Ultra High Precision Z Foil Though-Hole Resistor

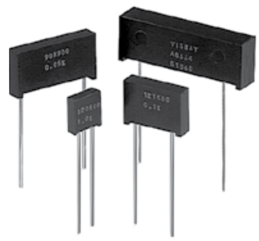
with TCR of ±0.2 ppm/°C, Tolerance of ±0.005% (50 ppm), Load Life Stability of ±0.005%

FEATURES

- **Temperature coefficient of resistance (TCR):** ±0.2 ppm/°C typical (–55°C to +125°C, +25°C ref.) (see table 1)
- Rated power: to 1 W at +125°C (see table 2)
- Resistance tolerance: to ±0.005% (50 ppm)
- Load life stability: ±0.005% at 70°C, 2000 h or ±0.015% at 70°C, 10000 h (see table 4)
- Resistance range: 5 Ω to 600 kΩ
- Bulk Metal® Foil resistors are not restricted to standard values; specific "as required" values can be supplied at no extra cost or delivery (e.g. 1K2345 vs. 1K)
- Total accumulated change in resistance value over life or Total Error Budget <0.1% (or tighter with PMO)**
- Electrostatic Discharge (ESD): at least to 25 kV
- Non-inductive, non-capacitive design
- Rise time: 1 ns effectively no ringing
- Current noise: ≤0.010 μV_{RMS}/V of applied voltage (<–40 dB)
- Thermal EMF: 0.05 µV/°C typical
- Voltage coefficient: <3 ppm/V
- Low inductance: <0.08 µH typical
- Thermal stabilization time <1 s (to reach within 10 ppm of steady state value)
- Pattern design minimizing hot spots
- Terminal finish: lead (Pb)-free or tin/lead alloy
- Matched sets are available per request (TCR tracking: to 0.5 ppm/°C)
- Military established reliability "R" level resistor available (see resistor model RNC90Z)
- Screen/test flow as modified from S-311-P813 proposed by NASA available (see datasheet for resistor model 303143)
- Prototype quantities available please contact foil@vpgsensors.com

INTRODUCTION

The Bulk Metal® Foil resistor is based on a special thermo-metalic stress concept wherein a proprietary bulk metal cold rolled foil is cemented to a ceramic substrate. It is then photoetched into a resistive pattern. Then it is laser adjusted to any desired value and tolerance. Because the metals used are not drawn, wound or mistreated 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 does not. Z Foil resistors achieve maximum stability and near-zero TCR. These performance characteristics are built-in for every unit, and do not rely on screening or other artificial means for uniform performance.



Pb-free Available
RoHS* COMPLIANT

The stability of a resistor depends primarily on its history of exposures to temperature. Stability is affected by:

1. Reversible changes in the ambient temperature and heat from adjacent components (defined by the Temperature Coefficient of Resistance, or TCR)
2. Short-term steady-state self-heating (defined by Power TCR or PCR)
3. Irreversible destabilizing shock of suddenly-applied power
4. Long-term exposure to applied power (load-life stability)

In very high-precision resistors, these effects must be taken into account to achieve high stability with changes in load (Joule Effect) and ambient temperature.

Vishay Foil Resistors' Z Foil technology provides an order of magnitude reduction in the Bulk Metal Foil element's sensitivity to temperature changes – both external and internal. This technology provides TCR of ±0.2 ppm/°C typical (military range: –55°C to +125°C, +25°C ref), and a PCR of 5 ppm at rated power.

In order to take full advantage of this TCR improvement, it is necessary to take into account the differences in the resistor's response to each of the above-mentioned effects. The Z series has been developed to successfully deal with these factors.

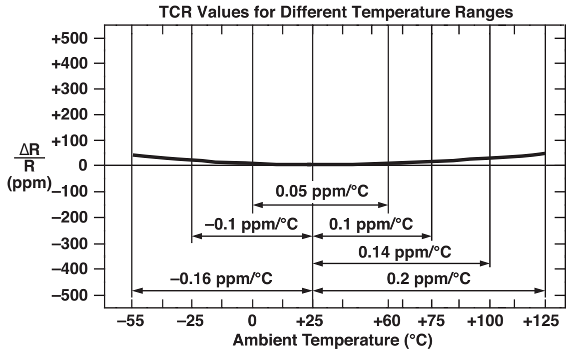
* This datasheet provides information about parts that are RoHS-compliant and/or parts that are non-RoHS-compliant. For example, parts with lead (Pb) terminations are not RoHS compliant. Please see the information/tables in this datasheet for details.

** See PMO page 5

TABLE 1 – TYPICAL TCR AND MAX. SPREAD (–55°C to +125°C, +25°C ref.)

VALUE	STANDARD TOLERANCE	TYPICAL TCR AND MAX. SPREAD (ppm/°C)
100 Ω to 600 kΩ	±0.005%	±0.2 ±0.6
80 Ω to <100 Ω	±0.005%	±0.2 ±0.8
50 Ω to <80 Ω	±0.01%	±0.2 ±1.0
25 Ω to <50 Ω	±0.01%	±0.2 ±1.3
10 Ω to <25 Ω	±0.02%	±0.2 ±1.6
5 Ω to <10 Ω	±0.05%	±0.2 ±2.3

FIGURE 1 – TYPICAL RESISTANCE/ TEMPERATURE CURVE
(for more details, see table 1)



Note
The TCR values for <100 Ω are influenced by the termination composition and result in deviation from this curve

