

Bulk Metal[®] Foil Resistors

Military and Space Applications



Stress Measurements



Process Control



Hospital Patient Bed Weighing



Precision Navigation Systems



Axle Overload Protection

Military and Space

- Military and space applications have reliability requirements that exceed the standard processes of electronic component manufacturing
- MIL style 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 is ensured



Military and Space

- Different qualification conformance inspection plans are applicable depending on the application, ranging from a **DSCC** specification, up to a MIL spec 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

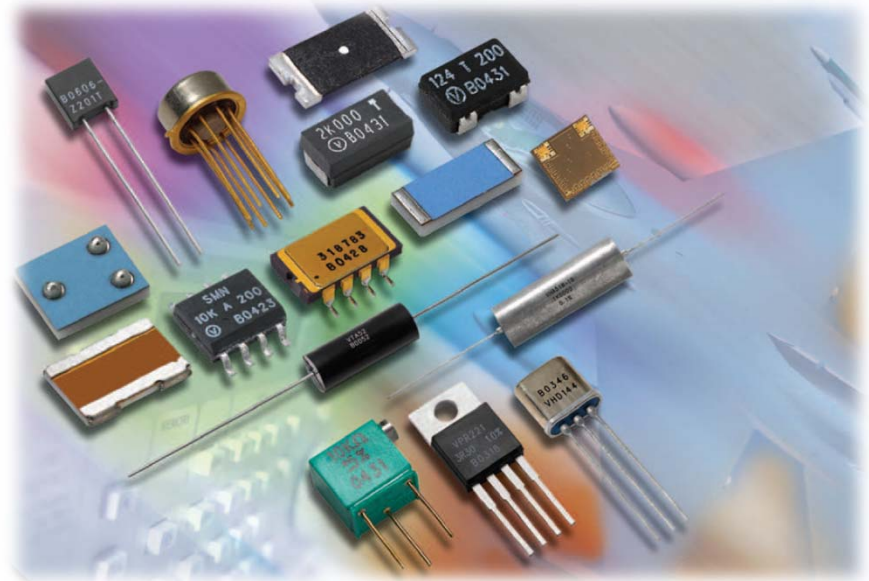


Key Parameters of Resistors

- Temperature Coefficient of Resistance
- Initial Tolerance
- **Electrostatic Discharge (ESD)**
- **Total Error Budget**
- Reliability
- Long Term Stability (Load life & Shelf Life)
- Thermal Noise and Current Noise
- Inductance and Capacitance
- Power Coefficient of Resistance

Main Resistor Technologies

- Bulk Metal[®] Foil
(Classical, Z-Foil and Z1-Foil)
- Wirewound
- Thin Film

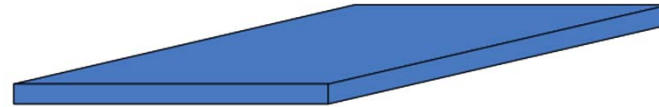


Vishay Foil Resistors

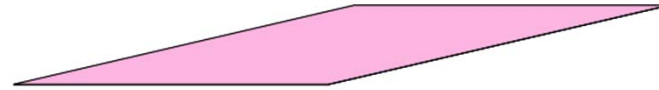
- The Bulk Metal Foil resistor is based on a special concept where a proprietary bulk metal cold-rolled Foil is cemented to a ceramic substrate.
- It is then photo-etched into a resistive pattern and trimmed using a ladder-rung technique to within very tight tolerances of the nominal value.
- Because the resistive metal used is not drawn, wound or mechanically stressed in any way during manufacturing process, the Bulk Metal Foil resistor maintains all its design, physical and electrical characteristics while winding of wire, or sputtering of thin films, or thick film glazing do not.

Foil Resistor Basic Construction Concept

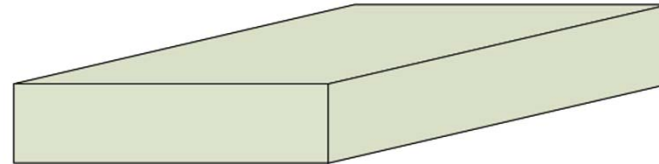
Bulk Metal[®] Foil



Adhesive



Ceramic Substrate



TCR Concept

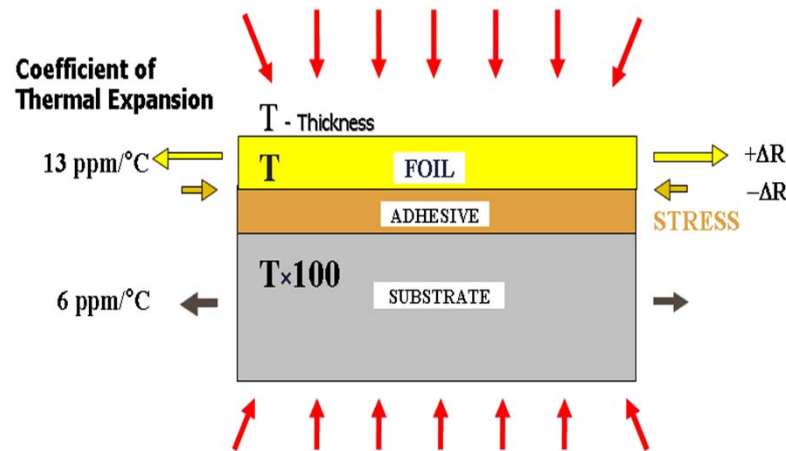
- Theoretical Background
 - The resistor's TCR is defined, in units of ppm/°C, as:

