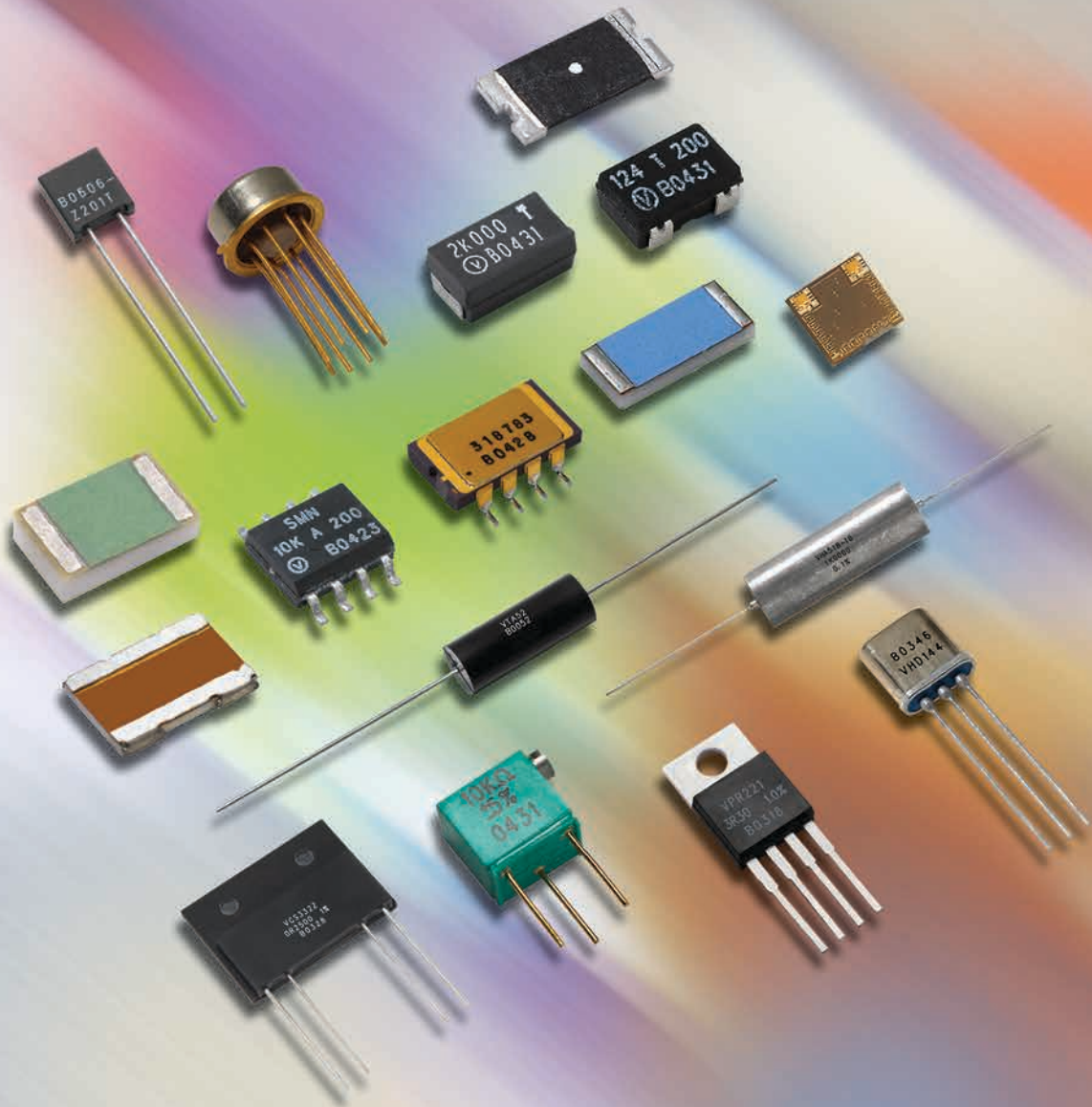


# VFR Resistors in Action

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



## 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

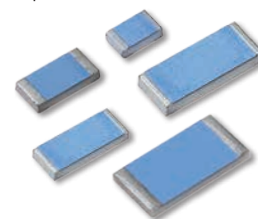
- The most precise and reliable resistor available, used for decades in the aerospace industry:
  - Absolute TCR for RNC90Z: 2 ppm/°C maximum at –55°C to +175°C range
  - Absolute TCR for RNC90Y: 5 ppm/°C maximum at –55°C to +125°C range;
  - 10 ppm/°C maximum at 125°C to +175°C range
  - Absolute tolerance: 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



## 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

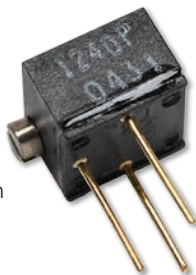
- Low-noise preamplifier for implementation into differential amplifier circuit
- Tight settability required to maintain accurate amplifier gain
- Trimmer technology, which provides consistent and reliable performance

### 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  $\mu\text{VRMS/V}$  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.



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

#### 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):  $\pm 0.2$  ppm/ $^{\circ}\text{C}$  typical at  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ,  $25^{\circ}\text{C}$  ref.
  - Power rating: to 0.4 W at  $+70^{\circ}\text{C}$
  - Resistance tolerance: to  $\pm 0.005\%$
  - Load-life stability: to  $\pm 0.005\%$  at  $+70^{\circ}\text{C}$ , 2000 h at rated power
  - Non-inductive, non-capacitive design
  - Rise time: 1 ns without ringing
  - Current noise: 0.010  $\mu\text{VRMS/V}$  of applied voltage ( $<-40$  dB)
  - Thermal EMF: 0.05  $\mu\text{V}/^{\circ}\text{C}$
  - Voltage coefficient:  $<0.1$  ppm/V
  - Inductance:  $<0.08$   $\mu\text{H}$
