

Authors: Yuval Hernik, Hero Faienstein & Yosi Tzabari

Tel: +972-3-557-0852

E-mail: Yuval.Hernik@vishaypg.com;

Hero.Faienstein@vishaypg.com & Yosi.Tzabari@vishaypg.com

What do Precision Resistors, Advanced Medical Applications, and the Baby Boom Generation All Have in Common?

Introduction:

With an ever-increasing demand for new ultrasounds, medical imaging, and surgical equipment, in addition to biotech and biomedical technologies, the medical industry is a significant growth engine for precision resistors. One of the latest and fastest-growing trends in the medical industry is home-based healthcare technologies, such as patient monitoring systems. This trend is being driven in large part by the aging baby boomer generation, many of whom now require home care.

With the increasing focus on home-based applications, we are seeing an increase in the computing power of medical devices, in addition to the miniaturization of their electronic components. These advances enable smaller, more mechanically simple, and increasingly powerful designs that at the same time are highly reliable and stable. The miniaturization of their electronic components also allows for greater portability and accessibility – key factors in home-based applications, and instrumental to the success of worldwide medical initiatives such as telemedicine and body area networks.

With higher levels of automation, newer portable devices are also less complicated to operate than their predecessors. In the near future, the skill-set required to use these devices may be reduced to the point where they could become mainstay tools of the trade for every medical practitioner. However, while providing many advantages, the miniaturization of electronic components within medical devices also raises some potential design challenges, making it especially difficult for design engineers when choosing a precision resistor.

Performance, long-term stability, precise control, and safety are critical factors for every medical application. Unfortunately, for designers of medical equipment, there are some trade-offs that must be considered when designing front-end circuits for these devices. Performance parameters in the front-end circuit components affect diagnostic performance, just as system configuration and objectives can affect the choice of a precision resistor.

It is essential for designers to understand the specifications and requirements that are of particular importance to their application, their effect on system performance, and how they are affected by integrated circuit (IC) design trade-offs — in terms of integration and passive components. Taking these considerations

Vishay Precision Group

3 Great Valley Parkway, Suite 150 • Malvern, PA • USA • Phone +1-484-321-5300 • Fax +1-484-321-5301

into account will help the designer to achieve the most advantageous system partitioning and reduce the chance of any surprises down the road.

Other important design considerations in medical equipment include providing immunity to single-event upsets in electronics, such as radiation from oncology equipment, and damage caused by electrostatic discharge (ESD). Designers sometimes discount the effects of ESD damage in the erroneous belief that only active components are sensitive to it, or that damaged resistors can simply be culled from the lot or detected and removed after being installed in equipment.

In reality, ESD in some resistors can result in latent or hidden damage that does not show up until the units cause catastrophic system failures in the field. It is important to consider this matter before choosing a resistor, especially when the product will be used at home or on the go.

Vishay Foil Resistors' (VFR) Bulk Metal® Foil resistors are immune to upsets such as radiation, eliminating any need for redundancy, and withstands ESD spikes at least to 25 kV. VFR's Bulk Metal Foil technology includes many types of resistors with a variety of standard configurations that can withstand unconventional environments. A number of Foil resistor configurations and chip packages, from the 0603 wrap-around size and up, are available – providing an array of power ratings, resistance values, and other operating specifications to meet the stability and reliability needs of medical applications.

The stability of a resistor depends primarily on its temperature, which is affected by changes in the ambient temperature and heat from adjacent components (defined by the temperature coefficient of resistance, or TCR); and self-heating as a result of load (defined by the power coefficient of resistance, or Power TCR, which is ΔR due to self-heating). These performance characteristics are particularly important in medical instrumentation and equipment, where Bulk Metal Foil resistors deliver proven reliability and stable performance, even when exposed to unstable levels of temperature and humidity or other harsh environmental conditions. Furthermore, Foil resistors also feature a non-inductive ($<0.08 \mu\text{H}$) and non-capacitive design.

VFR's long track record of success in medical applications and its long-term commitment to the medical and military markets, which share a significant overlap, have made Bulk Metal Foil the preferred resistor for applications including non-invasive equipment; diagnostic, imaging, and laboratory equipment; patient monitoring systems; instrumentation; and pharmaceutical delivery and dispensing systems.

