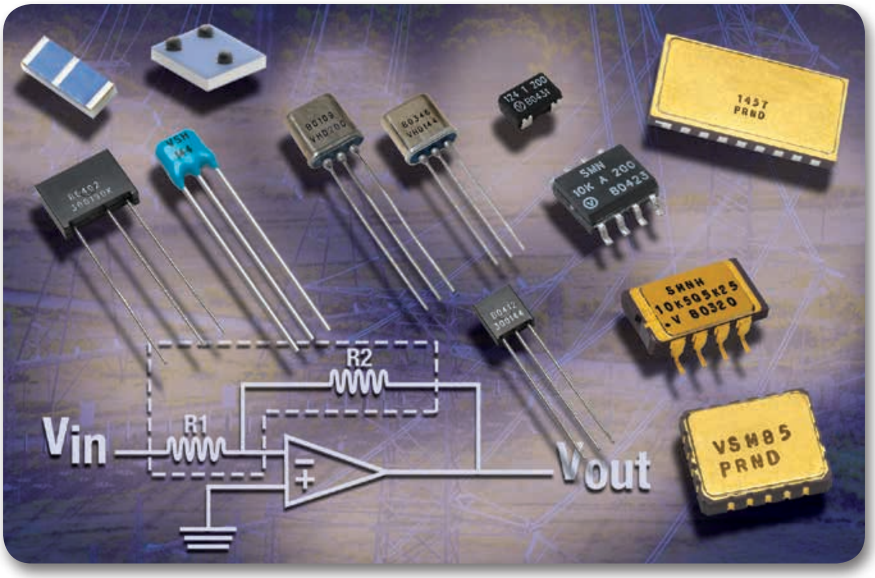
Dividers and Resistor Networks

Key Benefits

- Absolute Temperature Coefficient of Resistance (TCR):
  - ±0.2 ppm/°C (–55°C to +125°C, +25°C ref.) typical with Z Foil
- TCR tracking: 0.1 ppm/°C
- Power coefficient of resistance (PCR) tracking, "ΔR due to self heating": 5 ppm at rated power
- Resistance tolerance (absolute and match): ±0.005%
- Load-life ratio stability: <0.005% (50 ppm) 1 W and 70°C for 2000 h
- Thermal EMF: 0.05 µv/°C
- Electrostatic discharge (ESD) at least to 25 kV
- Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
- Current noise: 0.010 µVRMS/V of applied voltage (<–40 dB)
- Shelf-life stability: ±2 ppm typical (for hermetically sealed resistors) after at least six years
- VFR resistors are not restricted to standard values; specific "as required" values can be supplied at no extra cost or delivery (e.g. 1.2345 kΩvs. 1 kΩ)
- Prototype quantities available in just five working days or sooner

Applications

- Military
- Aerospace and avionics
- Automotive
- Telecommunications
- Industrial
- Medical
- Test equipment
- Instrumentation
- High-precision amplifiers
- Laboratory
- Audio
- Electron beam applications
- Bridge networks
- Differential amplifiers
- Weigh scales
- Down-hole (high temperature)



Our goal is to find solutions for challenging applications. For any questions, please contact foil@vpgsensors.com

Voltage Dividers and Resistor Networks

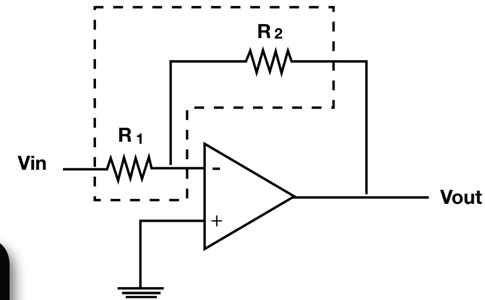
Today, circuit designers are demanding voltage dividers that approach the ideal in performance: stable, high-speed, high-accuracy components that will operate with assured, predictable reliability for years in a variety of environments. VFR voltage dividers and resistor networks are meeting those demands and add the dimensions of convenience and economy to resistor needs. Our extensive experience relieves the circuit designer of the complicated, costly, and wasteful procedure of calculating the value of individual resistor components; ordering them; stabilizing, aging, or matching the units; and then assembling and testing their own resistor arrays. The VFR approach to dividers is simple and straightforward; our solution consists of any combination of resistors, and the end result is what matters. As a result, the only data we require from the designer is the overall electrical performance specifications, the environment operational, and the desired physical requirements.

Four fundamental factors determine how "ideal" a precision voltage divider will be:

1. Initial absolute resistance value, or how closely the absolute resistance value can be achieved
2. How precisely the value of individual resistors can be controlled
3. How precisely the end-of-life tolerance is maintained under a wide range of operating conditions and stress factors (temperature, humidity, load, ESD, etc.)
4. Fast response without ringing and fast thermal stabilization, and the ability of the resistor to react to rapid switching without adversely affecting the circuit function

Most resistor technologies compromise the theoretical ideal performance in one or more ways. For example, the winding of wire and the evaporation or sputtering of extremely thin metal each produce metallurgical changes in the resistance materials, and these noticeably deteriorate the electrical characteristics. Such changes are not predictable, and thus randomly alter performance parameters. The form factor of other units also introduces losses in high-frequency performance, limits power dissipation, and prohibits size reduction.

VFR networks are the only devices to have perfected these four factors to eliminate the inter-parameter compromises inherent in all other types of technologies. All important characteristics —tolerance, long-term stability, temperature coefficient, power coefficient, ESD, noise, capacitance, and inductance— are optimized, approaching the theoretical ideal in total performance.



Typical Resistor Network Applications*

Diagram 1. Inverting Amplifier

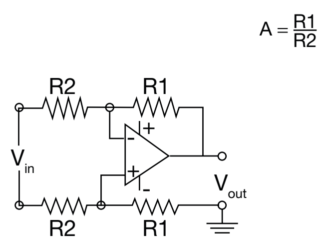


Diagram 2. Power Supply Voltage Filter

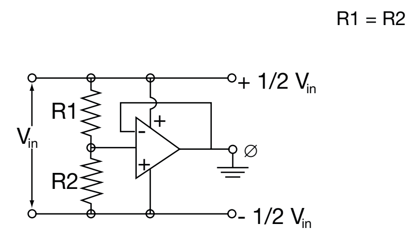


Diagram 3. Follower with Gain

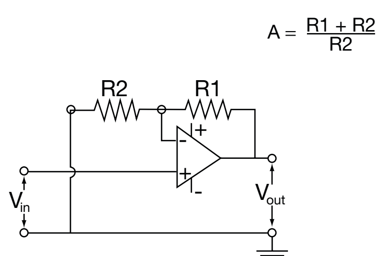


Diagram 4. Instrumentation AMP w/ Shield Driver

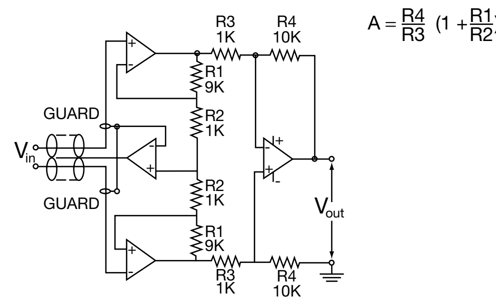


Diagram 5. Differential Input Amplifier

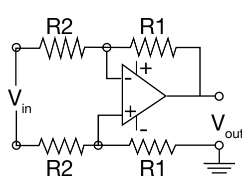


Diagram 6. Current Driver

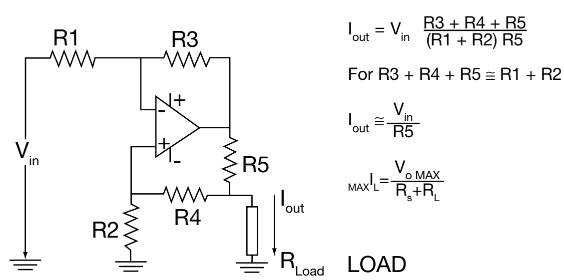


Diagram 7. Differential input instrumentation amplifier

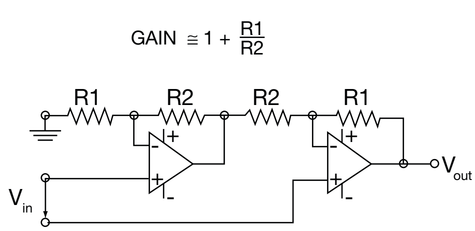
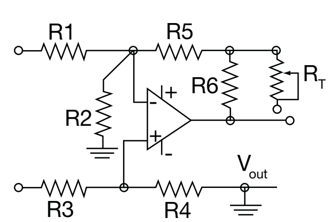
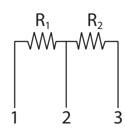
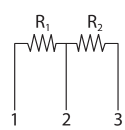
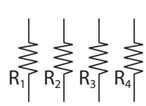
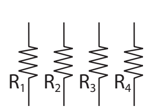


Diagram 8. High common mode voltage rejection unity gain differential amplifier



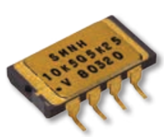
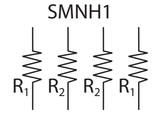
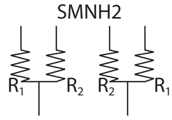
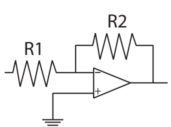
* These diagrams are supplied to illustrate typical resistor network applications. VFR assumes no responsibility for specific use or performance.

Voltage Dividers and Resistor Networks

Model and Product Description	Global Model	Resistance Range	Best Resistance Tolerance		TCR (–55°C to +125°C +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
			Absolute	Ratio Match			
Voltage Dividers							
DSMZ (Z Foil) Ultra high-precision, surface-mount, molded voltage divider 	Y4485	Any value 100Ω to 10 kΩ per resistor  	±0.02%	0.01%	Absolute: ±0.2 ppm/°C Tracking: 0.1 ppm/°C	Entire package 0.1W Each resistor 0.05W at +70°C	0.005%
DSM High-precision, surface-mount, molded voltage divider 	Y1485	Any value 100Ω to 12 kΩ per resistor  	±0.02%	0.01%	Absolute: ±2 ppm/°C Tracking: ±0.5 ppm/°C	Entire package 0.1W Each resistor 0.05W at +70°C	0.005%
SMNZ (Z Foil) Ultra high-precision, surface-mount, 4-resistor network dual in-line, molded package, 50 mil pitch 	Y1747	Any value 100Ω to 10 kΩ per resistor  	±0.02%	0.01%	Absolute: ±0.2 ppm/°C Tracking: 0.1 ppm/°C	Entire package 0.4W Each resistor 0.1W at +70°C	0.005%
SMN High-precision, surface-mount 4-resistor network dual in-line, molded package, 50 mil pitch 	Y1365	Any value 100Ω to 10 kΩ per resistor  	±0.02%	0.01%	Absolute: ±2 ppm/°C Tracking: ±0.5 ppm/°C	Entire package 0.4W Each resistor 0.1W at +70°C	0.005%

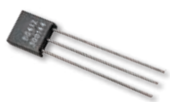
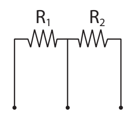
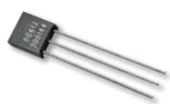
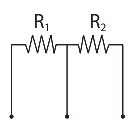
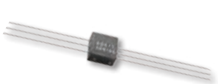
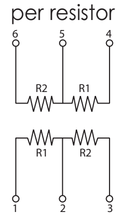
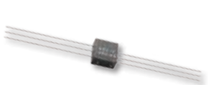
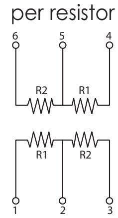
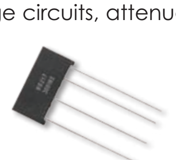
* Tighter performances and higher or lower value resistances are available for all models.

Voltage Dividers and Resistor Networks

Model and Product Description	Global Model	Resistance Range	Best Resistance Tolerance		TCR (-55°C to +125°C +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
			Absolute	Ratio Match			
Voltage Dividers and Resistor Networks							
SMNH1, 2*, ** High-precision, hermetically-sealed, 4-resistors, surface-mount resistor network 	Y1521 Y1522	Any value 5Ω to 33 kΩ per resistor SMNH1  SMNH2 	±0.005%	0.005%	Absolute : ±2 ppm/°C Tracking: ±0.5 ppm/°C	Entire package 0.4W Each resistor 0.1W at +70°C	0.005%
VFCD1505 (Z Foil) Ultra high-precision flip-chip, voltage divider 	Y1685	10Ω to 10 kΩ 	±0.01%	±0.01% (±0.005% is available)	Tracking: 0.1 ppm/°C	0.1W at +70°C, for the entire package divided proportionally between the two elements	Absolute: 0.01% Ratio: 0.005%

* Shelf life stability: 2 ppm.
** Available with Z Foil Technology.
Tighter performances and higher or lower value resistances are available for all models.