- 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.

### End Product

DC test instrument

### Function

Digitize an AC signal

### Customer Requirements

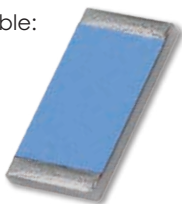
- Short-term stability
- Low sensitivity to temperature (external and internal)
- Precision required due to resource constraints
- Requires resistor of minimal size due to real estate constraints

## The VFR Solution

### VFPC2010 (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:  $\pm 0.005\%$  for 2000 h at rated power and  $+70^{\circ}\text{C}$
  - Absolute TCR: 0.2 ppm/ $^{\circ}\text{C}$  typical at  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  range,  $+25^{\circ}\text{C}$  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):  $\pm 0.05$  ppm/ $^{\circ}\text{C}$  typical ( $0^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$ )  
 $\pm 0.2$  ppm/ $^{\circ}\text{C}$  typical ( $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ,  $+25^{\circ}\text{C}$  ref.)
  - Resistance tolerance: to  $\pm 0.01\%$
  - Power coefficient of resistance (PCR), “ $\Delta R$  due to self heating”:  
5 ppm at rated power
  - Load-life stability:  $\pm 0.005\%$  ( $+70^{\circ}\text{C}$  for 2,000 h at rated power)
  - Power rating: to 600 mW at  $+70^{\circ}\text{C}$
  - 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



Flexible Terminations

## 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:  $\pm 20$  ppm/°C max. (-55°C to +125°C, +25°C ref.)
  - Resistance tolerance:  $\pm 0.5\%$
  - Four-terminal (Kelvin) design: allows for precision accurate measurements
  - Power rating: 1 W to 3 W
  - Short-time overload:  $\pm 0.1\%$  typical
  - Thermal EMF: 3  $\mu$ V/°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