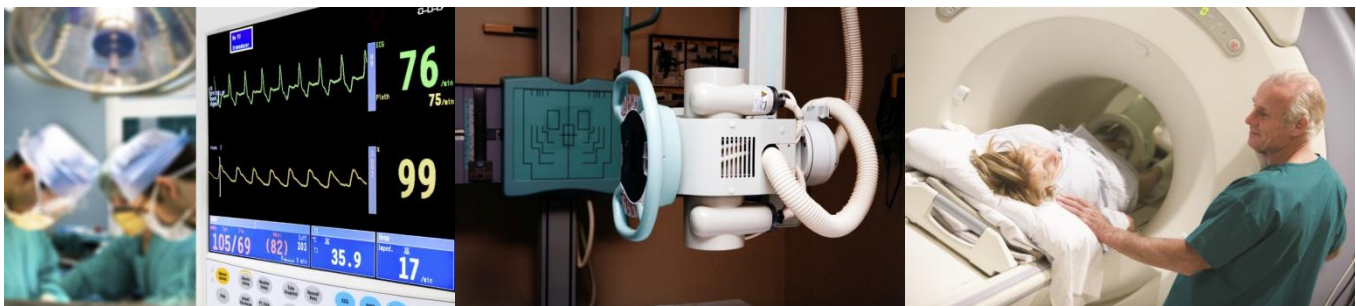
There is a growing trend toward joint research among resistor manufacturers and medical hardware specialists to develop new systems that meet medical market requirements as well as stable resistors that will be less sensitive to ESD (especially for latent effects), surges, and temperature variations.

As a leading supplier to the worldwide medical market, Vishay Foil Resistors has produced a steady stream of breakthroughs in component technology, including new Z- and Z1-Foil resistors that provide a temperature coefficient of $\pm 0.2 \text{ ppm}/^\circ\text{C}$ and a power coefficient (or Power TCR) of 5 ppm at rated power, which is a ten-fold improvement over standard thin film resistors. The Z- and Z1-Foil technologies are the ideal solutions to meet the demand for medical products that consume less power, require smaller components for portability, and provide high performance. Many medical applications require custom or semi-custom component solutions, which VFR is capable of producing in its ISO-9001-certified manufacturing facility.

In 2011, the demand for all types of medical devices continues to rise dramatically above the expectations. Several factors contribute to the increased demand: an aging population that continues to grow, improved healthcare and coverage worldwide – especially in the industrialized world – and advancements in resistor

technologies that have led to the development of new solutions engineered to deliver better care. As medical technology continues to advance in amazing ways that make our lives smarter and more dynamic, the capabilities of portable devices continues to grow.

Newly developed medical devices are considered among the most sophisticated signal processing machines in widespread use today. As in any complex and challenging application, there are many trade-offs in implementation due to performance requirements, physics, and cost. Some system-level understanding about the function of precision resistors and the differences in resistor technologies is necessary to fully appreciate and choose the desired front-end IC functions and performance levels, especially when amplifiers are involved, such as low-noise amplifiers (LNA); time gain compensation amplifiers (TGC); and analog-to-digital converters (ADC).

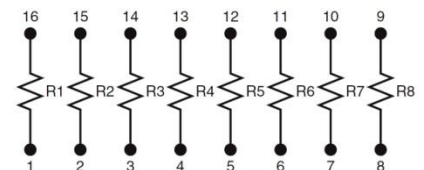


Following are a few examples demonstrating the use of Bulk Metal Foil resistors in medical applications.

1. End Product – Cardiac Mapping System, Real-Time Display of Heart Electrical Activity

Customer Schematic/Specifications

- Resistance value: 10 kΩ per resistor
- Absolute tolerance: 0.005% (50 ppm)
- Ratio tolerance: 0.005% among R1 through R4 and R5 through R8
- Absolute TCR (temperature coefficient of resistance): 1 ppm/°C maximum (0°C to +50°C)
- TCR tracking: 0.5 ppm/°C among R1 through R4 and R5 through R8
- High ratio stability under working conditions

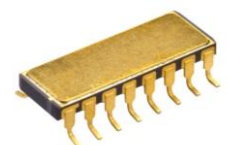


The Vishay Foil Resistors Solution

VSM46

Hermetically sealed, high-precision, 16-terminal network in a gull wing configuration.