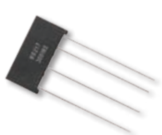
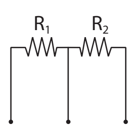
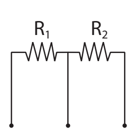
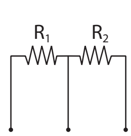
Voltage Dividers and Resistor Networks

Model and Product Description	Global Model	Resistance Range	Best Resistance Tolerance		TCR (-55°C to +125°C +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
			Absolute	Ratio Match			
Voltage Dividers							
300144Z (Z Foil) Ultra high-precision, small package molded voltage divider 	Y1691	Any value from 100Ω to 20 kΩ per resistor 	±0.005%	0.005%	Absolute: ±0.2 ppm/°C Tracking: 0.1 ppm/°C	0.2W at +70°C, for the entire package divided proportionally between the two elements	±0.005%
300144* High-precision, small package molded voltage divider 	Y0006	Any value from 100Ω to 20 kΩ per resistor DLA 87026 	±0.005%	0.005%	Absolute: ±2 ppm/°C Tracking: 0.5 ppm/°C	0.2W at +85°C, for the entire package divided proportionally between the two elements	±0.005%
300145Z (Z Foil) Ultra high-precision, small package molded pair of voltage dividers 	Y1735	Any value from 100Ω to 20 kΩ per resistor 	±0.005%	0.005%	Absolute: ±0.2 ppm/°C Tracking: 0.1 ppm/°C	0.2W at +70°C, for the entire package divided proportionally between the two elements	±0.005%
300145 High-precision, small package molded pair of voltage dividers 	Y0035	Any value from 100Ω to 20 kΩ per resistor 	±0.005%	0.005%	Absolute: ±2 ppm/°C Tracking: 0.5 ppm/°C	0.2W at +85°C (per voltage divider)	±0.005%
300190Z-9Z, 300210Z-12Z (Z Foil) Ultra high-precision, molded resistor networks 2R, 3R, 4R, voltage dividers, bridge circuits, attenuators 	Refer to datasheet	Any value from 1Ω to 100 kΩ per resistor	±0.005%	0.01%	Absolute: ±0.2 ppm/°C Tracking: 0.1 ppm/°C	0.6W at +70°C 0.3W at +125°C	

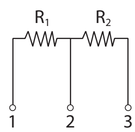
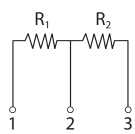
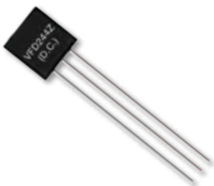
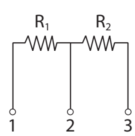
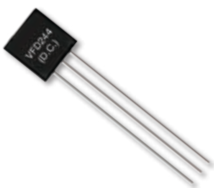
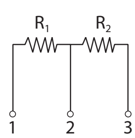
* 300144 uncalibrated resistors are available.
Tighter performances and higher or lower value resistances are available for all models.

Voltage Dividers and Resistor Networks

VISHAY FOIL RESISTORS
A VPG Brand

Model and Product Description	Global Model	Resistance Range	Best Resistance Tolerance		TCR (–55°C to +125°C +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
			Absolute	Ratio Match			
Voltage Dividers							
300190-9, 300210-12 High-precision, molded resistor networks 2R, 3R, 4R, voltage dividers, bridge circuits, attenuators 	Refer to datasheet	Any value from 1Ω to 150 kΩ per resistor	±0.005%	0.005%	Absolute: ±2 ppm/°C Tracking: 0.5 ppm/°C	0.5W per resistor at +70°C 0.25W per resistor at +125°C	±0.001%
VSR144 Industrial molded voltage divider 	Y0094	Any value 100Ω to 20 kΩ 	±0.05%	0.02%	Absolute : ±4 ppm/°C Tracking: 1.5 ppm/°C	0.2W at +70°C, for the entire package divided proportionally between the two elements	±0.001%
VHD144*, ** Hermetic version of the molded divider 300144 	Y0076	Any value from 100Ω to 20 kΩ per side 	±0.005%	0.005%	Absolute: ±2 ppm/°C Tracking: 0.5 ppm/°C	0.2W	±0.001%
VHD200*, ** Hermetically-sealed, oil-filled voltage divider, ultimate ratio match and TCR tracking 	Y5076	Any value from 100Ω to 20 kΩ per side 	±0.005%	0.001%	Absolute: ±2 ppm/°C Tracking: 0.1 ppm/°C	0.1W	±0.001%

* Shelf life stability: 2 ppm
** Available with Z Foil Technology.
Tighter performances and higher or lower value resistances are available for all models.

Model and Product Description	Global Model	Resistance Range	Best Resistance Tolerance		TCR (–55°C to +125°C +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability 2000 Hours, +70°C Under Power-Typical
			Absolute	Ratio Match			
Voltage Dividers							
VSH144Z (Z Foil) Ultra high-precision, low profile, conformally coated voltage divider resistor 	Y1680	Any value from 100Ω to 20 kΩ per resistor  	0.01%	0.01%	Absolute: ±0.2 ppm/°C Tracking: 0.1 ppm/°C typical	0.2W at +70°C, for the entire package divided proportionally between the two elements	±0.01%
VSH144 Low profile, conformally coated, high-precision voltage divider resistor 	Y1767	Any value from 100Ω to 20 kΩ per resistor  	0.01%	0.01%	Absolute: ±2 ppm/°C Tracking: 0.5 ppm/°C typical	0.2W at +70°C, for the entire package divided proportionally between the two elements	±0.01%
VFD244Z (Z Foil) Ultra high-precision voltage divider resistor 	Y0115	Any value from 1Ω to 100 kΩ per resistor  	0.005%	0.005%	Absolute: ±0.2 ppm/°C Tracking: 0.1 ppm/°C typical	1W at +70°C, for the entire package divided proportionally between the two elements	±0.005%
VFD244 High-precision voltage divider resistor 	Y0114	Any value from 1Ω to 150 kΩ per resistor  	0.005%	0.005%	Absolute: ±2 ppm/°C Tracking: 0.5 ppm/°C typical	1W at +70°C, for the entire package divided proportionally between the two elements	±0.005%

Tighter performances and higher or lower value resistances are available for all models.

Hermetically Sealed Resistors

Key Benefits

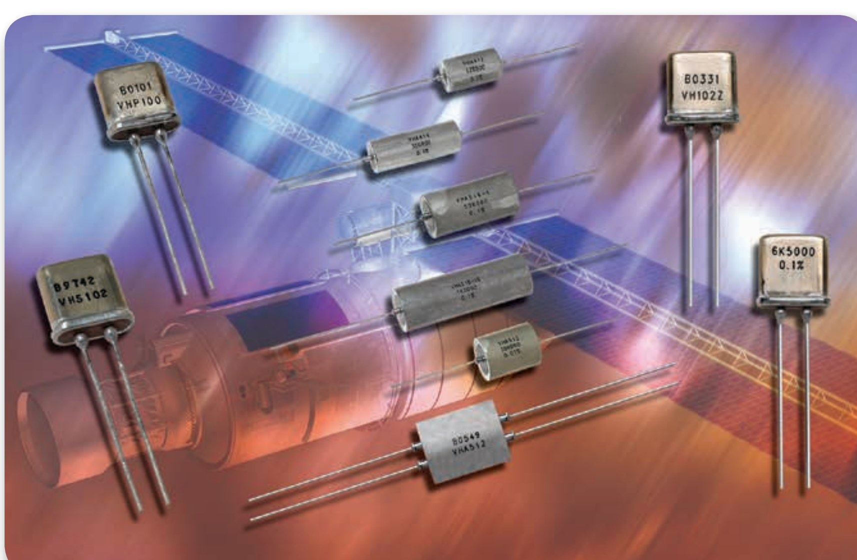
- Essentially zero TCR
- Resistance tolerance: ±0.001%
- Power coefficient of resistance (PCR) tracking, "ΔR due to self heating": 5 ppm at rated power
- Load-life stability: to ±0.005% +70°C, 2000 h at rated power
- Resistance range: 1Ω to 3.3 MΩ
- Available with four-terminal (Kelvin) connections
- Shelf-life stability: 2 ppm after at least six years
- Oil-filled for ultra hermetically (also available as oil-free)
- High degree of hermeticity: <10-7 atmospheric cc/s
- Non-inductive, non-capacitive design
- Prototype quantities available in just five working days or sooner
- Certification to NIST standards available
- Available with laboratory- and metrology-level precision and long-term stability with additional in-house oriented processes, such as:
  - Special TCR plotting
  - Mounted chip stabilization
  - Thermal shock and bake prior to sealing
  - Combined thermal shock and power conditioning on finished product
  - Thermal and power conditioning
- Foil resistors are not restricted to standard values; specific "as required" values can be supplied at no extra cost or delivery (e.g. 1.2345 kΩ vs. 1 kΩ)
- Electrostatic discharge (ESD) at least to 25 kV
- Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
- Current noise: 0.010 µVRMS/V of applied voltage (<–40 dB)

Applications

- Metrology
- Military
- Aerospace
- Medical
- Test equipment
- Instrumentation amplifiers
- Laboratory
- Industrial
- Measurements systems

Vishay Foil Resistors' H and HZ Series of Bulk Metal® Foil Resistors Selected for *Electronic Design's Annual* "Top 101 Components"

Vishay Foil Resistors' New-Generation, Ultra-Precision VHP100 Bulk Metal® Foil Resistor Wins Product of the Year Award from *Electronic Products Magazine*



Our goal is to find solutions for challenging applications. For any questions, please contact foil@vpgsensors.com

Hermetically Sealed Resistors

VFR hermetically sealed resistors eliminate the ingress of both oxygen, which degrades resistors over long periods, and moisture, which degrades resistors more quickly. A series of radial- and axial-configured resistors are placed in an enclosure impervious to gas transmission. Some of the models are simply standard through-hole products that are encapsulated; ie. VHZ555 is the hermetic version of Z555.

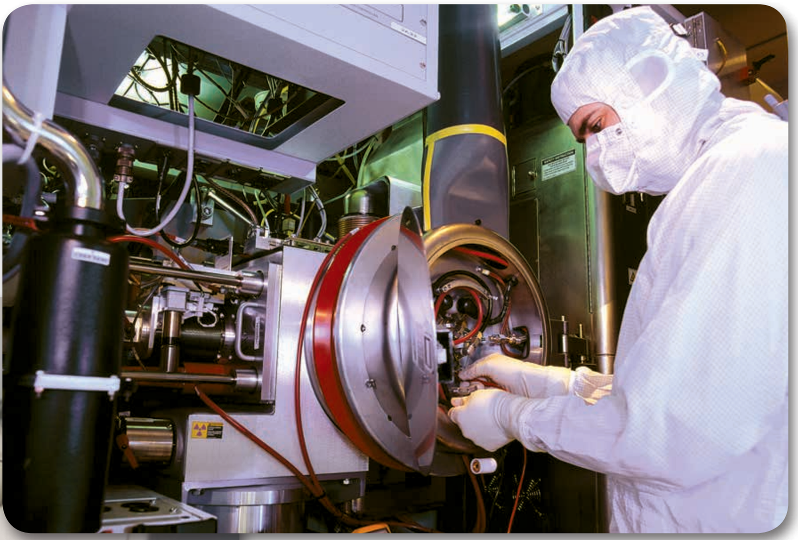
The degree of hermeticity is usually determined by exposure to pressurized helium and then measuring the rate at which the helium escapes. VFR hermetically sealed resistors offer a remarkably low degree of hermeticity at less than 1x10-7 cc per second at normal atmospheric pressure.

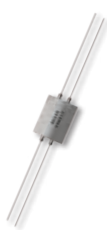
Different forms of seal designs can be implemented:

- Oil-filled seals — the oil acts as a thermal conductor, thus eliminating long-term degradation of the elements of un-sealed resistors, while at the same time allowing the device to accept short periods of overload without degradation
- Rubber fill between the metal housing and resistance element acts both as a mechanical damper and thermal transfer path
- Glass-to-metal seal enclosures employing Kovar eyelets allow the OFHC solder-plated copper leads to pass through the enclosure to minimize the thermal EMF from the lead junctions

Other resistor technologies tend to face several problems with the effects of oxygen and moisture. Thin film technology, for example, can easily be damaged permanently by moisture. Condensation of microscopic quantities of water vapor on the surface of the NiCr thin film resistive element results in the dissolution of ionic contaminations on the surface and the formation of electrolyte solution. Since all plastics and all epoxies are hydroscopic, thermal cycling causes the resistor to “breathe in” water vapor that picks up encapsulation contaminates, which are then condensed inside the package. Under low-power DC voltage, the ionic etching of thin NiCr films can cause rapid and significant resistance changes in a few minutes, completely destroying the resistor (open circuit) within a few hours. This is why any damage to the humidity protection (coating or package) in thin film resistors inevitably results in its failure.

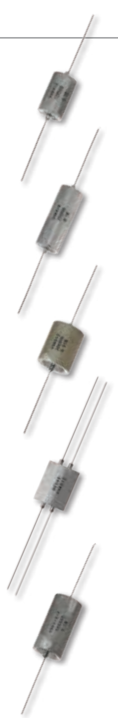
Bulk Metal resistive elements in VFR resistors are one hundred times thicker than thin film resistive elements and therefore are much less vulnerable to the etching process. Hermetic versions of these resistors then completely eliminate any moisture influence whatsoever.



Product		Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability, 2000 Hours +70°C Under Power
Hermetically Sealed - Z Foil*								
VH102Z (Z Foil)		Y5077	Hermetic version of the molded Z201 and Z555 devices	10Ω to 100 kΩ	±0.005%	±0.2 ppm/°C Available with low window TCR over the required temp. range	0.6W	±0.005%
VHZ555 (Z Foil)		Y1635		4.99Ω to 121 kΩ	±0.005%	±0.2 ppm/°C	0.6W	±0.005%
VHP202Z (Z Foil)		Y1748 Y6071	Oil-filled hermetically sealed ultra high-precision resistors [4-lead terminal (Kelvin connection) available on special request]	5Ω to 100 kΩ	±0.001% (1 K to max value)	±0.2 ppm/˚C	0.3W	±0.002% at +25°C
VHA412Z (Z Foil)		Y1749			±0.001% (1 K to max value)	±0.2 ppm/˚C	0.3W	±0.002% at +25°C
VHA414Z (Z Foil)		Y1751		5Ω to 200 kΩ	±0.001% (1 K to max value)	±0.2 ppm/˚C	0.5W	±0.002% at +25°C
VHA512Z** (Z Foil)		Y1750		5Ω to 300 kΩ	±0.001% (1 K to max value)	±0.2 ppm/˚C	0.75W	±0.002% at +25°C
VHA516-4Z** (Z Foil)		Y1752		5Ω to 400 kΩ	±0.001% (1 K to max value)	±0.2 ppm/˚C	1.0W	±0.002% at +25°C
VHA516-5Z** (Z Foil)		Y1753		5Ω to 500 kΩ	±0.001% (1 K to max value)	±0.2 ppm/˚C	1.25W	±0.002% at +25°C
VHA516-6Z** (Z Foil)		Y1754		5Ω to 600 kΩ	±0.001% (1 K to max value)	±0.2 ppm/˚C	1.5W	±0.002% at +25°C
VHA518-7Z** (Z Foil)		Y1755		5Ω to 700 kΩ	±0.001% (1 K to max value)	±0.2 ppm/˚C	1.75W	±0.002% at +25°C
VHA518-8Z** (Z Foil)		Y1756		5Ω to 800 kΩ	±0.001% (1 K to max value)	±0.2 ppm/˚C	2.0W	±0.002% at +25°C
VHA518-9Z** (Z Foil)		Y1757		5Ω to 900 kΩ	±0.001% (1 K to max value)	±0.2 ppm/˚C	2.25W	±0.002% at +25°C
VHA518-10Z** (Z Foil)		Y1758		5Ω to 1.0 MΩ	±0.001% (1 K to max value)	±0.2 ppm/˚C	2.5W	±0.002% at +25°C
VHA518-11Z** (Z Foil)		Y1759		5Ω to 1.1 MΩ	±0.001% (1 K to max value)	±0.2 ppm/˚C		±0.002% at +25°C

* Tighter performances and higher or lower value resistances are available for all models.
** Available in 4-lead terminal: VHA512(Z) please use 302073(Z), VHA516(Z) please use 302074(Z), VHA518(Z) please use 302075(Z).