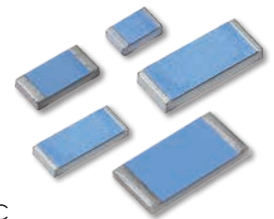
- Custom networks designed to the customer's requirements; normal values are:
  - Absolute tolerance: 0.005%
  - Tolerance match: 0.002%
  - Absolute TCR: 2 ppm/°C typical at -55°C to +125°C, +25°C ref.
  - TCR tracking: <0.5 ppm/°C
  - Hermeticity of 10<sup>-7</sup> atmospheric cc/s: the hermetic package 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



## 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)*

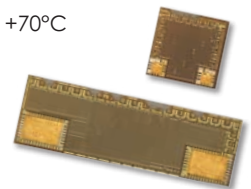
- The most precise and reliable resistor available, used for decades in the aerospace industry:
  - Absolute TCR: 2 ppm/°C typical at -55°C to +125°C, +25°C ref.
  - Foil technology, which exhibits low noise <-40 dB
  - Ratio stability: <0.001% for 2,000 h at rated power and +70°C
  - Absolute tolerance: 0.005%
  - Tolerance match: 0.001%
  - TCR tracking: 0.1 ppm/°C
  - Hermeticity of 10<sup>-7</sup> 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 M $\Omega$  required
- Extreme precision and reliability

## The VFR Solution

### VHA518-11Z

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

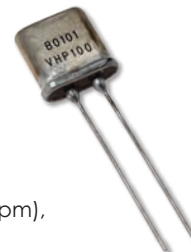
- A robust design for the most accurate performance:
  - Power rating: 1.2 W to 2.5 W at +25°C
  - Maximum voltage capacity: 600 V
  - Resistance range: 5  $\Omega$  to 1.1 M $\Omega$
  - Absolute tolerance: 0.001%
  - Absolute TCR: 0.2 ppm/°C typical at -55°C to +125°C, +25°C ref.
  - Load-life stability:  $\pm 0.002\%$  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



### 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  $\pm 0.005\%$  (50 ppm), available to  $\pm 0.001\%$  (10 ppm)
  - No humidity effect: hermetically sealed against moisture
  - Load-life stability:  $\pm 50$  ppm typical for 2,000 h at +70°C and rated power
  - Shelf-life stability:  $\pm 2$  ppm typical after at least six years
  - Current noise: 0.010  $\mu\text{VRMS}/\text{V}$  of applied voltage (<-40 dB)
  - Thermal EMF: 0.05  $\mu\text{V}/\text{°C}$  typical
  - Oil-filled as standard, air-filled available upon request



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



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



## 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

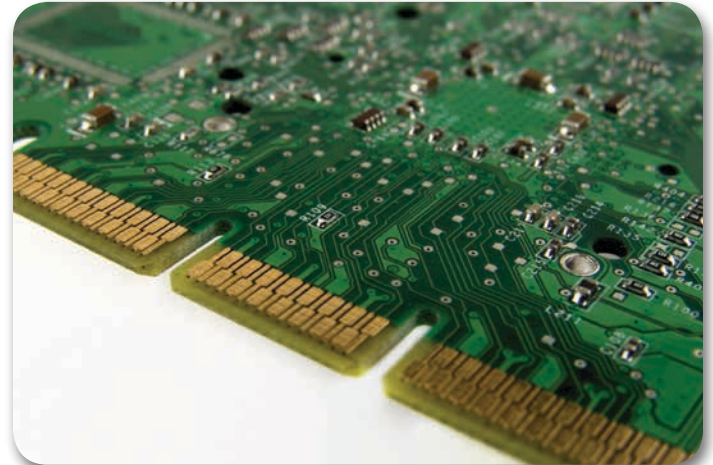
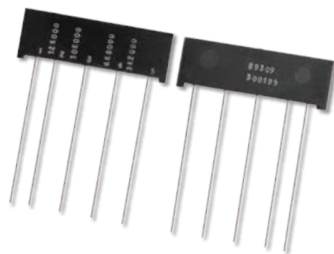
- Network with specific configuration
- Precise measurements are necessary to ensure the safety of the circuit and the proper trigger for the circuit breaker
- Performance should be reliable within the temperature range of  $-40^{\circ}\text{C}$  to  $70^{\circ}\text{C}$
- Must endure both sporadic and 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/ $^{\circ}\text{C}$
  - Absolute TCR: 2 ppm/ $^{\circ}\text{C}$  typical at  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  range,  $+25^{\circ}\text{C}$  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):  $\pm 0.05$  ppm/ $^{\circ}\text{C}$  typ. ( $0^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$ )  
 $\pm 0.2$  ppm/ $^{\circ}\text{C}$  typ. ( $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ,  $+25^{\circ}\text{C}$  ref.)
  - TCR tracking: 0.1 ppm/ $^{\circ}\text{C}$  typical
  - Resistance tolerance: Absolute  $\pm 0.02\%$   
Match 0.01%
  - Power rating at  $70^{\circ}\text{C}$ : Entire package 0.1 W  
Each resistor 0.05 W
  - Ratio stability: 0.005% (0.05 W at  $+70^{\circ}\text{C}$  for 2000 h)
  - Short-time overload: 0.005%
  - Non-inductive, non-capacitive design
  - Rise time: 1 ns, effectively no ringing