$$TCR = \frac{\Delta R}{R_{ref} \Delta T}$$

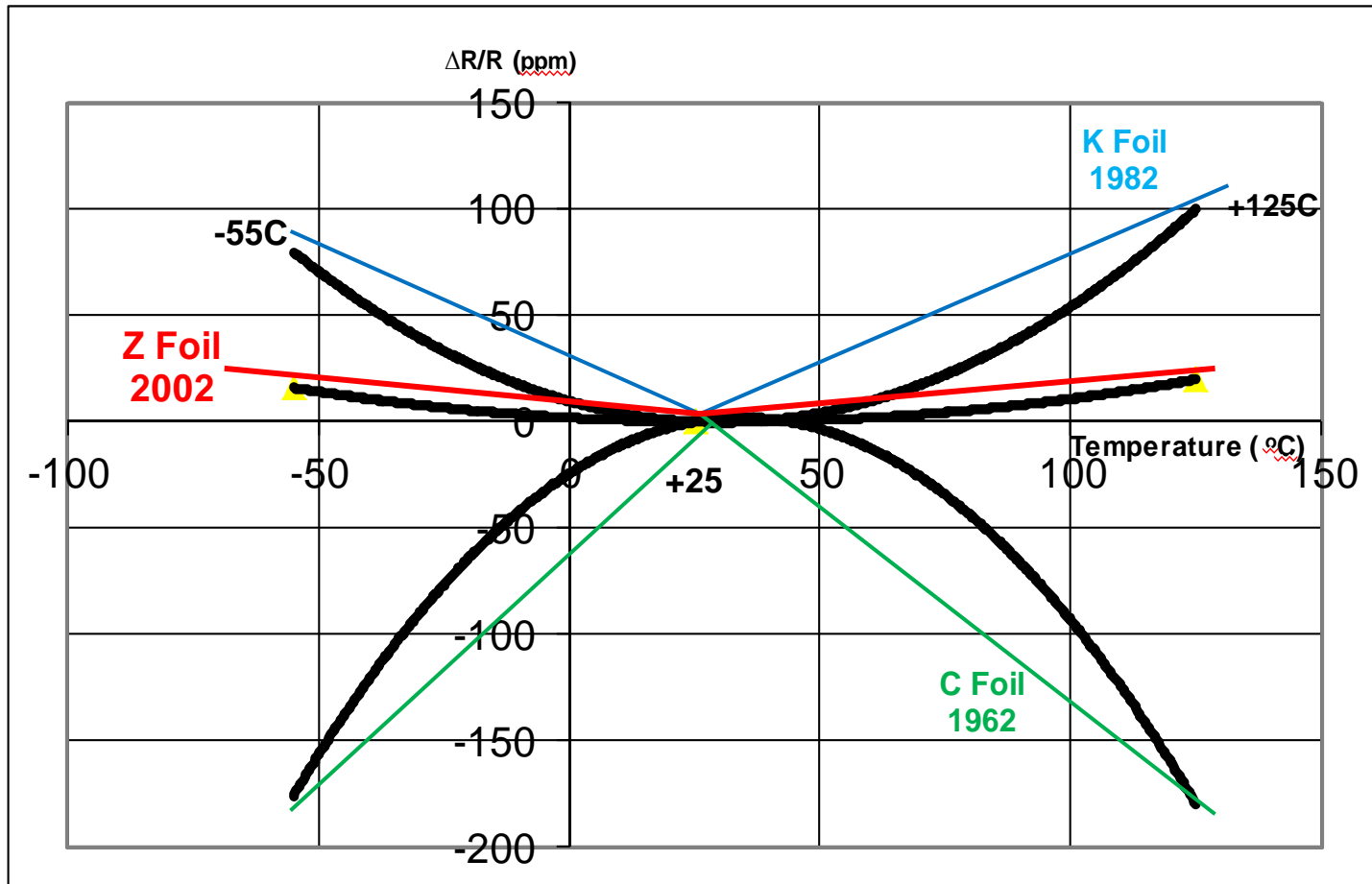
- It is a figure of merit for the resistor's temperature stability
- Foil resistors achieve maximum stability and near-Zero TCR
- This uniform performance is built-in for every unit, and does not depend on screening or other artificial means

TCR Concept

- The TCR of the Foil resistor is achieved by matching two opposing effects: the inherent increase in resistance due to temperature increase vs. the compression-related decrease in resistance due to that same temperature increase
- The two effects occur simultaneously resulting in an unusually low, predictable, repeatable, and controllable TCR