Hermetically Sealed Resistors

Product		Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, +25°C ref.) Typical	Rated Power at +70°C	Load Life Stability, 2000 Hours +70°C Under Power
Hermetically Sealed								
VHS102		Y0077 Y0088	Hermetic version of the molded S102C, S102K, and S555 devices	1Ω to 150 kΩ	±0.005%	±2 ppm/°C	0.6W at +70°C 0.3W at +125°C	±0.005%
VH102K		Y5787 Y0787		1Ω to 100 kΩ	±0.005%	±1 ppm/°C		±0.005%
VHS555		Y0087		1Ω to 150 kΩ	±0.005%	±5 ppm/°C maximum		±0.005%
VHP100 VHP102 (0.2" L.S.)		Y0078 Y5078	Ultra high-precision resistor with very narrow TCR window	100Ω to 150 kΩ	±0.005%	<60 ppm window (-55°C to +125°C)	0.3W at +70°C	±0.005%
VHP101 VHP103 (0.2" L.S.)		Y4078 Y6078		100Ω to 150 kΩ	±0.005%	<10 ppm window (+15°C to +45 °C)	0.3W at +70°C	±0.005%
VHP202		Y0024	Oil-filled hermetically sealed high-precision resistors [4-lead terminal (Kelvin connection) available on special request]	5Ω to 150 kΩ	±0.001% (1 K to max value)	±2 ppm/°C	0.3W	±0.002% at +25°C
VHA412		Y0019				±2 ppm/°C		±0.002% at +25°C
VHA414		Y0025		5Ω to 335 kΩ		±2 ppm/°C	0.5W	±0.002% at +25°C
VHA512**		Y0023		5Ω to 500 kΩ		±2 ppm/°C	0.75W	±0.002% at +25°C
VHA516-4**		Y0104		5Ω to 668 kΩ		±2 ppm/°C	1.0W	±0.002% at +25°C
VHA516-5**		Y0105		5Ω to 835 kΩ		±2 ppm/°C	1.25W	±0.002% at +25°C
VHA516-6**		Y0106		5Ω to 1 MΩ		±2 ppm/°C	1.5W	±0.002% at +25°C
VHA518-7**		Y0107		5Ω to 1.17 MΩ		±2 ppm/°C	1.75W	±0.002% at +25°C
VHA518-8**		Y0108		5Ω to 1.34 MΩ		±2 ppm/°C	2.0W	±0.002% at +25°C
VHA518-9**		Y0109		5Ω to 1.5 MΩ		±2 ppm/°C	2.25W	±0.002% at +25°C
VHA518-10**		Y0110		5Ω to 1.67 MΩ		±2 ppm/°C	2.5W	±0.002% at +25°C
VHA518-11**		Y0111		5Ω to 1.84 MΩ		±2 ppm/°C	2.5W	±0.002% at +25°C
VHP3, VHP4, VPR247		Y0065 Y0066 Y0830	Hermetically-sealed and molded power high-precision current sensing resistors	0.05Ω to 80 kΩ	±0.01%		3W in free air 10W on heat sink	±0.01% at +25°C

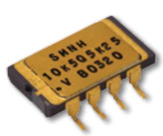
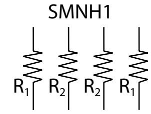
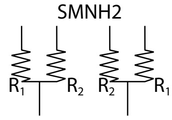
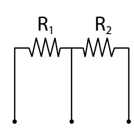
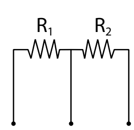
* Tighter performances and higher or lower value resistances are available for all models.
** Available in 4-lead terminal: VHA512(Z) please use 302073(Z), VHA516(Z) please use 302074(Z), VHA518(Z) please use 302075(Z).

Selector Guides

Hermetically Sealed Resistors

VISHAY FOIL RESISTORS A VPG Brand

Selector Guides

Model and Product Description	Global Model	Resistance Range	Resistance Ratio Available	Best Resistance Tolerance		TCR (–55°C to +125°C +25°C ref.) Typical	Rated Power at +70°C
				Absolute	Ratio Match		
Hermetic Voltage Divider							
SMNH1, 2*, ** High-precision, hermetically sealed, 4-resistors, surface-mount resistor network 	Y1521 Y1522	Any value 5Ω to 33 kΩ per resistor SMNH1  SMNH2 	Any ohmic value ratio within resistance range	±0.005%	0.005%	Absolute : ±2 ppm/°C Tracking: ±0.5 ppm/°C	Entire package 0.4W Each resistor 0.1W at +70°C
VHD144*, ** Hermetically sealed (air-filled) version of the molded divider 300144 	Y0076	Any value from 100Ω to 20 kΩ per side 	Any ohmic value ratio within resistance range	±0.005%	0.005%	Absolute: ±2 ppm/°C Tracking: 0.5 ppm/°C	0.2W at +85°C
VHD200*, ** Hermetically sealed, oil-filled voltage divider, ultimate ratio match and TC tracking 	Y5076	Any value from 100Ω to 20 kΩ per side 	Any ohmic value ratio within resistance range	±0.005%	0.001%	Absolute: ±2 ppm/°C Tracking: 0.1 ppm/°C	0.2W at +85°C
FSR **Secondary Standard Foil Resistor serves as a reference and calibration device** 	Y4028 New	1Ω to 150 kΩ	Any ohmic value ratio within resistance range	Absolute: ±0.005%		±0.3 ppm/°C (+15°C to +45°C +25°C ref.)	±0.75W at 25°C

* Shelf-life stability: 2 ppm.
** Available with Z Foil Technology.
Tighter performances and higher or lower value resistances are available for all models.

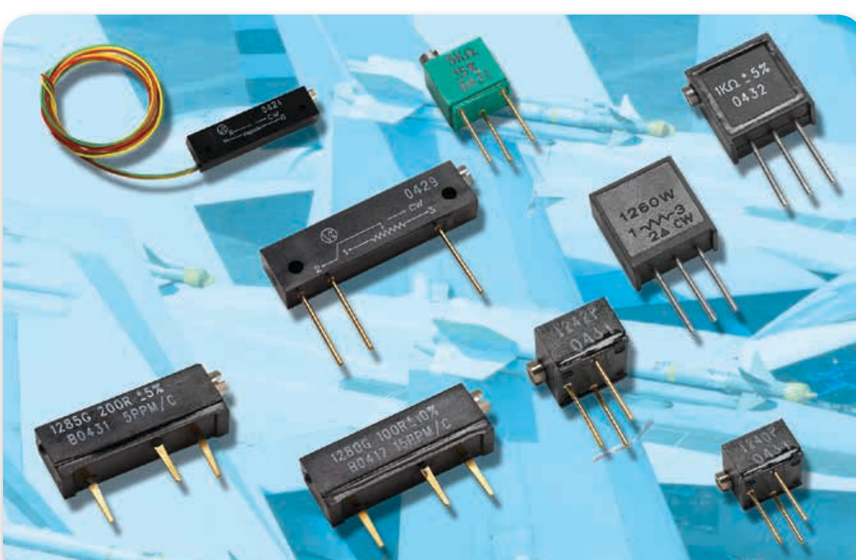
Trimming Potentiometers

Key Benefits

- Absolute temperature coefficient of resistance (TCR): ±5 ppm/°C (–55°C to +125°C, +25°C ref.)
- TCR through the wiper: ±25 ppm/°C
- Settability: down to ±0.005%
- Setting stability: to 0.1%
- Load-life stability: 0.1% typical ΔR, 1.0% maximum
- ΔR under full rated power at +85°C for 10 000 h
- Tap test: 0.05%
- All trimmers undergo noise and linearity tests during
- the standard production process
- O-ring prevents ingress of fluids during any board
- cleaning operation
- Prototype quantities available in just fice working days or sooner
- A smooth and unidirectional resistance with lead screw adjustment
- Power rating: 0.25 W at +85°C
- Electrostatic discharge (ESD) at least to 25 kV

Applications

- High-precision instrumentation
- Test equipment and automatic test equipment
- Laboratory and industrial
- Audio equipment
- Military



Our goal is to find solutions for challenging applications. For any questions, please contact foil@vpgsensors.com

Trimmers

Trimmers are mechanically driven, variable resistors. A wiper is moved across the resistance element, picking off an intermediate voltage in the potentiometer mode, or adding resistance in the rheostat mode. Its inherent mechanical aspects have caused some users to avoid designing with trimmers and are of special concern when selecting trimmers for precision applications.

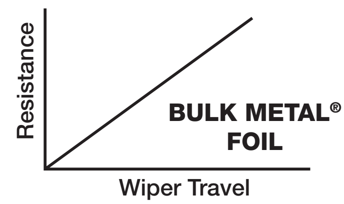
However, with VFR trimmers there is a smooth, unidirectional, and infinite resolution adjustment for lower ohmic values, and somewhat lesser resolution for values 5 kΩ and above. Foil also achieves a very low TCR end-to-end, and the TCR though the wiper can be specified (and is also relatively low). Further, the unique element resistive pattern design minimizes the capacitive and inductive reactance levels.

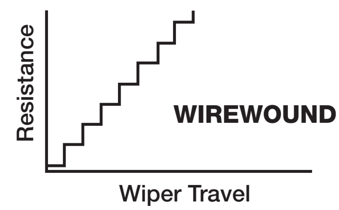
The trimmers' advanced virtually backlash-free adjustment mechanism makes them easy to set quickly and accurately, while firmly maintaining their value. The contact resistance variation is now reduced through the use of a multi-fingered wiper on a planer surface — a comparison between the competing technologies shows these capabilities in the figure below.

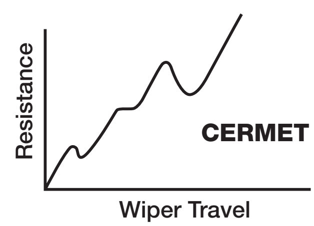
Four key points:

1. Foil trimmers are preferred for precise adjustment
2. Foil trimmers are preferred when the adjustment must be stable with mechanical vibration and temperature excursion
3. Foil trimmers introduce the least noise
4. The applied O-ring seal is the surest protection against contaminants

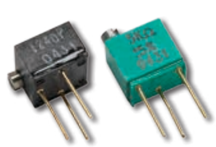
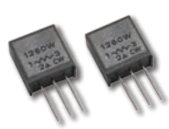
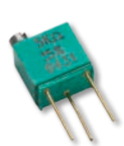
All in all, VFR trimmers have become the devices of choice for precise adjustment.







Trimming Potentiometers

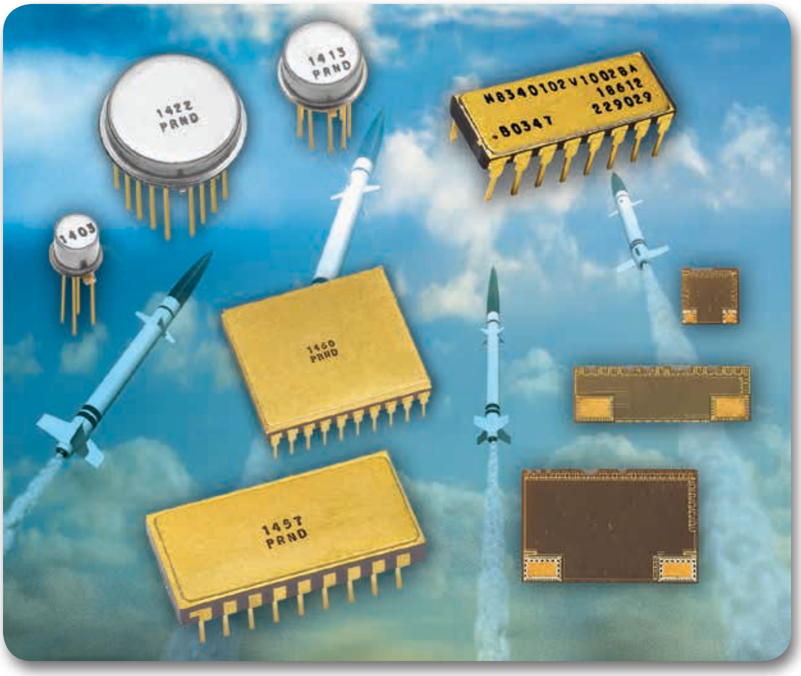
Model	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +150°C +25°C ref.)	Rated Power	Termination Style
Trimmers							
1240 	Y4053 Y5053 Y0053	Precision trimming potentiometers, ¼ inch square, RJ26 style DLA 87126, multi turn	5Ω to 10 kΩ	±5%	±10 ppm/°C	0.25W at +85°C	W-edge mount, top adjust X-edge mount, side adjust P-horizontal mount, side adjust
1260 	Y0069 Y4069	Precision trimming potentiometers, ⅜ inch square, RJ24 style, multi turn	5Ω to 10 kΩ	±5%	±10 ppm/°C	0.25W at +85°C	W-edge mount, top adjust X-edge mount, side adjust
1202 	Y0051-P Y6050-PB Y5051-Y Y7050-YB Y5050-L Y0050-LB	Precision trimming potentiometers, 1¼ inch rectilinear, RJ12 style, multi turn	2Ω to 20 kΩ	±5%	±10 ppm/°C	0.5W at +85°C	P-in line pins Y-staggered pins L-flexible leads B-panel mounted
1242 	Y0057 Y4057	Precision trimming potentiometers QPL, ¼ inch square, qualified to MIL-PRF-22097, Char. F, RJ26, multi turn	50Ω to 5 kΩ	±10%	±10 ppm/°C	0.25W at +85°C	W-edge mount, top adjust X-edge mount, side adjust
1280G 	Y0056	Precision trimming potentiometers, ¾ inch rectilinear, multi turn	10Ω to 20 kΩ	±10%	±15 ppm/°C	0.75W at +25°C	Edge mount, side adjust
1285G 	Y0059	Precision trimming potentiometers, ¾ inch rectilinear, multi turn	10Ω to 20 kΩ	±5%	±5 ppm/°C	0.75W at +25°C	Edge mount, side adjust

* Tighter performances and higher or lower value resistances are available for all models.