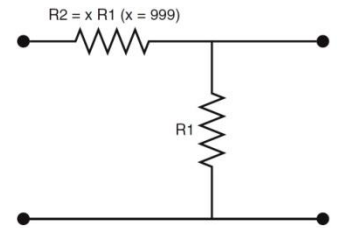
- Offers the best combination of tracking under power and temperature during service life
- The common behavior of all resistors mounted into the same hermetic package contributes to the excellent load life and ratio stability
- Saves mounting time and real estate on PCB instead of using discrete resistors
- Datasheet: <http://www.vishaypg.com/foil-resistors/list/product-63029/>



2. End Product – Tomography Control of Magnetic Field Activity

Customer Schematic/Specifications

- Ultra precision attenuator with very high ohmic value ratio: 1:1000
- $R1 < 25 \Omega$; $R2 = 999 R1$
- Ratio definition: $R1$ to $(R1 + R2)$
- Initial attenuation accuracy: 0.003 %
- Total attenuation of ratio: (TCR + Shift under Load): 0.005 % after 2000 hours

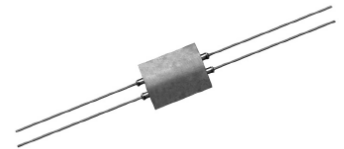


The Vishay Foil Resistors Solution

VHA512Z

Hermetically sealed, oil filled, network 4 Terminals Using Z-Foil Technology

- Custom design with stabilization
- High ratio stability: 0.005 % under working conditions and ambient temperature variations
- Absolute TCR of 1 ppm/°C (10°C to +45°C)
- Shelf life drifts < 2 ppm after 6 years
- Datasheet: <http://www.vishaypg.com/foil-resistors/list/product-63120/>



3. End Product – Miniature Sensors with 3D Medical Imaging for Precise Diagnostics and Surgery

Customer Schematic/Specifications

- Resistance value: 0.2 Ω
- Absolute tolerance: <0.5%
- End-of-life tolerance: <1%
- Absolute TCR: <5 ppm/°C (+30°C to +50°C)
- Working power: 1 W
- Power TCR: <5 ppm at rated power
- Low excess noise

The Vishay Foil Resistors Solution

VCS1625ZP

Ultra-precision surface-mount current sensing chip resistor in a 4-terminal design with power to 1 W

- A compact SMD size with Kelvin connections
- TCR: 4 ppm/°C (+30°C to +50°C)
- Power TCR: <5 ppm at rated power
- Tight tolerance: 0.1%
- Thermal EMF: <0.1 $\mu V/^\circ C$
- Thermal stabilization time: <1 s (nominal value achieved within 10 ppm of steady state value)
- Datasheet: <http://www.vishaypg.com/foil-resistors/list/product-63155/>



4. End Product – Motor Control

The long-term stability and precision requirements of motor-driven medical equipment lend themselves to component technologies with a history of high reliability. These products are subjected to a large volume of tests in order to assure their compliance with all the required approval agencies (i.e. FDA, UL, and CE), which can be very expensive. Once the units are tested and they comply, manufacturers are not always allowed to change a component in the circuit without going through the testing process again.

Some of these agencies require that the equipment be recalibrated on a recurring schedule to ensure its accuracy and compliance. This process can be time-consuming and costly as well. In applications with motor-driven devices, there is a control circuit that probably contains a current sense resistor for control of motor speed and torque. With their load-life stability and precision, Bulk Metal Foil resistors have long been at the top of the industry for their ability to hold the initial tolerance.

Customer Schematic/Specifications

- Flexible terminations to ensure minimal stress transference
- Resistance values: 120 Ω and 350 Ω
- Absolute tolerance: 0.01%
- Working power: 200 mW
- Absolute TCR: <3 ppm/ $^{\circ}$ C (-10 $^{\circ}$ C to +50 $^{\circ}$ C)
- End-of-life tolerance: <0.1%
- Improved load-life stability: <0.05% for 2000 hours under rated power
- Low inductance and capacitance
- Fast response time <1 ns effectively no ringing