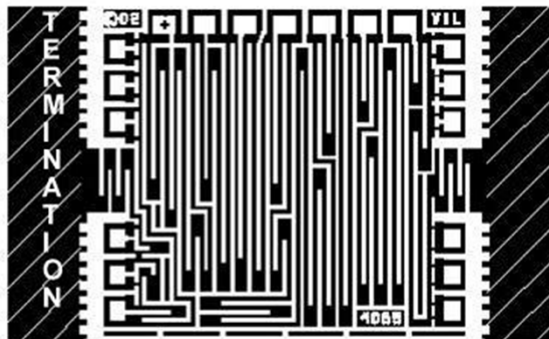


The Foil Development Over the Years

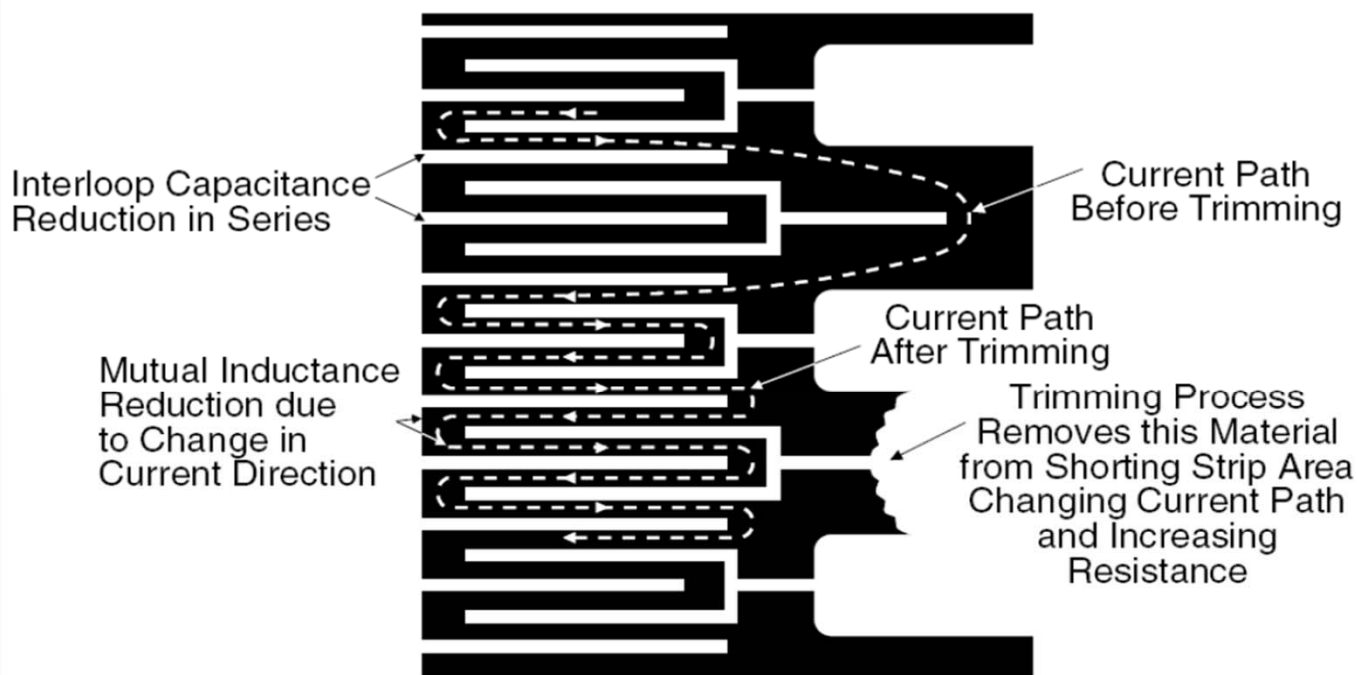


Trimming

- Trimming operations increase resistance in precise steps but from remote locations so that the etched grid in the active area remains reliable with no hot spots (caused by current density around the laser's trim kerf as in other technologies) and, most importantly, noise-free
- The resistive pattern also minimizes inductance and capacitance



“Ladder Rung” Trimming Technique



NOTE: Foil shown in black, etched spaces in white

ESD

- 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
- Different resistor technologies exhibit various levels of sensitivity to ESD damage
- Damage to an ESD-sensitive device depends on the device's ability to dissipate energy and withstand the energy of the voltage levels involved, and is generally exhibited by a change in the electrical resistance of the device
- This is especially crucial in devices which require high precision and reliability

ESD

- The superiority of Bulk Metal[®] foil precision resistors over thin film, when subjected to ESD, is a consequence of 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
- Tests have indicated that foil chip resistors can **withstand ESD events at least to 25,000 V** (data available), while Thin Film 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)

Total Error Budget

- This term refers to the allowed deviation due to several stress factors, such as **TCR** and **Load life**, initial tolerance, resistance to soldering heat, moisture, and so forth
- It is generally calculated according to:

$$TEB = \sum_{i=1}^n \sqrt{(\Delta R_1)^2 + (\Delta R_2)^2 + \dots + (\Delta R_n)^2}$$