Hybrid Chips and Custom-Designed Hermetically Sealed Networks (PRND)

Key Benefits

- Temperature coefficient of resistance (TCR):
  - 0.05 ppm/°C typical (0°C to +60°C)
  - 0.2 ppm/°C typical (-55°C to +125°C, +25°C ref.)
- TCR tracking: 0.5 ppm/˚C
- Flexible schematic designs
- Resistance tolerance:
  - Absolute ±0.005%;
  - Match 0.002%
- Resistance values: 5 Ω to 80 kΩ
- Load-life stability: ΔR = 0.01%, ΔRatio = 0.005% at +25°C for 2000 hr at rated power
- Shelf-life stability per resistor: 0.0002% (2 ppm)
- High degree of hermeticity: <5 x 10^{-7} cc/sec
- Rated power per package up to 2.4 W
- Resistance tolerance:
  - Absolute: to ± 0.01%;
  - Match: to 0.01%
- Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
- Current noise: 0.010 μVRMS/V of applied voltage (<–40 dB)
- VFR resistors are not restricted to standard values; specific "as required" values can be supplied at no extra cost or delivery (e.g. 1.2345 kΩ vs. 1 kΩ)
- Electrostatic discharge (ESD) at least to 25 kV
- Available for high-temperature applications
- No engineering charges, no minimum quantities
- Quick prototype delivery
- Custom-designed chip arrays are available



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Hybrid Chips and Custom-Designed Hermetically Sealed Networks (PRND)

Customers have the opportunity to order hybrid chips and custom-designed hermetically sealed networks for implementation into their design projects.

Hybrid Chips

Hybrid chips with gold-plated pads enable gold-wire bonding between the components in circuits. The use of gold-wire bonding maintains the characteristics necessary for the chip to have a low thermal EMF, since using the same elements and materials reduces potential differences that can cause an EMF. The customer has wide flexibility in determining the implementation and selection of chips. Chips are available in a variety of sizes, trimming specifications, and foil technology — including the latest Z Foil hybrid chips.

Untrimmed chips can be ordered, allowing user trimming to be performed either before or after bonding — using standard epoxies—onto the hybrid circuit substrate using standard laser, air abraid, or manual adjustment techniques. The VFR precision trimming system allows for adjustment to precise resistance values without concern over mechanical override and control problems encountered in laser or air abraid trimming of solid geometry resistance patterns.

This ability to trim resistor chips to tolerance levels never before available to hybrid manufacturers gives project managers the ability to increase the value of their hybrid services and retain more profit within the facility. Now, instead of buying precision resistors in separate packages or modules (which require additional PC board real estate) and integrating them into a system, project managers can utilize VFR resistor chips or matched sets to manufacture the entire hybrid circuit in-house. This eliminates the need to "pin-out" for precision resistor requirements because the precision resistors are inside, as part of the hybrid microcircuit design.

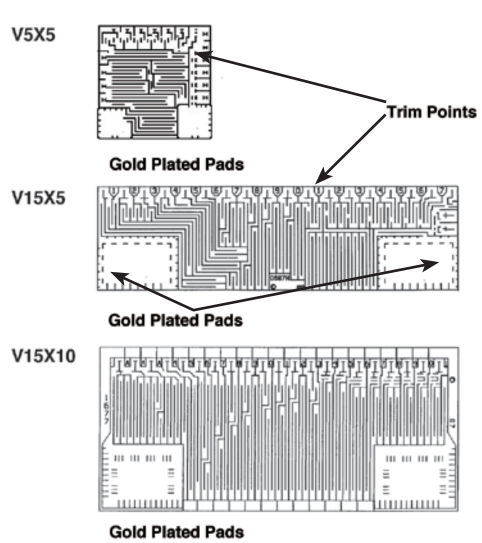
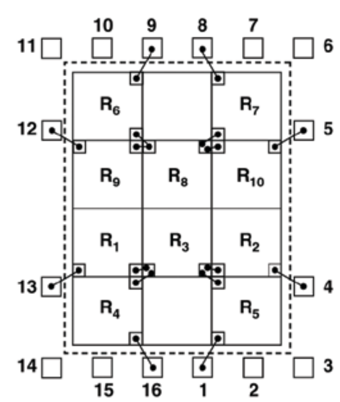


Figure 1. Trimming chip resistors

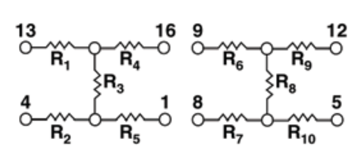
PRNDs

Precision resistor network devices (PRNDs) are custom-designed, hermetically sealed networks that can be configured to any circuit schematic and specifications the customer desires. Multiple resistors are deliberately arranged within the devices and connected by gold-wire bonding. Our application engineers are experienced in designing networks that operate properly and avoid potential problems such a high heat concentrations or elongated gold-wires, which can reduce the network's reliability. To have your PRND designed, please send your desired schematics and specifications to our Application Engineering department.

Figure 2. Sample circuit design and chip layout

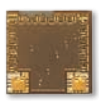


NOTE:
Usable area is represented by the dotted lines — a rectangle 0.150" x 0.200". Illustrations not to scale. Chips shown undersize for clarity. Drawing view is from the top looking down into package.



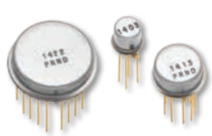
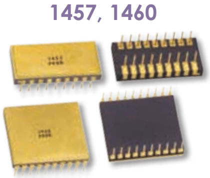
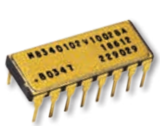
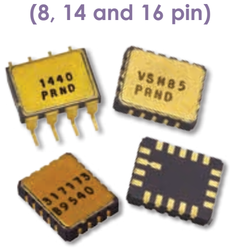
Hybrid Chips and Custom-Designed Hermetically Sealed Networks (PRND)

VISHAY FOIL RESISTORS
A VPG Brand

Hybrid Chip Type	Global Model	Product Description	Resistance Range*	Best Tolerance	TCR (–55°C to +125°C, 25°C ref.) Typical	Rated Power at +70°C
V5x5PT (0.050" x 0.050") 	Y4045	Hybrid chips (gold-plated termination pads)	5Ω to 10 kΩ	±0.005%	±2 ppm/°C	0.05W
V15x5PT (0.150" x 0.050") 	Y4047	Hybrid chips (gold-plated termination pads)	5Ω to 33 kΩ	±0.005%	±2 ppm/°C	0.1W
V15x10PT (0.150" x 0.100") 	Y4475	Hybrid chips (gold-plated termination pads)	33 kΩ to 80 kΩ	±0.005%	±2 ppm/°C	0.15W
V5X5PU	Y4044	**Untrimmed** gold wire-bondable hybrid chips (gold-plated termination pads)	Good for 5Ω to 10 kΩ	±0.005%	±2 ppm/°C	0.05W
V15X5PU	Y4046		Good for 5Ω to 33 kΩ			0.1W
V15X10PU	Y4471		Good for 33Ω to 80 kΩ			0.15W
Z Foil						
V5X5ZT	Y4033	Ultra high-precision hybrid chips (gold-plated termination pads)	50Ω to 5 kΩ	±0.01%	±0.2 ppm/°C	0.05W
V15X5ZT	Y4034		50Ω to 30 kΩ	±0.01%	±0.2 ppm/°C	0.1W
V5X5ZU	Y4036	Ultra high-precision **untrimmed** hybrid chips (gold-plated termination pads)	Good for 50Ω to 5 kΩ	±0.01%	±0.2 ppm/°C	0.05W
V15X5ZU	Y4037		Good for 50Ω to 30 kΩ	±0.01%	±0.2 ppm/°C	0.1W

* Tighter performances and higher or lower value resistances are available for all models.
Hybrid chips are also available for high temperature applications. For more information, please refer to HTH series on page 24.

Hybrid Chips and Custom-Designed Hermetically Sealed Networks (PRND)

Package Type	Product Description	Resistance Range*	Best Tolerance	TCR (-55 °C to +125 °C, +25 °C ref.) Typical
PRND				
TO: 1401, 1403, 1413, 1417, 1419, 1421, 1422 	Glass to metal seal headers	5Ω to 80 kΩ per resistor	Absolute: ±0.005% Ratio match: 0.002%	Absolute: ±2 ppm/°C Tracking: 0.5 ppm/°C
DIP: 1442, 1445, 1446, 1457, 1460 	Ceramic dual-in-line package	5Ω to 80 kΩ per resistor	Absolute: ±0.005% Ratio match: 0.002%	Absolute: ±2 ppm/°C Tracking: 0.5 ppm/°C
1445Q (7 resistors) 1446Q (8 resistors) 	QPL Networks qualified to MIL-PRF 83401 Characteristic "C" Schematic A	100Ω to 10 kΩ	Absolute: ±0.1% Ratio match: 0.1%	Absolute: ±50 ppm/°C Tracking: 5 ppm/°C
VSM40, 42, 45, 46 (8, 14 and 16 pin) 	Hermetic resistor networks in gull wing configuration	5Ω to 80 kΩ	Absolute: ±0.005% Match: ±0.002%	Absolute: ±2 ppm/°C Tracking: ±0.5 ppm/°C
VSM85, 86, 87, 88, 89 	Hermetic resistor networks in leadless chip carrier (LCC) configuration	5Ω to 80 kΩ	Absolute: ±0.005% Match: ±0.002%	Absolute: ±2 ppm/°C Tracking: ±0.5 ppm/°C
VSM57 		5Ω to 80 kΩ	Absolute: ±0.005% Match: ±0.002%	Absolute: ±2 ppm/°C Tracking: ±0.5 ppm/°C

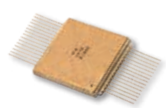
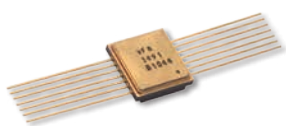
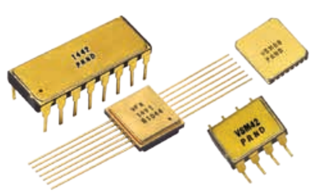
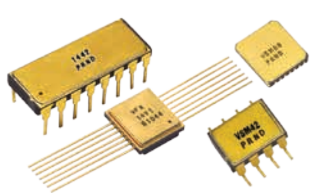
Networks built to customer requirements. Send schematics and electrical specification to Application Engineering Dept. at foil@vpgsensors.com.

* Tighter performances and higher or lower value resistances are available for all models.

Hybrid Chips and Custom-Designed Hermetically Sealed Networks (PRND)

VISHAY FOIL RESISTORS A VPG Brand

Selector Guides

Package Type	Product Description	Resistance Range*	Best Tolerance	TCR (-55 °C to +125 °C, +25 °C ref.) Typical
PRND				
1476 	Hermetic resistor networks in flatpacks configuration	5Ω to 80 kΩ	Absolute: ±0.005% Match: ±0.002%	Absolute: ±2 ppm/°C Tracking: ±0.5 ppm/°C
1491 		5Ω to 80 kΩ	Absolute: ±0.005% Match: ±0.002%	Absolute: ±2 ppm/°C Tracking: ±0.5 ppm/°C
PRND EEE 	Custom hermetically sealed precision resistor network devices (PRND) with screen/test flow in compliance with EEE-INST-002 and MIL-PRF-83401	5 to 60 KΩ	Absolute: ±0.005% Ratio match: 0.002%	Absolute: ±2 ppm/°C Tracking: 0.5 ppm/°C
PRND HT 	Custom hermetically sealed precision resistor network devices (PRND) for high temperature applications up to +230°C	5 to 125 KΩ (per chip)	Absolute: ±0.01% Ratio match: 0.005%	Absolute: ±2.5 ppm/°C Tracking: 2.5 ppm/°C

Networks built to customer requirements. Send schematics and electrical specification to Application Engineering Dept. at foil@vpgsensors.com.

* Tighter performances and higher or lower value resistances are available for all models.

Avionics, Military, and Space (AMS)

Avionics, military, and space (AMS) applications have reliability requirements that exceed the standard processes of electronic component manufacturing. Military-style (MIL) testing consists of electrical and environmental stresses that may be applied to each resistor, or to a sample of parts from each production lot. By reviewing the behavior of the parts when they are subjected to the specified tests, the performance of a lot is guaranteed to a higher level of reliability and lot-to-lot uniformity. Different qualification inspection plans are applicable depending on the application, ranging from a DLA specification up to a MIL-qualified component with an established reliability level. Additionally, custom screening plans, such as those modeled after NASA EEE-INST-002 guidelines, or plans intended to qualify products for use in higher temperatures, may be considered. Contact our Application Engineering department for the appropriate qualification inspection for your project.