The Vishay Foil Resistors Solution

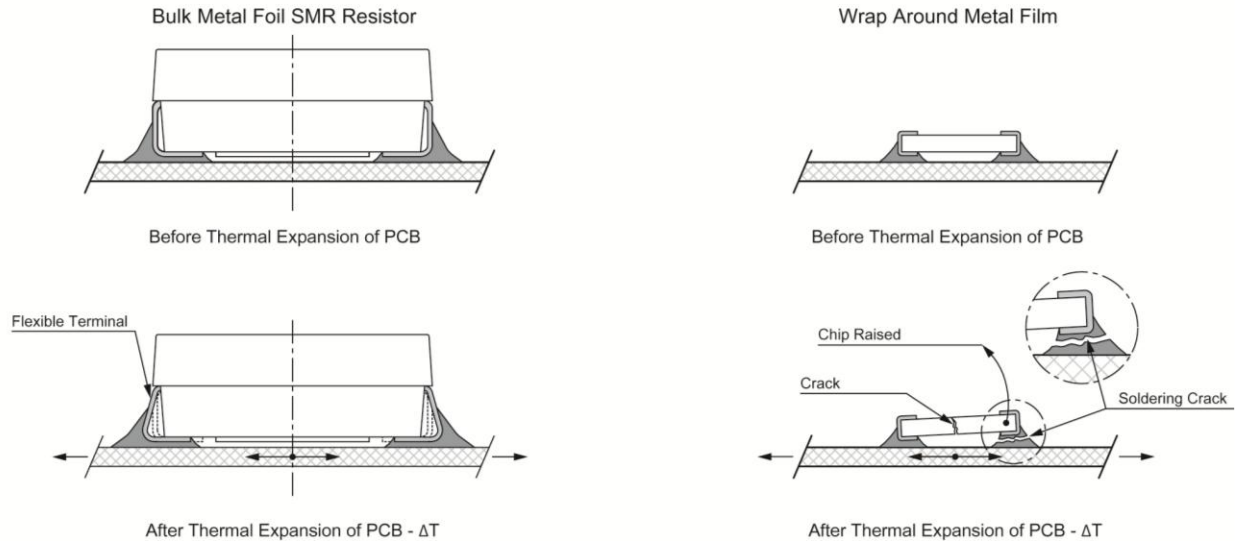
SMR3DZ

New Z-Foil ultra-high-precision wrap-around chip resistor for improved load-life stability and flexible terminations to ensure minimal stress transference from the PCB due to load-induced temperature gradients and a difference in thermal coefficient of expansions (TCE)

- Flexible terminations ensure minimal stress transference from the PCB due to a difference in thermal coefficient of expansion (TCE)
- TCR: 2 ppm/ $^{\circ}$ C maximum (-10 $^{\circ}$ C to +50 $^{\circ}$ C)
- Power TCR : 5 ppm at rated power
- Tight tolerance: 0.01%
- Load-life stability: \pm 0.005%, 2000 hours at working power
- Rise time <1 ns (without ringing)
- End-of-life tolerance: <0.1%
- Datasheet: <http://www.vishaypg.com/foil-resistors/list/product-63118/>



SMRxDZ Flexible Termination - Thermal Expansion Effect



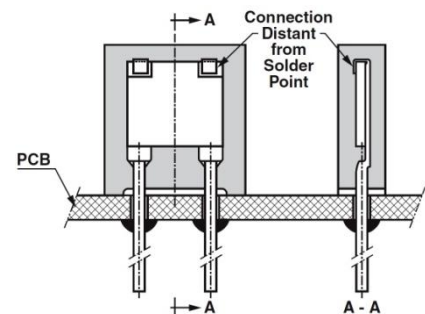
Note:

It is well known that chip sizes of 1206 and larger occasionally delaminate from the printed circuit board or develop cracks. This is due to stresses introduced into the chip by handling of the PC board and stress due to thermal shock. Vishay Foil Resistors has introduced a chip in a molded package with flexible terminations that does not change due to the above, e.g. no cracks and no separation from the board.

5. End Product – LED Driver for Oxygen Sensor

Customer Schematic/Specifications

- High stability with varying currents
- Leaded configuration (more robust for stress than SMD)
- Small third harmonic effect: The effect of the third harmonic is very critical as it confuses the signal
- Resistance value: 120 Ω
- Absolute tolerance: 0.05%
- Absolute TCR: <1 ppm/ $^{\circ}\text{C}$ (+18 $^{\circ}\text{C}$ to +45 $^{\circ}\text{C}$)
- ESD >10 kV
- Low sensitivity for self heating