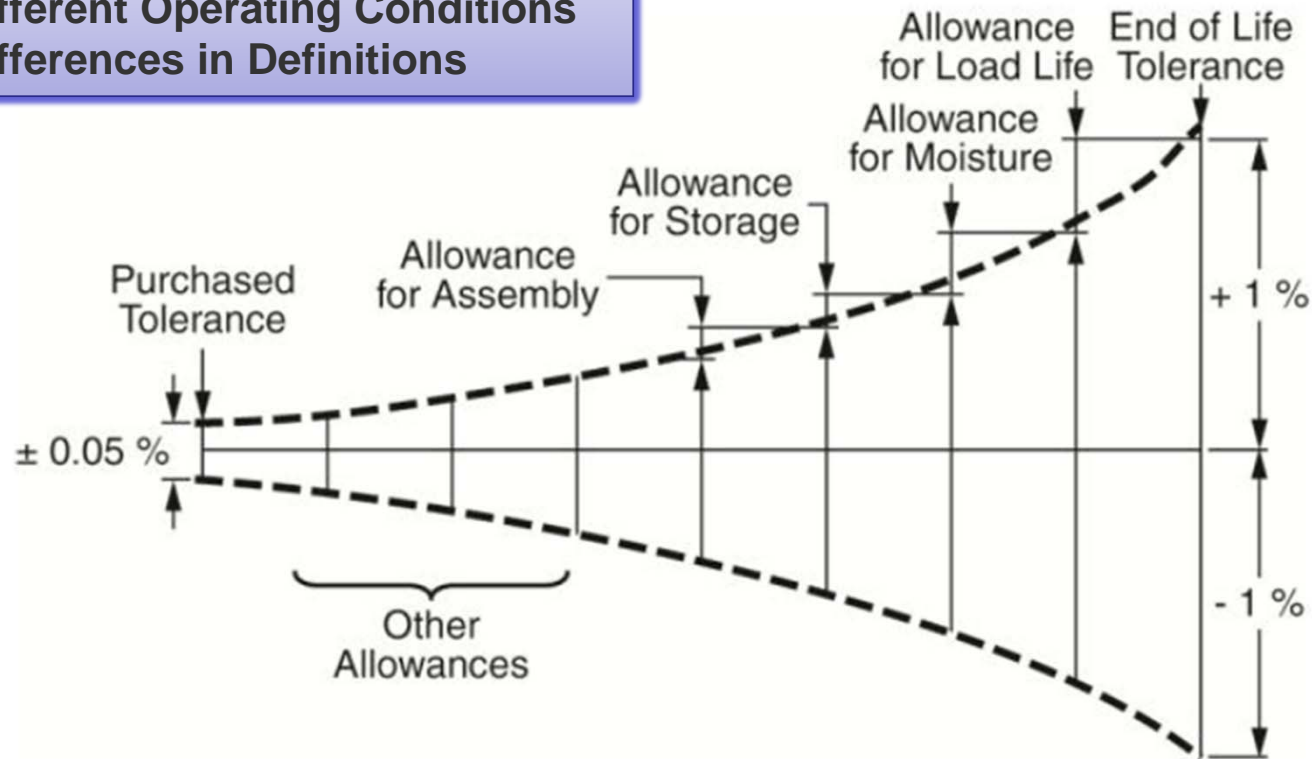
where ΔR_i refers to resistance deviation due to certain stress factors

Comments relating to TORs

(Technical Operating Requirement)

End-Of-Life Tolerance

1. Different Technologies
2. Different Operating Conditions
3. Differences in Definitions



High Reliability Qualification Options

- **DSCC Specifications** – Group A and B of a given MIL spec
- **MIL Spec** – Parts listed on QPL of a MIL spec, can be ER-level
- **EEE-INST-002 style testing** – NASA’s general recommendations for screening, derating, and qualification
- **Extreme Temperature Conditioning** – Intended to guarantee higher reliability for applications outside the MIL range, -55C to +125C
- **Custom Qualifications** – Source Control Drawings and oriented tests

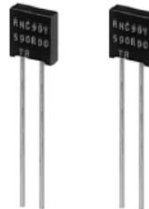
High Reliability Qualification Options

- **EPPL** - European Preferred Parts List
The EPPL is covered by ESCC
(European Space Components Coordination)
- **ESA** - European Space Agency
- **CECC** - ENELEC Electronic Components Committee-
European Committee for Electrotechnical
Standardization

Established Reliability (ER)

Model	Failure Rate	Mil Spec No.	Resistance Range (Ω)	TCR (Mil Range)	Absolute Tolerance	Termination Type
RNC90Y	Level R	MIL-PRF-55182/9	4R99 - 121 K	± 5 ppm/ $^{\circ}\text{C}$	0.005 %	Lead
RNC90T*				± 2 ppm/ $^{\circ}\text{C}$	0.01 %	
RNC90Z			30R1 - 121 K			
RNC90S*						