Standards in brief:

(1) **Defense Logistics Agency (DLA)** — The DLA is known to more than 24,000 military and civilian customers, plus 10,000 contractors, as one of the largest suppliers of weapons systems spare parts. The DLA was formerly known as the Defense Supply Center Columbus (DSCC)

(2) **EEE-INST-002** (Instruction for EEE parts selection, screening, qualification, and derating) — The purpose of this standard is to establish baseline criteria for selection, screening, qualification, and derating of EEE parts for use on NASA GSFC space flight projects. This standard shall provide a mechanism to assure that appropriate parts are used in the fabrication of space hardware that will meet mission reliability objectives within budget constraints

(3) **EPPL** (European Preferred Parts List) — The EPPL is covered by ESCC 12300 (European Space Components Coordination), which provides the rules for establishing the list of preferred and suitable components to be used by European manufacturers of spacecraft hardware and associated equipment

(4) **ESA** (European Space Agency) — The ESA has committed to developing a coherent, single set of user-friendly standards for all European space activities called the European Co-operation for Space Standardization. The ultimate goal of building such a standardization system at the European level is to minimize life-cycle cost, while continually improving the quality, functional integrity, and compatibility of all elements in a space project. This goal is achieved by applying common standards for project management and for the development and testing of hardware and software

(5) CECC (CENELEC Electronic Components Committee-European Committee for Electrotechnical Standardization) — These manufacturer specifications are vital to designers who wish to use specific active and passive components that are approved to CECC QA schemes. The CECC Detail Specifications Service provides detailed information needed in electronics design, specification, maintenance, purchasing, and other functions that must locate and select electronic components

Our goal is to find solutions for challenging applications. For any questions, please contact foil@vpgsensors.com

Established Reliability (ER)

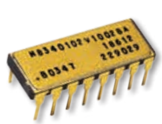
The RNC90Y established-reliability resistor has been the benchmark for high-precision, established-reliability discrete resistors since 1982. In 2000, the Z201 resistor achieved a technological breakthrough with a TCR of 0.2 ppm/°C, allowing the introduction of the RNC90Z, an established-reliability "R" level resistor with a TCR limit of ±2 ppm/°C over the extended range of –55°C to +175°C. This is a significant improvement over the existing RNC90Y's ±5ppm/°C TCR specification.

Model		Failure Rate	MIL Spec No.	Resistance Range (Ω)	TCR (MIL Range)	Absolute Tolerance	Termination Type
RNC90Y		Level R	MIL-PRF-55182/9	4.99Ω – 121 kΩ	±5 ppm/°C	0.005%	Lead
RNC90T*				4.99Ω – 121 kΩ	±5 ppm/°C	0.005%	Lead
RNC90Z				30.1Ω – 121 kΩ	±2 ppm/°C	0.005%	Lead
RNC90S*				30.1Ω – 121 kΩ	±2 ppm/°C	0.005%	Lead

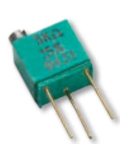
* 0.200" lead spacing

QPL

VFR's models 1445Q and 1446Q networks are qualified to MIL-PRF-83401, characteristic C, schematic A. Actual performance exceeds all the requirements of MIL-PRF-83401 characteristic C.

Model		MIL Spec No.	Termination Type	Resistance Range (Ω)	Absolute Tolerance	Number of Resistors	Absolute TCR (–55˚C to +125˚C, +25˚C ref.)
1445Q		MIL-PRF-83401	14 pin DIP	100Ω – 10 kΩ	0.1%	7	100R - 1k 10 ppm/°C 1k - 10k 5 ppm/°C
1446Q			16 pin DIP	100Ω – 10 kΩ	0.1%	8	

VFR's RJ26 quarter-inch precision trimming potentiometer is qualified to MIL-PRF-22097.

Model		MIL Spec No.	Termination Type	Resistance Range (Ω)	Absolute Tolerance	Setability	TCR Through the Wiper (–55°C to +125°C, +25°C ref.)
RJ26 (Trimmer)		MIL-PRF-22097	Leaded	50Ω, 100Ω, 200Ω, 500Ω, 1 kΩ, 2 kΩ, 5 kΩ	10%	0.05%	±25 ppm/°C

Type	Construction	DLA (1) and MIL Spec Number	EEE-INST-002 (2) and MIL Spec Number	EPPL (3)	ESA (4)	CECC (5)	Nominal TCR MIL Range (ppm/°C)	Typical Load Life Stability
DLA, EEE-INST-002, EPPL, ESA and CECC Foil Products								
PRND	Custom hermetically sealed precision resistor network device		PRND EEE MIL-PRF-83401				2	0.05%
FRSM0603	Wrap around surface mount Z1 Foil Technology		303261 MIL-PRF-55342				0.2	0.005%
FRSM0805			303262 MIL-PRF-55342					
FRSM1206			303263 MIL-PRF-55342					
FRSM1506			303264 MIL-PRF-55342					
FRSM2010			303265 MIL-PRF-55342					
FRSM2512			303266 MIL-PRF-55342					
VSMP0805	Wrap-around surface mount	07024 MIL-PRF-55342	303134 MIL-PRF-55342					
VSMP1206		07025 MIL-PRF-55342	303135 MIL-PRF-55342					
VSMP1506		03010 MIL-PRF-55342	303136 MIL-PRF-55342					
VSMP2010		06001 MIL-PRF-55342	303137 MIL-PRF-55342					
VSMP2512		06002 MIL-PRF-55342	303138 MIL-PRF-55342					
VSM0805		07024 MIL-PRF-55342					2	
VSM1206		07025 MIL-PRF-55342					2	
VSM1506		03010 MIL-PRF-55342					2	
VSM2010		06001 MIL-PRF-55342					2	
VSM2512		06002 MIL-PRF-55342					2	
VSM2018		93030 MIL-PRF-55342					0.2	

Notes:

(1) DLA (Defense Logistics Agency, formerly known as DSCC)

(2) EEE-INST-002 (Instruction for EEE Parts Selection, Screening, Qualification, and Derating)

(3) EPPL (European Preferred Parts List)

(4) (ESA -European Space Agency

(5) (CENELEC Electronic Components Committee-European Committee for Electrotechnical Standardization

All the above resistors are also available on the shelf as standard products.

Avionics, Military, and Space (AMS)

VISHAY FOIL RESISTORS
A VPG Brand

Type	Construction	DLA (1) and MIL Spec Number	EEE-INST-002 (2) and MIL Spec Number	EPPL (3)	ESA (4)	CECC (5)	Nominal TCR MIL Range (ppm/°C)	Typical Load Life Stability
DLA, EEE-INST-002, EPPL, ESA and CECC Foil Products								
SMR1DZ	Molded, flexible terminations with robust construction	06020 MIL-PRF-55182	303139 MIL-PRF-55182				0.2	0.005%
SMR1D		06020 MIL-PRF-55182					2	
SMR3DZ		06021 MIL-PRF-55182	303140 MIL-PRF-55182				0.2	
SMR3D		06021 MIL-PRF-55182					2	
VCS1625Z	Current sense with Kelvin connections for high accuracy	08003 MIL-PRF-55342	303119Z MIL-PRF-55342				0.2	
VCS1625		00803 MIL-PRF-55342	303119 MIL-PRF-55342	✔			2	
CSM2512		07011 MIL-PRF-49465	303144 MIL-PRF-49465				15 Max	0.05%
CSM3637		07012 MIL-PRF-49465	303145 MIL-PRF-49465					
Z201	Through-hole		303143 S-311-P813				0.2	2
Z201L			303143L S-311-P813					
RS92N, RS92NA, AN						✔	2	0.005%
S102		89039 MIL-PRF-89039					2	0.005%
300144	Through-hole voltage divider	87026 MIL-PRF-55182					2	0.005%
300144Z		87026 MIL-PRF-55182					0.2	
1240	Trimmer	87126 MIL-PRF-39035					10	0.1%

Notes:

(1) DLA (Defense Logistics Agency, formerly known as DSCC)

(2) EEE-INST-002 (Instruction for EEE Parts Selection, Screening, Qualification, and Derating)

(3) EPPL (European Preferred Parts List)

(4) (ESA -European Space Agency

(5) (CENELEC Electronic Components Committee-European Committee for Electrotechnical Standardization

All the above resistors are also available on the shelf as standard products.

Example of Test Flow

Models #303144 and 303145—fixed resistors CSM2512 and CSM3637 with screen/test flow in compliance with EEE-INST-002 (Tables 2A and 3A, Film/Foil, Level 1) MIL-PRF-55342 and MIL-PRF-49465.

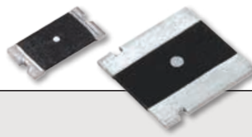


Table 2. EEE-INST-002 (Table 2A Film/Foil, level 1) 100% Tests/Inspections [1]	
RC Record	In tolerance
Thermal Shock	25 x (- 65 °C to + 150 °C)
RC Record	ΔR = 0.1 %
High Temperature Exposure	+ 170 °C, 100 h, no power
RC Record	In tolerance ΔR = 0.2 %
Final Inspection	5 % PDA on ΔR, 10 % PDA on out of tolerance
Visual Inspection	Magnification 30 x to 60 x
Mechanical Inspection	Dimensions, workmanship, 3 units sample size

Note

[1] VFR Resistors will perform a pre-cap visual inspection 100% in the production flow prior to overcoating.

Table 3. EEE-INST-002 (Table 3A Film/Foil, level 1) Destructive Tests – MIL-PRF-49465 [2]		
Group 2	Sample size: 3(0)	
	Solderability	MIL-STD-202, method 208
Group 3	Sample size: 10(0) - mounted on FR4	
	TCR measurement per MIL-STD-202, method 304 - 55 °C/+ 25 °C/+ 125 °C	303144: 3 mΩ to < 100 mΩ: ± 20 ppm/°C 100 mΩ to 200 mΩ: ± 25 ppm/°C 303145: 2 mΩ to ≤ 3 mΩ: ± 25 ppm/°C > 3 mΩ to < 100 mΩ: ± 20 ppm/°C 100 mΩ to 200 mΩ: ± 25 ppm/°C
	Low temperature storage per MIL-PRF-49465	ΔR = 0.2 % - 55 °C ± 2 °C, 24 h ± 4 h ambient no load dwell for 2 h to 8 h at + 25 °C
	Low temperature operation per MIL-PRF-55342	ΔR = 0.2 % - 65 °C ambient no load dwell for 1 h rated power for 45 min no load dwell at + 25 °C for 24 h ± 4 h
	Short time overload per MIL-STD-49465	ΔR = 0.3 % 5 x rated power at + 25 °C for 5 s, not to exceed maximum current rating
Group 4	Sample size: 9(0) - mounted on FR4	
	Resistance to soldering heat	ΔR = 0.05 % 10 s to 12 s at + 260 °C reflow method
	Moisture resistance per MIL-STD-202, method 106 (7a and 7b not required)	ΔR = 0.05 % 240 h, no power
Group 5	Sample size: 9(0)	
	Shock per MIL-STD-202, method 213, condition I	ΔR = 0.05 % 100G, 6 ms axes Z and Y, 10 shocks per axis
	Vibration per MIL-STD-202, method 204, condition D	ΔR = 0.05 % 10 Hz to 2000 Hz, 20G 2 axes, 6 h per axis
Group 6	Sample size: 12(0) - mounted on FR4	
	Life test per MIL-PRF-49465	ΔR = 1 % 2000 h, + 70 °C, rated power

Table 3. EEE-INST-002 (Table 3A Film/Foil, level 1) Destructive Tests — MIL-PRF-49465 (2)		
Group 7B	Sample Size: 10(0) - mounted on FR4 Solder mounting integrity per MIL-PRF-55342	 303144: 3 kg force, 30 s 303145: 5 kg force, 30 s
Group 9	Sample size: 5(0) - mounted on FR4 High temperature exposure per MIL-PRF-49465	 ΔR = 0.3 % 1000 h, + 170 °C ± 7 °C, no power
Group 10(3)	Sample size: For 303144: 12 For 303145: 4 Outgassing	Per ASTM E595

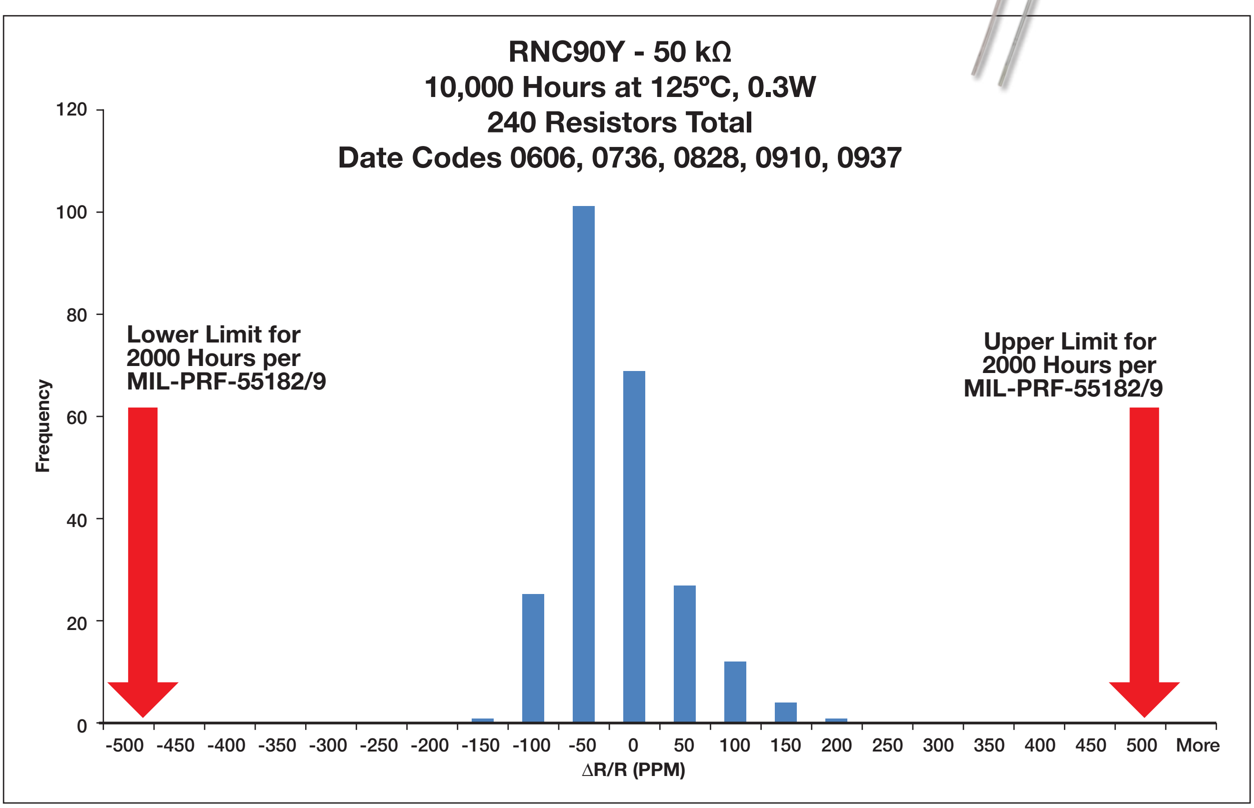
Notes

(2) Units selected randomly from lots which successfully passed the table 2A testing

(3) Optional, per customer request.