The Vishay Foil Resistors Solution

Z203

Z1-Foil ultra-high-precision resistor for improved load-life stability

- Temperature coefficient of resistance (TCR): 0.5 ppm/°C maximum (+18°C to +45°C)
- Power TCR: 5 ppm at rated power
- Tight tolerance: 0.05%
- Load-life stability: to $\pm 0.005\%$ (50 ppm) at 70°C, 10,000 hours at 0.15 W
- Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady state value)
- Low sensitivity for self heating
- Electrostatic discharge (ESD) at least to 25,000 V
- Voltage coefficient: <0.1 ppm/V
- Datasheet: <http://www.vishaypg.com/foil-resistors/list/product-63186/>



6. End Product – Acoustic (Ultra-Sonic) Microscopes for Bio-Medical Analysis

Customer Schematic/Specifications

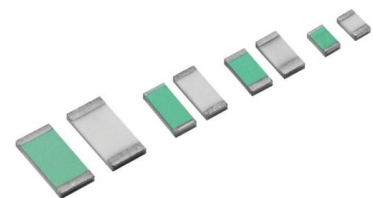
The customer required a surface-mount resistor with fast response time, high-frequency capability, and low total error budget (improved load-life stability)

The Vishay Foil Resistors Solution

FRSM0805

The customer tested the Z1-Foil FRSM0805 with 1.345 k Ω resistance and a frequency analyzer above 500 MHz, and found that the FRSM0805 has a better frequency performance than the standard thick film resistor at the same size.

- 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.)
- Load-life stability:
 $\pm 0.0025\%$ at 70 °C, 2,000 hours at rated power
 $\pm 0.005\%$ at 70 °C, 10,000 hours at rated power
- Thermal stabilization time <1 s (nominal value achieved within 10 ppm of steady state value)
- Electrostatic discharge (ESD) at least to 25 kV
- Short-time overload: 0.005%
- Rise time: 1 ns with effectively no ringing
- Current noise: 0.010 μ VRMS/V of applied voltage (< - 40 dB)
- Voltage coefficient: 0.1 ppm/V
- Non inductive: 0.08 μ H
- Datasheet: <http://www.vishaypg.com/foil-resistors/list/product-63209/>



7. End Product – Re-Design Infusion Equipment Test Device

Customer Schematic/Specifications

- Trimmer with a resistance value of 10 k Ω
- The customer replaced cermet with Foil technology for better adjustability (less time to adjust) and improved linearity
- The engineer had to solve problems related to the step function of the output, long setting time, and shock/vibration effects of the trimmer value

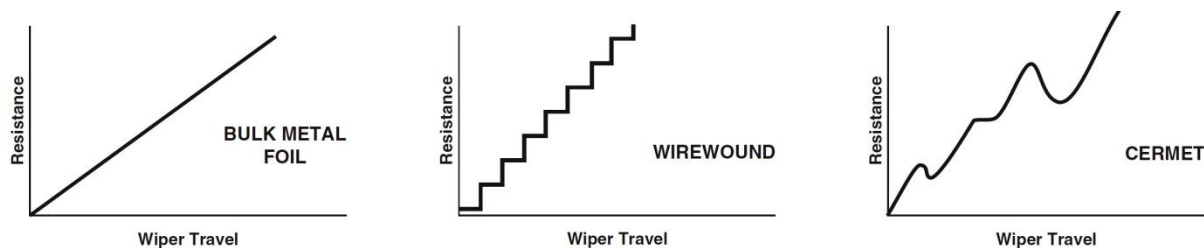
The Vishay Foil Resistors Solution:

1260W

1260W precision trimming potentiometer with a 10 k Ω resistance and 5% tolerance



- Temperature coefficient of resistance (TCR): ± 10 ppm/ $^{\circ}\text{C}$ (-55°C to $+150^{\circ}\text{C}$, ref. at $+25^{\circ}\text{C}$); through the wiper: ± 25 ppm/ $^{\circ}\text{C}$
- A smooth and unidirectional resistance change with lead screw adjustment
- Load-life stability: 0.1% typical ΔR , 1.0% maximum ΔR under full rated power at $+85^{\circ}\text{C}$ for 10,000 hours
- Settability: 0.05% typical; 0.1% maximum
- Setting stability: 0.1% typical; 0.5% maximum
- Power rating: 0.25 W at $+85^{\circ}\text{C}$
- Resistance range: 5 Ω to 10 k Ω
- Resistance tolerance: $\pm 5\%$, $\pm 10\%$
- "O"-ring prevents ingress of fluids during any board cleaning operation
- Electrostatic discharge (ESD) at least to 25,000 V
- Datasheet: <http://www.vishaypg.com/foil-resistors/list/product-63054/>



8. End Product – Furnaces Control Units for Medical

Customer Schematic/Specifications

The project requires a long-term stable reference resistor for PT100 and PT1000 with very low TCR (temperature range 0°C to +50°C).