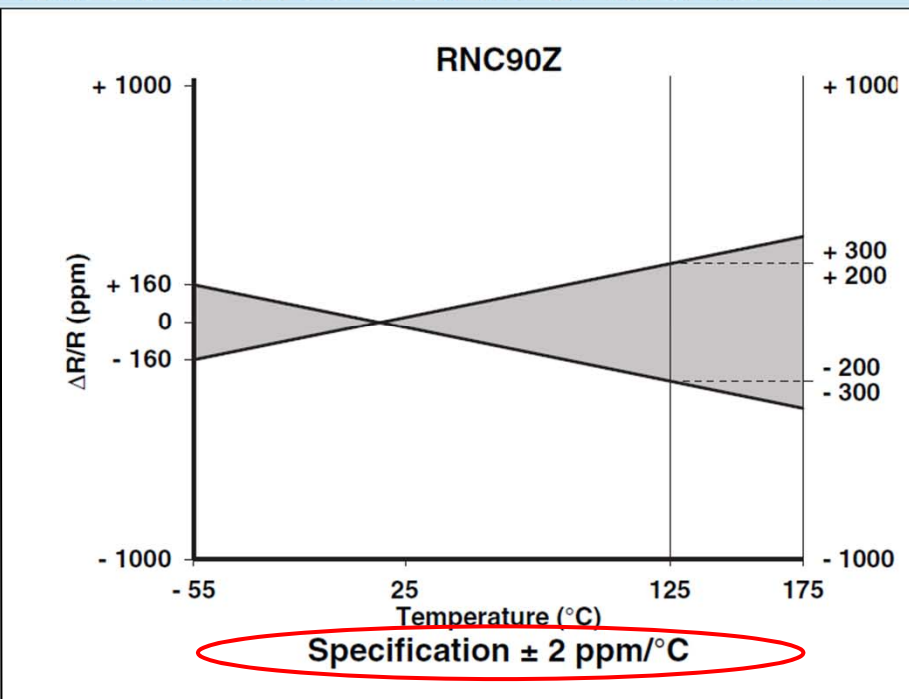
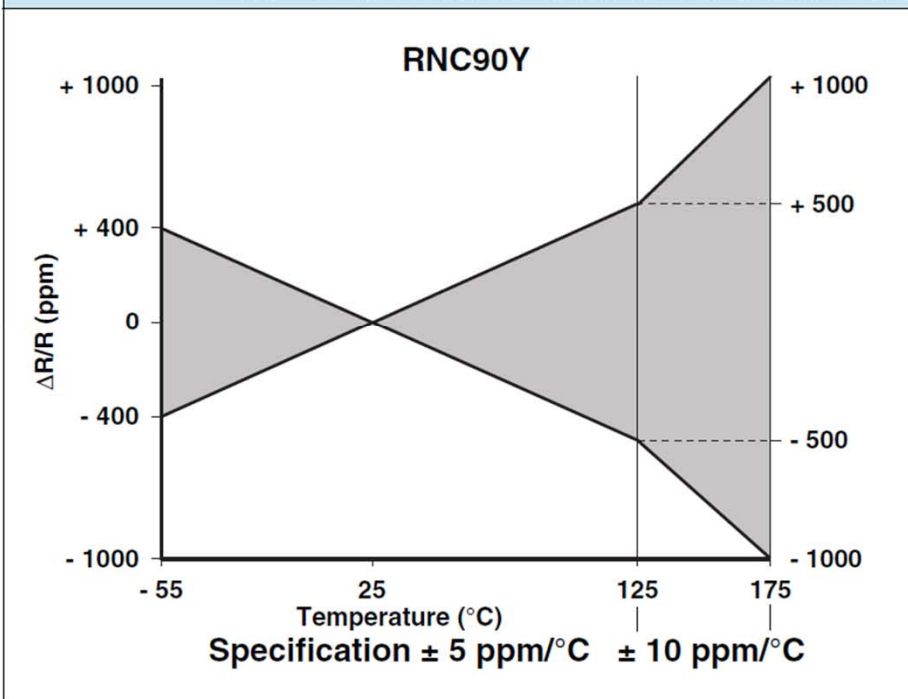
*0.200" lead spacing



Comments relating to TORs

(Technical Operating Requirement)

COMPARISON OF RNC90Y TO RNC90Z TEMPERATURE COEFFICIENT OF RESISTANCE



QPL

- VFR resistors 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 characteristics “C”

Model	Mil Spec No.	Termination Type	Resistance Range	Absolute Tolerance	No. of Resistors	Absolute TCR (Mil Range)
1445Q	MIL-PRF-83401	14 pin DIP	100 R - 10 K	0.1 %	7	100 R - 1 K 10 ppm/°C 1 K - 10 K 5 ppm/°C
1446Q		16 pin DIP			8	



QPL

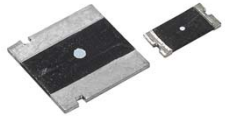
- Vishay Foil Resistors model RJ26 precision trimming ¼ inch potentiometer is qualified to Mil-PRF-22097

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



Custom Screening, QCI, and Derating modeled after EEE-INST-002

– **CSM Style** – 303144, 303145 Current Sensors



- Low value (2mR to 200mR) with 4-terminal Kelvin Connection
- Tested similar to MIL-PRF-49465 and MIL-PRF-55342

– **VSMP Style** – 303134 through 303138 Fixed Resistors



- 0805, 1206, 1506, 2010, 2512 chip resistors
- Designed to exceed MIL-PRF-55342 performance

– **VCS1625** – 303119 Current Sensors



- Low value (10mR to 10R) 4-terminal Kelvin Connection
- Tested similar to MIL-PRF-55342 and MIL-PRF-55182

Custom Screening, QCI, and Derating modeled after EEE-INST-002

- **SMR** – 303139, 303140 – SMD Flex-Lead Resistor
 - Tested in accordance with MIL-PRF-55182 and 55342
 - Flexible “J” Lead construction