Example of Load Life Results (10,000 h)

RNC90Y is a QPL product with established reliability (ER). It meets the requirements of MIL-PRF-55182/9.



Aerospace

The demands of the aerospace segment differ from the commercial segments in one major area — ongoing reliability. In some cases, there is only one chance to complete the mission, and the system cannot be brought back into the shop for repairs. Some systems must travel deep-space for 10 years or more before being activated. Every component must activate when required and perform flawlessly to the end of the mission. This is why VFR resistors, with their long-term consistency and reliability, are the only choice for aerospace applications.

End Product

Thruster control system for satellites

Function

Voltage control

Customer Requirements

- Propulsion system must be precise due to high sensitivity of forces in anti-gravity environments
- High reliability since there will be no servicing during its lifetime
- Established reliability in previous aerospace applications

The VFR Solution

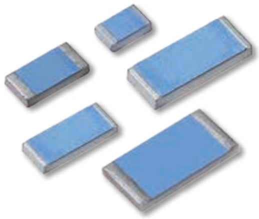
RNC90Y and RNC90Z

QPL resistors with established reliability (ER) that meet the requirements of MIL-PRF-55182/9

- The most precise and reliable resistor available, used for decades in the aerospace industry:
  - Absolute TCR for RNC90Z: 2 ppm/°C maximum at –55°C to +175°C range
  - Absolute TCR for RNC90Y: 5 ppm/°C maximum at –55°C to +125°C range;
  - 10 ppm/°C maximum at 125°C to +175°C range
  - Absolute tolerance: 0.005% (50 ppm)
  - Load-life stability: ±0.005% for 2000 h, 0.3 W and +125°C
  - Failure rate: Level R (per MIL-PRF-55182-9 and MIL-STD-690)

303134, 303135, 303136, 303137, 303138

Screen/test flow in compliance with EEE-INST-002, (Tables 2A and 3A, Film/Foil, Level 1) and MIL-PRF-55342



- Ultra high-precision surface-mount chip resistors, VSMP Z Foil technology configuration:
  - Temperature coefficient of resistance (TCR): 0.2 ppm/°C typical (–55°C to +125°C, +25°C ref.)
  - Resistance tolerance: to ±0.02%
  - Power coefficient "ΔR due to self heating": 5 ppm at rated power
  - Power rating: to 400 mW at +70°C
  - Load-life stability: ±0.03% at +70°C, 2000 h at rated power
  - Electrostatic discharge (ESD) at least to 25 kV
  - Short-time overload: 0.02%
  - Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
  - Rise time: 1 ns, effectively no ringing

VFR Resistors in Action

Audio – "Hear the Difference"

In audio systems, "high end" means faithful reproduction of the original signal and the absence of noise insertion by the electronic components — particularly the resistors. The audio discrimination level is sometimes beyond the instrument measuring capability, but nonetheless aurally detectable. VFR resistors offer the lowest noise available, and are essential components of any high-end audio system.

End Product

High-end audio preamplifier

Function

Line-level audio signal amplification

Customer Requirements

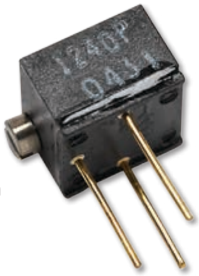
- Low-noise preamplifier for implementation into differential amplifier circuit
- Tight settability required to maintain accurate amplifier gain
- Trimmer technology, which provides consistent and reliable performance

For other recommendations for audio applications, please refer to the following resistors: VSH, S102C, Z201, Z203.

The VFR Solution

1240 Trimmer

Ultra-high-precision trimming potentiometer designed to meet or exceed the requirements of MIL-PRF-39035, Char. H, with a smooth and unidirectional output



- Current noise: 0.010 μVRMS/V of applied voltage (<–40 dB)
- Results in a high signal-to-noise ratio and a high common mode rejection ratio
- Settability: 0.05% typical; 0.1% maximum
- Setting stability: 0.1% typical; 0.5% maximum
- Trimmer design, which ensures a smooth and unidirectional output:
  - Wirewound technology exhibits a step function in response to wiper travel, while cermet technology has wide deviations in response to wiper travel
  - Only Bulk Metal Foil offers a linear and predictable response
- Immune to shock vibrations

* For further information, please see the application note Resistance Trimmers.

VAR Audio Resistor

Built on Bulk Metal Z Foil technology, with improved sound quality, the VAR provides a combination of low noise and low inductance/capacitance, making it unrivalled for applications requiring low noise and distortion-free properties.

- "Naked Z Foil resistor" design without mold or encapsulation for reduced signal distortion:
  - Temperature coefficient of resistance (TCR): ± 0.2 ppm/°C typical at –55°C to +125°C, 25°C ref.
  - Power rating: to 0.4 W at +70°C
  - Resistance tolerance: to ±0.005%
  - Load-life stability: to ±0.005% at +70°C, 2000 h at rated power
  - Non-inductive, non-capacitive design
  - Rise time: 1 ns without ringing
  - Current noise: 0.010 μVRMS/V of applied voltage (<-40 dB)
  - Thermal EMF: 0.05 μV/°C
  - Voltage coefficient: <0.1 ppm/V
  - Inductance: <0.08 μH
- Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
- Electrostatic discharge (ESD) at least to 25 kV

Automatic Test Equipment (ATE)

Automatic test equipment (ATE) performs at high speeds, reading and recording information from thousands of devices/ boards that would otherwise need to be probed by hand. Any introduction of spurious signals from the ATE machine or its components could result in failure to reject a faulty device, or conversely, cause spurious rejection of perfectly good product. If ever there was a place not to be "penny wise and pound foolish" it is in the resistor complement of an ATE. The wisest resistor choice for ATEs is a VFR resistor.

Flexible Terminations

End Product

DC test instrument

Function

Digitize an AC signal

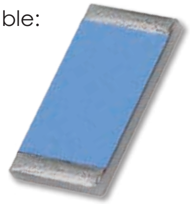
Customer Requirements

- Short-term stability
- Low sensitivity to temperature (external and internal)
- Precision required due to resource constraints
- Requires resistor of minimal size due to real estate constraints

The VFR Solution

VFCP2010 (Flip Chip with Z Foil)

Ultra-high-precision Z Foil flip chip resistor with 35% space savings vs. a wraparound design



- The most stable and precise resistor available:
  - Load-life stability: ±0.005% for 2000 h at rated power and +70°C
  - Absolute TCR: 0.2 ppm/°C typical at –55°C to +125°C range, +25°C ref.
  - Absolute tolerance: 0.01%
  - Flip chip design saves 35% more space than a wraparound design
  - Electrostatic discharge (ESD) at least to 25 kV
  - Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
  - Rise time: 1 ns, effectively no ringing

SMR1DZ/SMR3DZ (Z Foil)

Unique flexible terminations ensure minimal stress transference from the PCB due to a difference in temperature coefficient of expansions (TCE)

- Ultra-high-precision Z Foil molded surface-mount resistor:
  - Temperature coefficient of resistance (TCR): ±0.05 ppm/°C typical (0°C to +60°C) ±0.2 ppm/°C typical (-55°C to +125°C, +25°C ref.)
  - Resistance tolerance: to ±0.01%
  - Power coefficient of resistance (PCR), "ΔR due to self heating": 5 ppm at rated power
  - Load-life stability: ±0.005% (+70°C for 2,000 h at rated power)
  - Power rating: to 600 mW at +70°C
  - Matched sets with TCR tracking are available upon request
  - Electrostatic discharge (ESD) at least to 25 kV
  - Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
  - Rise time: 1 ns, effectively no ringing

VFR Resistors in Action

VISHAY FOIL RESISTORS A VPG Brand

Aviation

The electronics used in commercial avionics are exposed to dramatic temperature excursions, shock and vibration, moisture, and the test of time. In engine, cabin, and flight control applications, resistors need to maintain their values despite all of these factors. VFR resistors have a long history of applications in commercial aviation, supported by more than 30 years of load-life testing.

End Product

Aircraft engine

Function

High-temperature measurement control

Customer Requirements

- Precise voltage reference capable of measuring down to nano-volts
- Implementation into a microbridge configuration
- Must perform properly at a temperature of +80°C and power of 0.1 W

The VFR Solution

300144Z

Ultra-high-precision Z Foil voltage divider resistors

- Precise voltage divider with flexibility of use and accurate performance at high temperatures:
  - Absolute tolerance: 0.005%
  - Ratio tolerance: 0.005%
  - Absolute TCR: 0.2 ppm/°C typical at –55°C to +125°C, +25°C ref.
  - Power rating: to 0.2 W at +70°C
  - PCR: 5 ppm at rated power

303144, 303145

Screen/test flow in compliance with EEE-INST-002 (Tables 2A and 3A, Film/Foil, Level 1), MIL-PRF-55342, and MIL-PRF-49465

- Fixed resistors CSM2512 and CSM3637 for low-value current-sense resistors, providing power and precision in a four-terminal, surface-mount configuration:
  - Temperature coefficient: ±20 ppm/°C max. (–55°C to +125°C, +25°C ref.)
  - Resistance tolerance: ±0.5%
  - Four-terminal (Kelvin) design: allows for precision accurate measurements
  - Power rating: 1 W to 3 W
  - Short-time overload: ±0.1% typical
  - Thermal EMF: 3 μV/°C
  - Maximum current: up to 38 A

Check also: VFD244Z, VSH144, DSMZ, SMNZ

Cryogenics

Cryogenic applications require structural integrity capable of withstanding extreme thermal cycling without damage and without detriment to performance. VFR resistors have been used as heaters of small-mass samples and as circuit elements at cryogenic temperatures.

End Product

Liquefied natural gas transport system

Function

Temperature regulator

Customer Requirements

- Reliable performance in extremely low temperatures
- Flexibility in resistor configuration
- Use in high-humidity and high-pressure environments

The VFR Solution

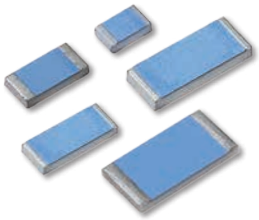
Custom-Designed Hermetically Sealed Networks

- Custom networks designed to the customer's requirements; normal values are:
  - Absolute tolerance: 0.005%
  - Tolerance match: 0.002%
  - Absolute TCR: 2 ppm/°C typical at –55°C to +125°C, +25°C ref.
  - TCR tracking: <0.5 ppm/°C
  - Hermeticity of 10-7 atmospheric cc/s: the hermetic package provides a seal around the resistive element, which protects it from the natural damage caused by moisture over time
  - Also available as DIP version

VSMP Series (0603, 0805, 1206, 1506, 2010, 2512) (Z Foil)

The VSMP Series is the industry's first device to provide high rated power, excellent load-life stability, and extremely low TCR all in one resistor

- Ultra-high-precision foil wraparound surface-mount chip resistor:
  - Temperature coefficient of resistance (TCR): 0.05 ppm/°C typical (0°C to +60°C) 0.2 ppm/°C typical (–55°C to +125°C, +25°C ref.)
  - Resistance tolerance: to ±0.01%
  - Power coefficient of resistance (PCR), "ΔR due to self heating": 5 ppm at rated power
  - Power rating: to 750 mW at +70°C
  - Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
  - Load-life stability: to ±0.005% at +70°C for 2000 h at rated power
  - Electrostatic discharge (ESD) at least to 25 kV
  - Short-time overload: ≤0.005%
  - Matched sets are available on request



VISHAY FOIL RESISTORS A VPG Brand

Down-Hole

The high temperature of down-hole applications is a huge challenge for electronic components and most resistor technologies. Temperatures upwards of +275°C are not uncommon and are even above the melting point of some solders. Thin film resistors are oxidized into oblivion by these temperatures and wirewound devices see major value shifts. Even VFR resistors cannot be exposed indefinitely to these temperatures, but the encapsulation of the foil element stands up to these environmental stresses long enough to enable down-hole measurements through dozens of deep travel cycles. The 100 times thicker resistive layer inherent in the foil resistor provides it with long-term stability in cold and hot environments and helps establish it as the preferred resistor for seismic oil exploration, as well as for down-hole applications.

End Product

Processor for motor control

Function

High-precision voltage reference

Customer Requirements

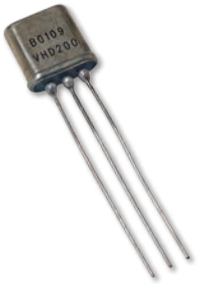
- Low noise and high common mode rejection ratio
- Long-term stability and minimal drift
- Will be used in high-humidity and high-pressure environments

The VFR Solution

VHD200

Oil-filled, hermetically sealed voltage dividers in a small package (oil-filled as standard, air-filled available upon request)

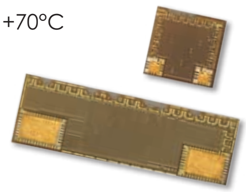
- The most precise and reliable resistor available, used for decades in the aerospace industry:
  - Absolute TCR: 2 ppm/°C typical at –55°C to +125°C, +25°C ref.
  - Foil technology, which exhibits low noise <–40 dB
  - Ratio stability: <0.001% for 2,000 h at rated power and +70°C
  - Absolute tolerance: 0.005%
  - Tolerance match: 0.001%
  - TCR tracking: 0.1 ppm/°C
  - Hermeticity of 10^{-7} atmospheric cc/s: the hermetic package provides a seal around the resistive element, which protects it from the natural damage caused by moisture over time. In addition, the VHD200 is oil-filled, which further protects the device from degradation and ensures long-term performance in any extreme environment
  - Shelf-life stability: 2 ppm for at least six years
  - Post-manufacture operations (PMO) are available for enhanced performance



V5X5Z, V15X5Z (Z Foil)

The V5X5Z and V15X5Z (Z Foil) offer an order of magnitude improvement over other chip resistors in hybrid circuits, and are also available for high-temperature applications

- Ultra-high-precision Bulk Metal Z Foil chip resistors:
  - Temperature coefficient of resistance (TCR):
    0.05 ppm/°C typical (0°C to +60°C)
    0.2 ppm/°C typical (–55°C to +125°C, +25°C ref.)
  - TCR tracking: to 0.5 ppm/°C
  - Resistance tolerance:
    Absolute to ±0.01% (user trimmable to ±0.005%)
    Match to 0.01%
  - Power rating: 50 mW to 100 mW at +70°C
  - Load-life stability: ±0.01% at +70°C for 10,000 h at rated power
  - Short-time overload: ≤0.02%
  - Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
  - Pattern design minimizing hot spots



Electron Beam

Electron beam machining is enabling a whole new range of applications, but its successful use depends on accuracy, speed, and repeatability. The resistors that drive the beam's X and Y coordinates, and which control the beam's intensity, must not add signals of their own due to temperature power fluctuations when operated as current sensor or other system fluctuations. They must also respond immediately to high-power pulse signals that drive the X/Y deflections. VFR resistors are the preferred resistive device for these applications.