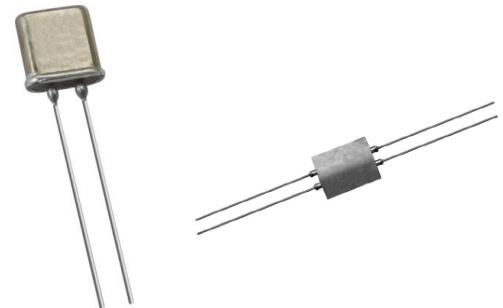
The Vishay Foil Resistors Solution

VHP101; VHA512

The best choice for this application is VHP101 (1 kΩ and higher) and VHA512 4-terminal (<1 kΩ) resistors with additional stabilization (PMO).

The following resistance values are required:

- 15 Ω, 0.01% (VHA512 4-terminal)
- 100 Ω, 0.005% (VHA512 4-terminal)
- 200 Ω, 0.005% (VHA512 4-terminal)
- 390 Ω, 0.005% (VHA512 4-terminal)
- 1 kΩ, 0.001% (VHP101)
- 2 kΩ, 0.001% (VHP101)
- 3.9 kΩ, 0.001% (VHP101)
- Datasheet (VHP101): <http://www.vishaypg.com/foil-resistors/list/product-63003/>
- Datasheet (VHA512): <http://www.vishaypg.com/foil-resistors/list/product-63006/>



9. End Product – Intravascular Cooling System

Customer Schematic/Specifications

- The intravascular cooling system treats patient hypothermia with a metalized heat-exchange catheter that adjusts the temperature of the blood.
- The customer required a resistor that can withstand a Human Body Model ESD discharge of >4 kV (HBM is modeled on a 100 pF capacitor charged to 4 kV with a 1.5 kΩ resistor in a series).

The Vishay Foil Resistors Solution

VSMP Series

Ultra-high-precision Z-Foil wraparound surface-mount chip resistor

- The circuit uses the VSMP0603 2.0 kΩ, VSMP0603 5.11 kΩ, VSMP1206 15.0 kΩ, and VSMP2512 90.9 kΩ resistors
- Absolute tolerance: 0.01%
- Enables temperature measurement and control to within 0.05°F
- Temperature coefficient of resistance (TCR): 0.05 ppm/°C typical (0°C to +60°C)
- Electrostatic discharge (ESD) at least to 25,000 V
- Load-life stability: to ±0.005% at 70°C, 2,000 hours at rated power
- Datasheet: <http://www.vishaypg.com/foil-resistors/list/product-63141/>



10. End Product – X-Ray Generator for CT System

Customer schematic/Specifications

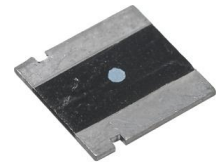
- Measure applied currents to monitor the equipment
- Ohmic value: 0.025 Ω
- Ambient temperature: 20°C to 35°C
- Absolute tolerance <0.25%
- Absolute TCR: <10 ppm/°C maximum

The Vishay Foil Resistors Solution

CSM3637Z (New)

Ultra-high-precision Bulk Metal Foil current sensing, surface-mount resistor

- A compact SMD size
- TCR: 5 ppm/°C
- Power rating: to 3 W
- Load-life stability to $\pm 0.2\%$ (70°C, 2,000 hours at rated power)
- Tight tolerance: 0.1%
- Low thermal EMF: <3 $\mu\text{V}/^\circ\text{C}$ (DC offset error, significant for low values)
- Proprietary processing technique produces extremely low resistance values with improved stability
- Datasheet: <http://www.vishaypg.com/foil-resistors/list/product-63208/>



Samples and production quantities of the Foil resistors are available now, with lead times of five days for prototype samples and from two days to five weeks for standard orders at the catalogue houses (depending on their shelf availability).

Further information about other Vishay Foil Resistors products is available at www.vishayfoilresistors.com. Follow Vishay Foil Resistors at <http://twitter.com/FoilResistor>.