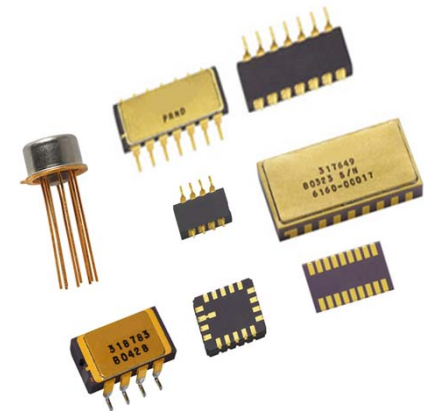


- **Z201** – 303143 – Through-Hole Precision Fixed Resistor
 - Exceeds the performance of the RNC90, MIL-PRF-55182/9
 - Values up to 100 k Ω
 - Best end-of-life error budget



PRND in Compliance with EEE-INST-002

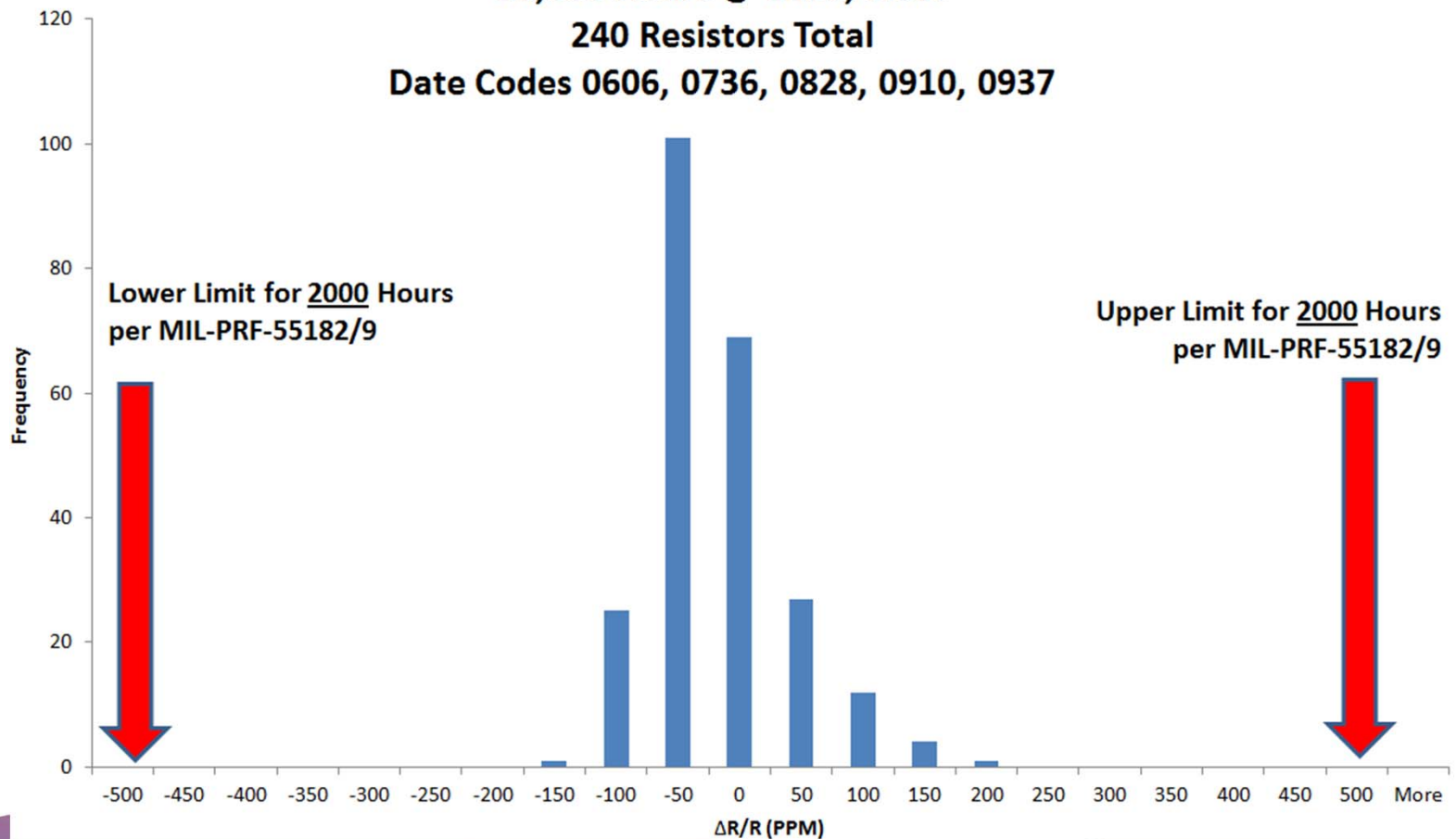
- Custom Hermetically Sealed Precision Resistor Network Device (PRND) With Screen/Test Flow in Compliance with EEE-INST-002: Tables 2A and 3A, Film/Foil, Level 1 and MIL-PRF-83401
 - Table 2A: 100% tests/inspections
 - Table 3A: Destructive tests per MIL-PRF-83401
- Available with various package types:
 - Gull Wing ,Flatpack, DIP, LCC, etc
- For more information, please contact us



Load Life

RNC90Y 10,000 hours

RNC90Y - 50K Ohms
10,000 Hours @ 125C, 0.3W
240 Resistors Total
Date Codes 0606, 0736, 0828, 0910, 0937