## 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

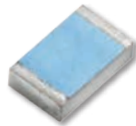
- Reliable performance for real-time accuracy
- High-speed response capabilities to detect instantaneous changes in environment
- Low TCR and low PCR specifications

## The VFR Solution

### VSMPO603 (Z Foil)

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

- Reliable, high-speed performance for real-time measurements:
  - Load-life stability:  $\pm 0.005\%$  for 2000 h at rated power and  $+70^{\circ}\text{C}$
  - Absolute TCR: 0.2 ppm/ $^{\circ}\text{C}$  typical at  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  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):  $\pm 0.05$  ppm/ $^{\circ}\text{C}$  ( $0^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$ )
  - Resistance tolerance: to  $\pm 0.001\%$  (10 ppm)
  - Load-life stability:  $\pm 0.002\%$  maximum ΔR ( $+60^{\circ}\text{C}$  for 2000 h at 0.1 W per chip)
  - Electrostatic discharge (ESD) up to 25 kV
  - Power rating: to 0.3 W at  $+25^{\circ}\text{C}$
  - 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/ $^{\circ}\text{C}$  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 sustain 10 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

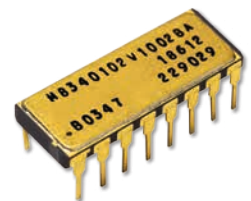
- The most reliable resistor for tasks that have no margin for error:
  - Temperature coefficient of resistance (TCR):  $\pm 0.2$  ppm/ $^{\circ}\text{C}$  typical ( $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ,  $+25^{\circ}\text{C}$  ref.)
  - Resistance tolerance: to  $\pm 0.005\%$
  - Load-life stability: to  $\pm 0.005\%$  at  $70^{\circ}\text{C}$  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  $\mu\text{VRMS}$ /volt of applied voltage ( $<-40$  dB)
  - Thermal EMF: 0.05  $\mu\text{V}/^{\circ}\text{C}$



### 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:  $<5 \times 10^{-7}$  cc/sec
  - Tested per MIL-PRF-83401
  - Ceramic package: 94% alumina ( $\text{Al}_2\text{O}_3$ )
  - Lid: gold-plated Kovar
  - Solder: tin/gold
  - Leads: alloy 42 (iron nickel) with 100  $\mu$  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 sense and voltage reference

### Customer Requirements

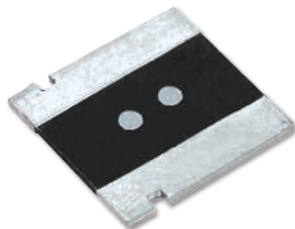
- High-precision measurement capabilities
- Accurate digital-to-analog conversion capabilities
- Low noise for best performance

### 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