End Product

Electron beam microscope

Function

Focusing mechanism

Customer Requirements

- High power rating and working voltage capacity
- Resistance of approximately 1 MΩ required
- Extreme precision and reliability

The VFR Solution

VHA518-11Z

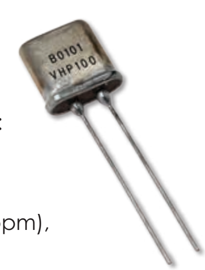
Oil-filled, hermetically sealed ultra-precision resistors; 11 resistor chips in series (Z Foil)

- A robust design for the most accurate performance:
  - Power rating: 1.2 W to 2.5 W at +25°C
  - Maximum voltage capacity: 600 V
  - Resistance range: 5 Ω to 1.1 MΩ
  - Absolute tolerance: 0.001%
  - Absolute TCR: 0.2 ppm/°C typical at –55°C to +125°C, +25°C ref.
  - Load-life stability: ±0.002% for 2,000 h at rated power and +25 °C
  - Hermeticity of 10^{-7} atmospheric cc/s: the hermetic package provides a seal around the resistive element, which protects it from the natural damage caused by moisture over time. In addition, the VHA518 is oil-filled, which further protects the device from degradation and ensures long-term performance in any extreme environment

Vishay Foil Resistors' H and HZ Series of Bulk Metal® Foil Resistors Selected for Electronic Design's Annual "Top 101 Components"

VHP100

Ultra-high-precision, hermetically sealed Bulk Metal Foil resistor with zero TCR; no humidity within a unique construction; minimizes the effects of stress factors; offers a total error budget of 2 ppm drift



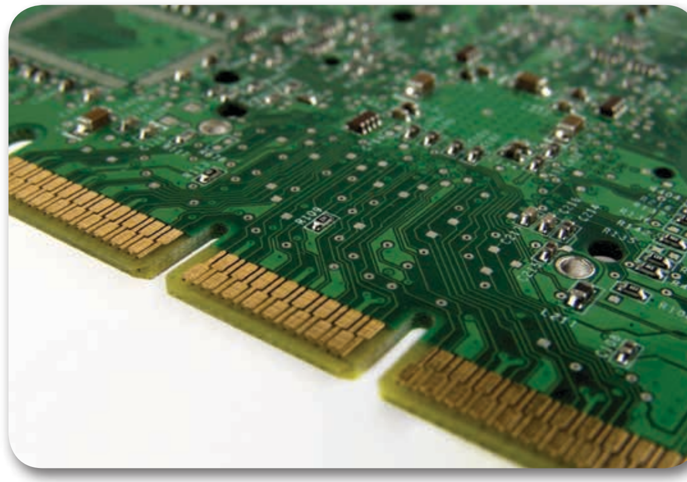
- Oil-filled, hermetically sealed resistor:
  - Essentially zero TCR
  - Absolute resistance change (window):
VHP100 <60 ppm (–55°C to +125°C)
VHP101 <10 ppm (+15°C to +45°C)
  - Resistance tolerance: to ±0.005% (50 ppm), available to ±0.001% (10 ppm)
  - No humidity effect: hermetically sealed against moisture
  - Load-life stability: ±50 ppm typical for 2,000 h at +70°C and rated power
  - Shelf-life stability: ±2 ppm typical after at least six years
  - Current noise: 0.010 µVRMS/V of applied voltage (<–40 dB)
  - Thermal EMF: 0.05 µV/°C typical
  - Oil-filled as standard, air-filled available upon request

Vishay Foil Resistors' New-Generation, Ultra-Precision VHP100 Bulk Metal® Foil Resistor Wins Product of the Year Award from Electronic Products Magazine

VFR Resistors in Action

Industrial

Industrial systems sometimes favor price over quality when it comes to electronic components, but when all factors are taken into consideration, quality resistors turn out to be the least expensive solution. In the long run, a reliable and stable resistor costs less than one that must be replaced or that requires additional circuitry to compensate for lack of precision. Factor in warranty repair expense, downtime in the hands of the customer, and transportation costs for repairs, and the "savings" from using second-rate resistors quickly disappear. Even when an assumed or measured returns rate is applied, the VFR resistor turns out to be the most economical solution.



End Product

High-voltage electrical circuit breaker

Function

Precision measurement control

Customer Requirements

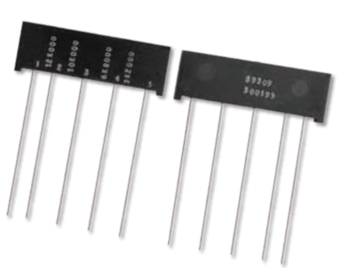
- Network with specific configuration
- Precise measurements are necessary to ensure the safety of the circuit and the proper trigger for the circuit breaker
- Performance should be reliable within the temperature range of –40°C to 70°C
- Must endure both sporadic and continuous short-time overload

The VFR Solution

300193Z

Ultra-high-precision Z Foil voltage divider and network resistor; three resistor chips, two configured as a voltage divider and the other as an individual resistor

- Precise voltage divider offering flexibility and accurate performance at high temperatures:
  - Ratio tolerance: 0.005%
  - Absolute tolerance: 0.005%
  - TCR tracking: 0.5 ppm/°C
  - Absolute TCR: 2 ppm/°C typical at -55°C to 125°C range, +25°C ref.
  - Short-time overload: 0.002%
  - Thermal stabilization time < 1 s (nominal value achieved within 10 ppm of steady-state value)



DSMZ (Z Foil)

The DSMZ surface-mount voltage divider provides a matched pair of Bulk Metal Z Foil resistors in a small epoxy molded package. The electrical specifications of this integrated construction offer improved performance and better real estate utilization over discrete resistors and matched pairs

- Ultra-high-precision Bulk Metal Z Foil surface-mount voltage divider:
  - Temperature coefficient of resistance (TCR):
    ±0.05 ppm/°C typ. (0°C to +60°C)
    ±0.2 ppm/°C typ. (-55°C to +125°C, +25°C ref.)
  - TCR tracking: 0.1 ppm/°C typical
  - Resistance tolerance:
    Absolute ±0.02%
    Match 0.01%
  - Power rating at 70°C:
    Entire package 0.1 W
    Each resistor 0.05 W
  - Ratio stability: 0.005% (0.05 W at +70°C for 2000 h)
  - Short-time overload: 0.005%
  - Non-inductive, non-capacitive design
  - Rise time: 1 ns, effectively no ringing

VFR Resistors in Action

Laboratory and Metrology

In lab and metrology applications, the only appropriate resistors are those that will retain their initial value over time. Hermetic packaging is a must since every laboratory will have some humidity fluctuations. Additional essentials include stability under temperature fluctuations, no thermally active junctions, and a low temperature coefficient of resistance. Only one resistor combines all of these characteristics: Bulk Metal Foil resistors.

End Product

Real-time hydrogen-specific process monitor

Function

Hydrogen gas measurement

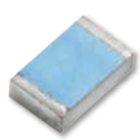
Customer Requirements

- Reliable performance for real-time accuracy
- High-speed response capabilities to detect instantaneous changes in environment
- Low TCR and low PCR specifications

The VFR Solution

VSMP0603 (Z Foil)

Ultra-high-precision foil wraparound surface-mount chip resistor (Z Foil)



- Reliable, high-speed performance for real-time measurements:
  - Load-life stability: ±0.005% for 2000 h at rated power and +70°C
  - Absolute TCR: 0.2 ppm/°C typical at –55°C to +125°C range
  - Power coefficient of resistance (PCR), "ΔR due to self heating": 5 ppm at rated power
  - Absolute tolerance: 0.01%
  - Rise time: 1 ns, effectively no ringing
  - Electrostatic discharge (ESD) at least to 25 kV
  - Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady state value)
  - Voltage coefficient: <0.1 ppm/V
  - Non-inductive: <0.08 µH

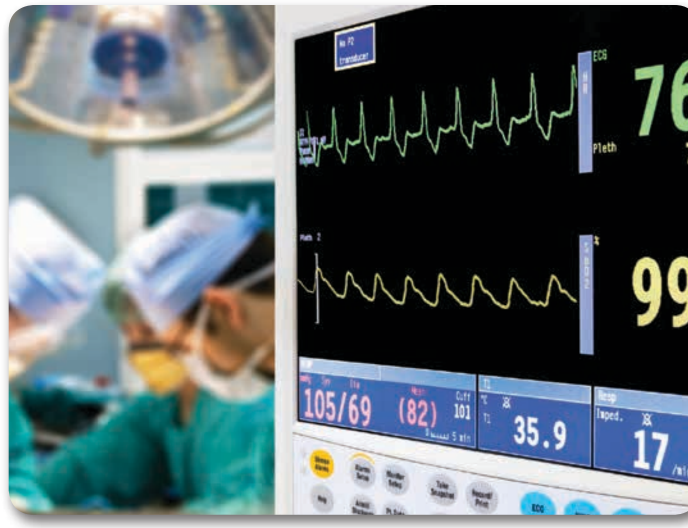
VHP203 (Z Foil)

The oil acts as a thermal conductor to eliminate the long-term degradation of unsealed resistor elements, while at the same time allowing the device to accept short periods of overload without degradation.

- Hermetically sealed miniature ultra-high-precision Z Foil technology resistors:
  - Temperature coefficient of resistance (TCR): ±0.05 ppm/°C (0°C to +60°C)
  - Resistance tolerance: to ±0.001% (10 ppm)
  - Load-life stability: ±0.002% maximum ΔR (+60°C for 2000 h at 0.1 W per chip)
  - Electrostatic discharge (ESD) up to 25 kV
  - Power rating: to 0.3 W at +25°C
  - Shelf-life stability: 2 ppm for at least six years
  - Current noise: 0.010 µVRMS/V of applied voltage (<–40 dB)
  - Thermal EMF: 0.05 µV/°C typical
  - Voltage coefficient: <0.1 ppm/V
  - Non inductive: <0.08 µH

Medical

Accurate and stable instrumentation in the medical field requires the ability to detect very small signals without producing false readings. For the complement of resistors surrounding the operational amplifier and anywhere else resistors are needed in medical applications, VFR resistors are the preferred choice.



End Product

Fluid injector device

Function

Current sensing for motor control

Customer Requirements

- Reliable measurements of motor control are necessary to perform injections at the precise location
- High-speed response necessary to perform given task
- Low sensitivity to short-time overload
- Surface-mount to preserve limited real estate
- Four-pad Kelvin connection desired as a way to improve accuracy

The VFR Solution

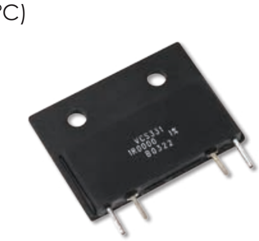
VCS1625ZP (Z Foil)

Ultra high-precision Z Foil surface-mount current-sensing chip resistor

- High-performance current sensing:
  - Load-life stability: 0.02% at 70°C, 2000h at rated power
  - Absolute tolerance: 0.2%
  - Absolute TCR: 0.05 ppm/°C typical at 0°C to +60°C range
  - Power coefficient of resistance (PCR), "ΔR due to self heating": 5 ppm at rated power
  - Rise time: 1 ns, effectively no ringing
  - Short time overload: <0.005%
  - Standard Kelvin connection configuration

VCS331Z, VCS332Z (Z Foil)

High-precision four-terminal power current-sensing resistors. When mounted on a heatsink, the devices can sustain10 W continuously without an appreciable change in resistance



- Four-terminal power current-sensing resistors:
  - Low temperature coefficient of resistance: 0.05 ppm/°C typical (0°C to +60°C)
  - Resistance tolerance: to ±0.01%
  - Rapid ΔR stabilization under transient loads
  - Tenfold improvement of power coefficient of resistance (PCR): 4 ppm/W
  - Thermal resistance: 6°C/W
  - Rise time: 1 ns, effectively no ringing
  - Power rating:
To 10 W on heatsink at +25°C
3 W in free air at +25°C
  - Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)
  - Load-life stability:
±0.005% (50 ppm), 3 W on heatsink at +25°C for 2,000 h
±0.01% (100 ppm), 3 W in free air at +25°C for 2,000 h

Military

VFR resistors have been used for more than 40 years in military equipment, even before a suitable MIL specification was established. In the late 60s, MIL-PRF-55182 was established and the RNC90 style was applied to the VFR resistors. Testing to the "R" failure rate was conducted and the devices have been used continuously ever since. Today, VFR resistors are serving in every category of military equipment that relies on electronics for its functionality.