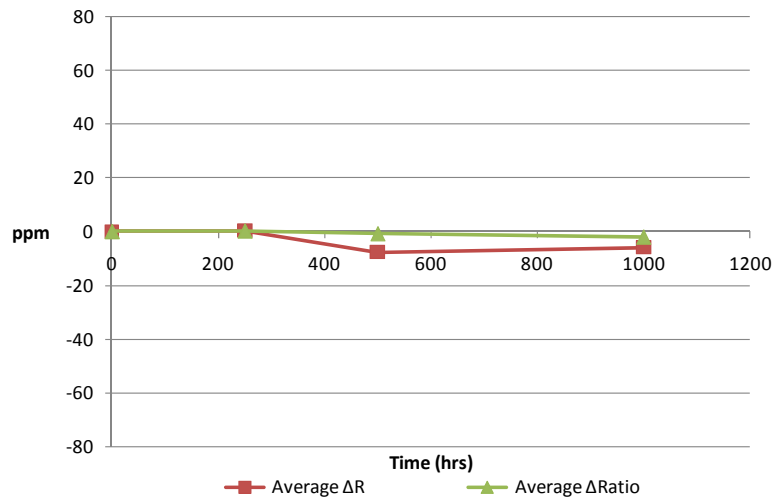


Load Life

1445Q and 1446Q (QPL) , 1000 hrs

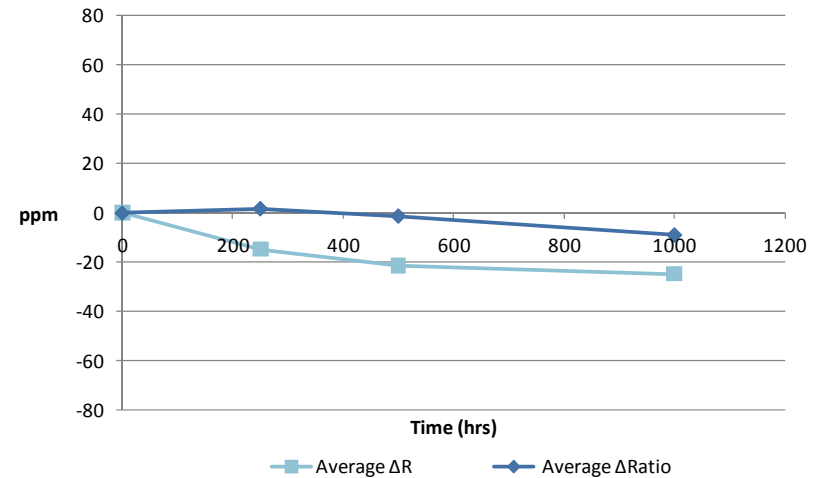
Load Life of 1445 QPL 10K @ +70°C 0.1W

(Average of 10 Network Devices, where each device includes 8 hybrid chips of 10K)

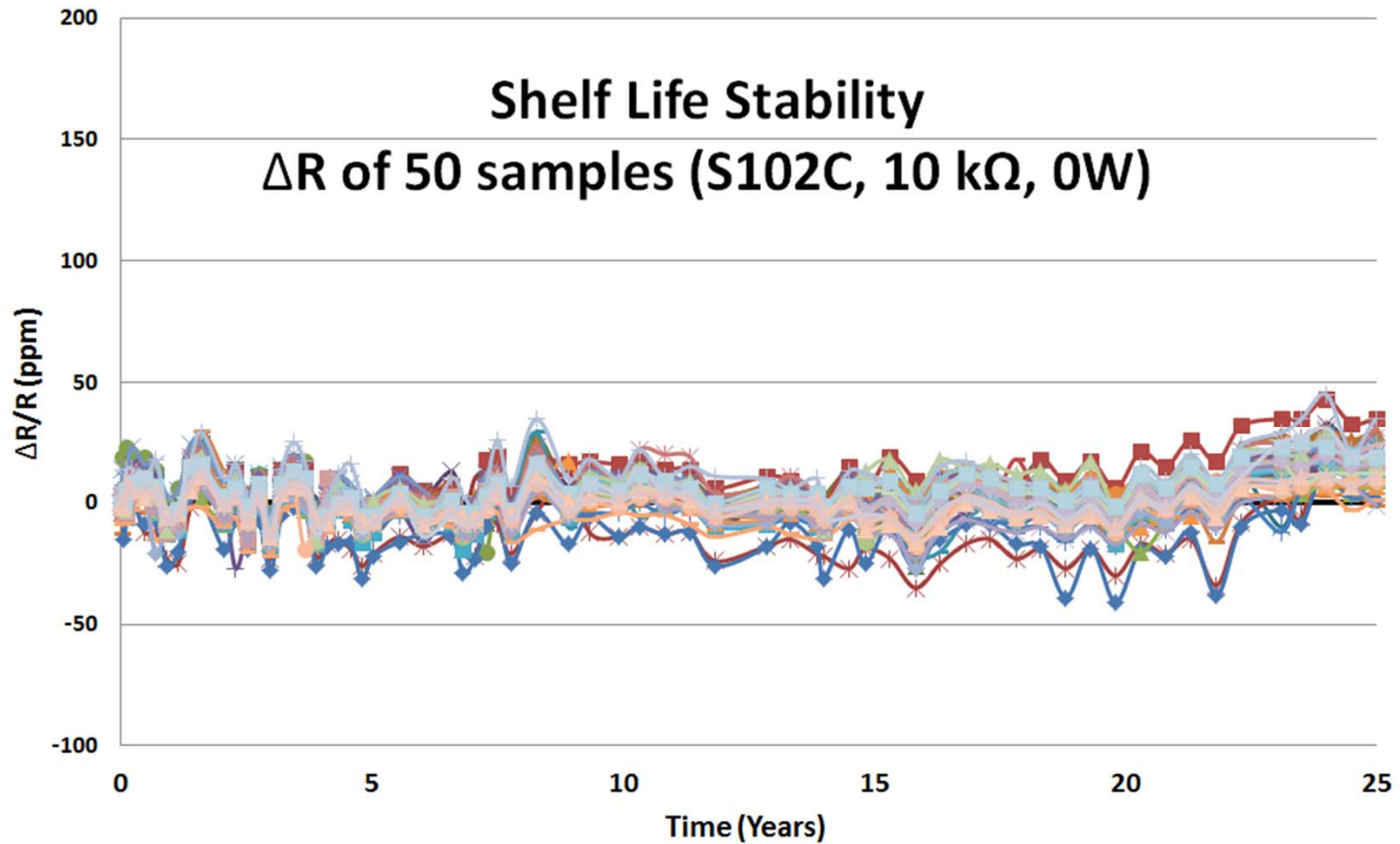


Load Life of 1446 QPL 10K @ +70°C 0.1W

(Average of 10 Network Devices, where each device includes 8 hybrid chips of 10K)

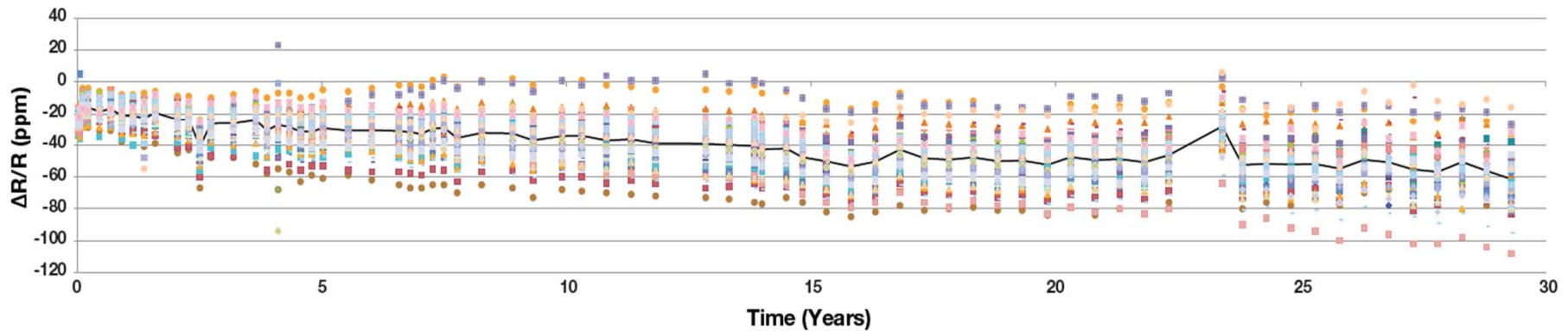


End of Life – S102C 25 Years Shelf Life



Long Term Stability – S102C, 29 Years

Long-Term Stability Over 29 Years, 0.1W at 70 °C, 50 Samples (S102C, 10K Ω)



Space and Military Foil Resistors

Key Features

- Temperature coefficient of resistance (TCR):
 - To ± 0.2 ppm/°C (- 55 °C to + 125 °C, + 25 °C Ref.)
- Resistance Range: 2 mΩ to 150 kΩ
- Resistance Tolerance: to 0.01%
- Power rating at +70 °C : from 0.1 W to 3 W
- Load life stability: to $\pm 0.005\%$ (70 °C, 2000 h at rated power)
- Thermal stabilization time < 1 s (nominal value achieved within 10 ppm of steady state value)
- Current noise: 0.010 μ V RMS/V of applied voltage(< - 40 dB)
- Non inductive: < 0.08 μ H
- Custom Post Manufacturing Operations (PMO) to enhance to reliability are an option

Inherent Characteristics of Foil Resistors

- VFR resistors are not restricted to standard values, specific “as-required” values (e.g., 100.1234 Ω vs 100 Ω) can be supplied at no extra cost or delivery
- **Electrostatic discharge (ESD): at least to 25 kV**
- Rise time: 1 ns, effectively no ringing
- Thermal stabilization time <1 s
(nominal value achieved within 10ppm of steady state value)
- Non-inductive, non-capacitive design
- Voltage coefficient: 0.1 ppm/V
- Current noise: 0.010 $\mu\text{V RMS/V}$ of applied voltage (<- 40dB)
- Thermal EMF: <0.1 $\mu\text{V}/^\circ\text{C}$

Foil Military and Space Resistors



For complete list of our Military and Space Products please refer to:

<http://www.vishaypg.com/foil-resistors/military/>

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