End Product

High-power pulse radio frequency transmitter

Function

Signal generator and feedback

Customer Requirements

- Real-time measurement capabilities
- Accurate digital-to-analog conversion capabilities
- High-speed response necessary to perform given task
- Able to withstand electrostatic discharges (ESD)
- High stability
- End-of-life tolerance: <0.1%

The VFR Solution

Z201 (Z Foil)

High-precision foil resistor

- The most reliable resistor for tasks that have no margin for error:
  - Temperature coefficient of resistance (TCR): ±0.2 ppm/°C typical (–55°C to +125°C, +25°C ref.)
  - Resistance tolerance: to ±0.005%
  - Load-life stability: to ±0.005% at 70°C for 2000 h at rated power
  - Electrostatic discharge (ESD) at least to 25 kV
  - Non-inductive, non-capacitive design
  - Rise time: 1 ns, without ringing
  - Current noise: 0.010 μVRMS/volt of applied voltage (<–40 dB)
  - Thermal EMF: 0.05 μV/°C

1445Q and 1446Q (QPL)

These networks are qualified to MIL-PRF-83401, characteristic C, schematic A, (Qualified Parts List - QPL). Actual performance exceeds all the requirements of MIL-PRF-83401, characteristic C

- QPL networks:
  - Hermetically sealed for maximum environmental protection – 100% leak protection
  - Gross leak: no bubbles
  - Fine leak: <5x10^{-7} cc/sec
  - Tested per MIL-PRF-83401
  - Ceramic package: 94% alumina (Al2O3)
  - Lid: gold-plated Kovar
  - Solder: tin/gold
  - Leads: alloy 42 (iron nickel) with 100 μ inches gold plating (MIL-STD-1276, type G-21-A)
  - Gold ball wire bonding
  - Foil chips V15X5

Precision Instrumentation

Whether they are used in the guidance system of a cruise missile, the autopilot of an airplane, or the remote responder of a weather station, VFR resistors are consistently the best choice for precision instrumentation because of their initial accuracy and long-term stability.

End Product

Chromatography data system validation instrument

Function

Unity gain inverting amplifiers and summing amplifiers

Customer Requirements

- TCR tracking and a tight tolerance ratio is essential for gain control
- Long-term stability and low drift are required for consistent performance
- Low-noise capabilities will not interfere with signal measurements

The VFR Solution

SMNZ (Z Foil)

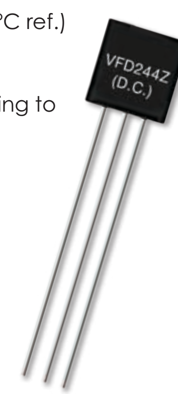
Ultra-high-precision Z Foil surface-mount, four-resistor network dual-in-line package

- The most precise network package for amplifier applications:
  - Absolute TCR: 0.2 ppm/°C typical at –55°C to 125°C range
  - TCR tracking: 0.1 ppm/°C typical at –55°C to +125°C range
  - Tolerance matching: 0.01%
  - Ratio stability: 0.005% for 2,000 h at rated power and +70°C
  - Power coefficient of resistance (PCR), "ΔR due to self heating": ±5 ppm at rated power
  - Current noise: 0.010 µVRMS/V of applied voltage (<–40 dB)
  - Electrostatic discharge (ESD) at least to 25 kV

VFD244Z (Z Foil)

Voltage divider with excellent initial resistance and ratio matching, tracking in operation, and fast response without ringing

- Bulk Metal Foil ultra-high-precision Z Foil voltage divider:
  - Temperature coefficient of resistance (TCR): ±0.05 ppm/°C typical (0°C to +60°C) ±0.2 ppm/°C typical (–55°C to +125°C, +25°C ref.)
  - TCR tracking: 0.1 ppm/°C typical
  - Resistance tolerance: absolute and matching to 0.005% (50 ppm)
  - Power rating: up to 1 W at 70°C
  - Load-life ratio stability: <0.005% (50 ppm) at 1 W and +70°C for 2000 h
  - Maximum working voltage: 350 V
  - Rise time: 1 ns, effectively no ringing
  - Current noise: 0.010 µVRMS/V of applied voltage (<–40 dB)
  - Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady-state value)



Weighing Scales

Whatever they're weighing, whether it's gems or pharmaceuticals, scales must be accurate day in and day out. Some are in harsh environments while others are in laboratories. But regardless of the application, accuracy and consistency are the prime targets. For nearly 50 years, VFR resistors have been key components in weighing systems, and they continue to serve this important sector today.

End Product

Weighing scale

Function

Current cense and voltage reference

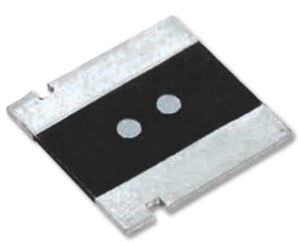
Customer Requirements

- High-precision measurement capabilities
- Accurate digital-to-analog conversion capabilities
- Low noise for best performance

The VFR Solution

CSM3637S

Bulk Metal Foil high-precision, current-sensing, power surface-mount metal strip resistor that meets the requirements of MIL-PRF-49465B



- The most precise and reliable resistor available:
  - Absolute tolerance: 0.2%
  - Absolute TCR: 20 ppm/°C maximum at –55°C to +125°C, +25°C ref.
  - Power rating: 2 W
  - Load-life stability: ±0.05% for 2,000 h at rated power and +70°C
  - Thermal EMF: <3 μV/°C

CSM2512S

Bulk Metal Foil high-precision, surface-mount resistor with four-terminal (Kelvin) design, which allows precise and accurate measurements with improved stability

- Current-sensing, power surface-mount metal strip resistor:
  - Temperature coefficient of resistance (TCR): ±15 ppm/°C maximum (–55°C to +125°C, +25°C ref.)
  - Load-life stability to ±0.05% (70°C for 2,000 h at rated power)
  - Power rating: 1 W
  - Resistance tolerance: ±0.1%
  - Short-time overload: ±0.1% typical
  - Thermal EMF: <3 μV/°C
  - Maximum current: up to 10 A

Check also: CSM3637Z, CSM3637P, CSM3637, CSM2512

VFR Resistors in Action

Rapid Prototype Sample Services

At VFR, we are dedicated to promoting successful relationships with all of our customers. One of the ways we help speed your time to market is by making prototype parts available quickly per request (via our field design engineers, see Contacts).

The prototype sample parts delivered by VFR's Fastlane Services are the same parts as produced in our standard production, ensuring they have all the features and benefits of foil technology:

- Temperature coefficient of resistance (TCR): ±0.2 ppm/°C (–55°C to +125°C, +25°C ref.)
- Resistance tolerance (absolute and match): to ±0.001%
- Load-life stability: ±0.005% typical after 2,000 h at 70°C and 0.3 W
- VFR resistors are not restricted to standard values; specific “as-required” values can be supplied at no extra cost or delivery (e.g. 1.00025 kΩ vs. 1 kΩ)
- Electrostatic discharge (ESD): at least to 25 kV
- Thermal EMF: 0.05 μV/°C
- Pattern design minimizing hot spots
- Matched sets with TCR tracking are available upon request
- Resistors for high-temperature applications (to +240°C)

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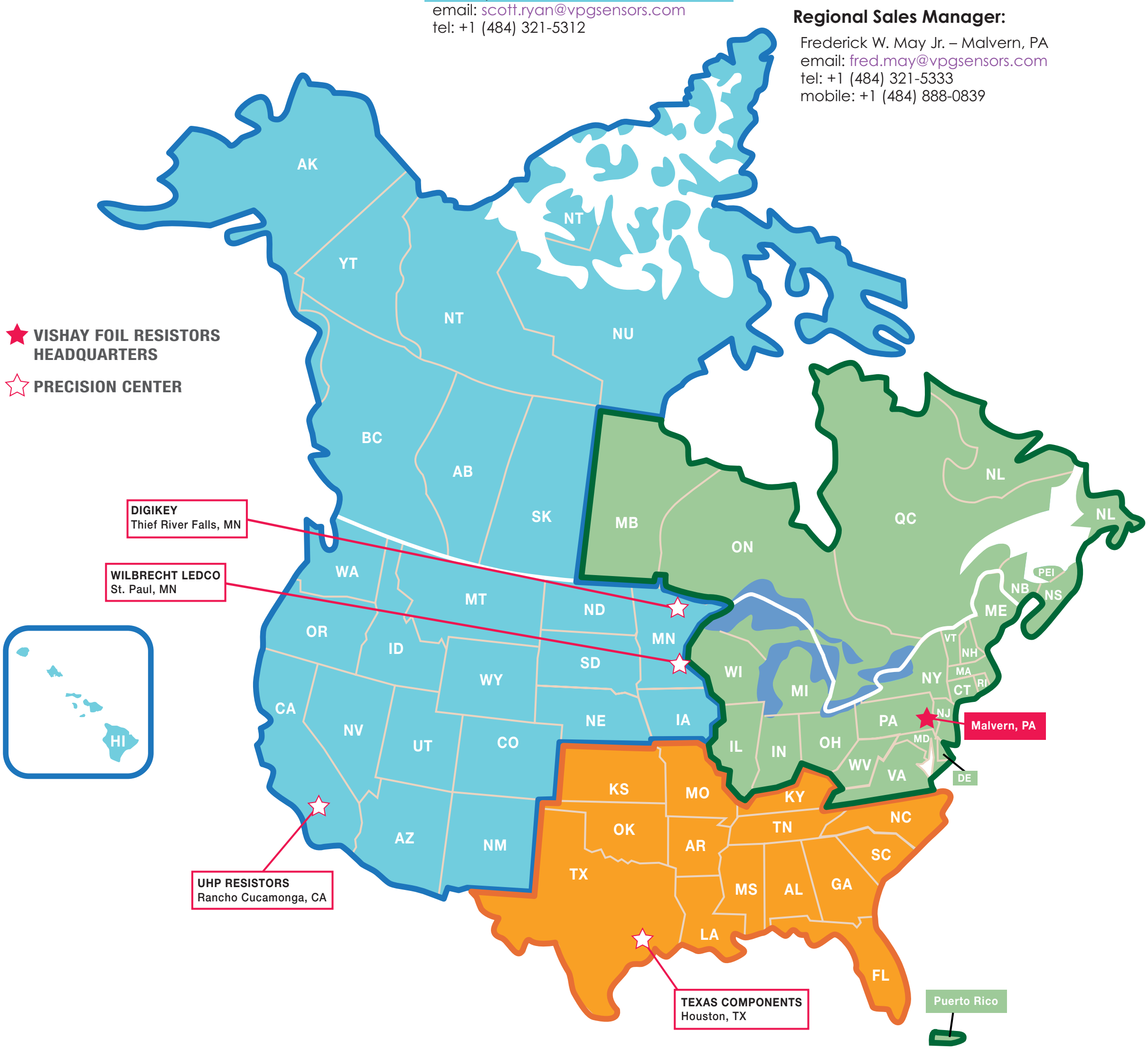

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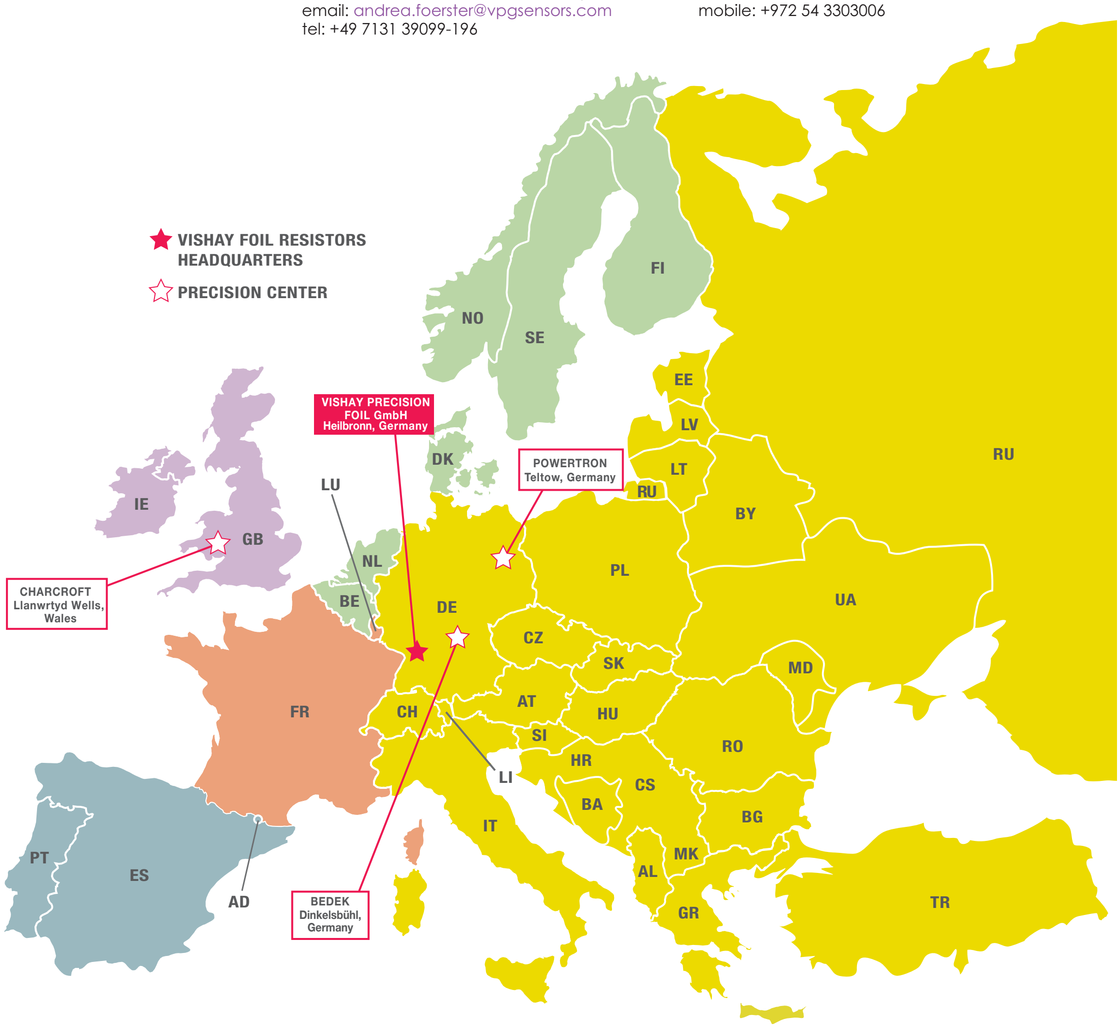

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