FIGURE 2 – POWER DERATING CURVE

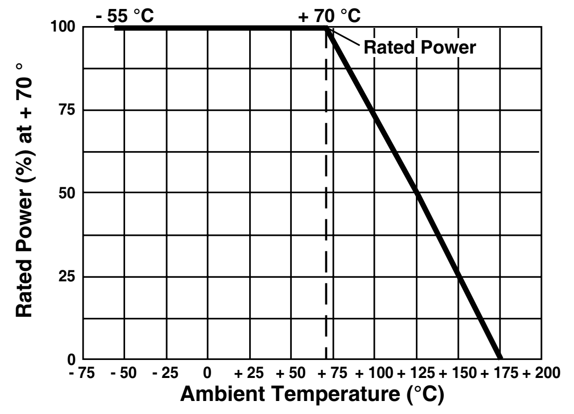
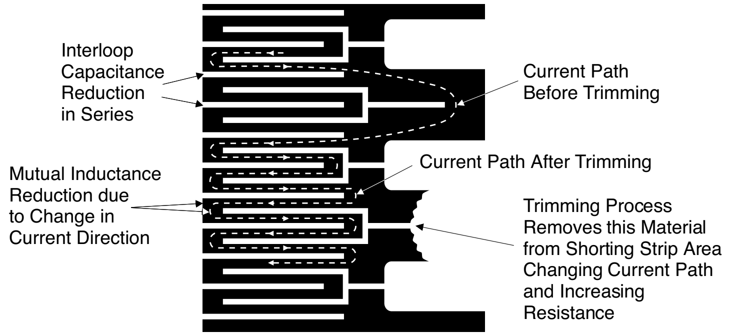


FIGURE 3 – TRIMMING TO VALUES (conceptual illustration)



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 Bulk Metal Foil resistors.

FIGURE 4 -THROUGH-HOLE STYLE (29 YEARS)

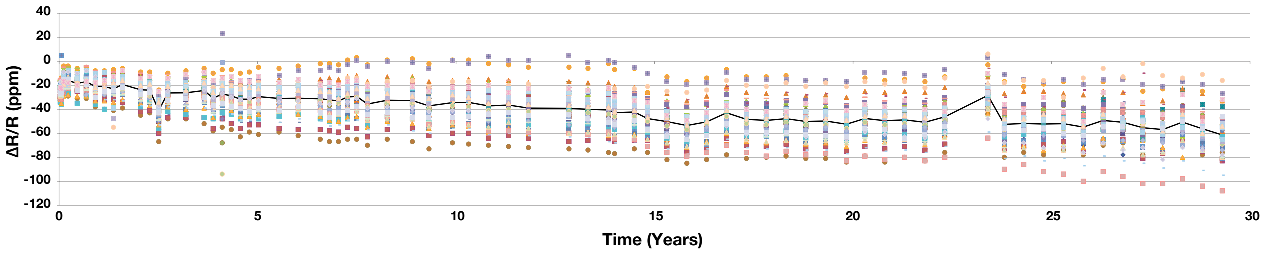


TABLE 2 – MODEL SELECTION

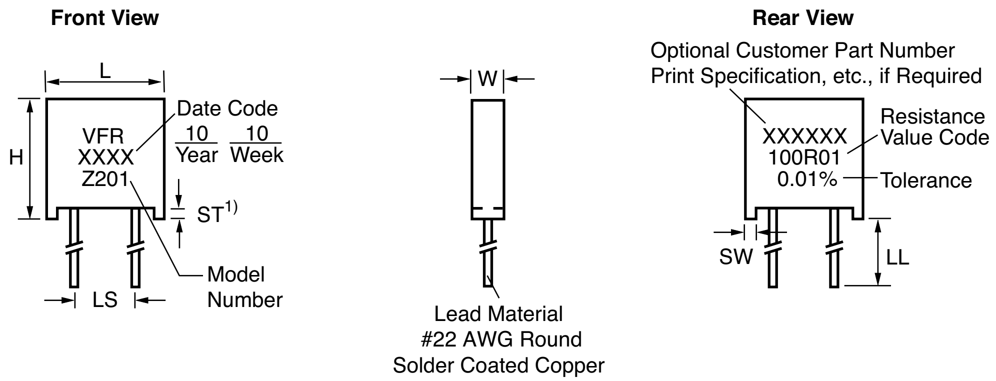
MODEL NUMBER	RESISTANCE RANGE [2]	MAXIMUM WORKING VOLTAGE	AMBIENT POWER RATING		AVERAGE WEIGHT	DIMENSIONS	
			at +70°C	at +125°C		INCHES	mm
Z201 (Z201L) [1]	5 Ω to 100 kΩ	300 V	0.6 W	0.3 W	0.5 g	W: 0.105 ±0.010 L: 0.300 ±0.010 H: 0.326 ±0.010 ST: 0.010 min. SW: 0.040 ±0.005 LL: 1.000 ±0.125 LS: 0.150 ±0.005 [1]	2.67 ±0.25 7.62 ±0.25 8.28 ±0.25 0.254 min. 1.02 ±0.13 25.4 ±3.18 3.81 ±0.13
Z204	5 Ω to 200 kΩ	350 V	1.0 W	0.5 W	1.25 g	W: 0.160 max. L: 0.575 max. H: 0.413 max. ST: 0.035 ±0.005 SW: 0.050 ±0.005 LL: 1.000 ±0.125 LS: 0.400 ±0.020	4.06 max. 14.61 max. 10.49 max. 0.889 ±0.13 1.27 ±0.13 25.4 ±3.18 10.16 ±0.51
Z205	5 Ω to 300 kΩ	350 V	1.5 W	0.75 W	1.75 g	W: 0.160 max. L: 0.820 max. H: 0.413 max. ST: 0.035 ±0.005 SW: 0.050 ±0.005 LL: 1.000 ±0.125 LS: 0.650 ±0.020	4.06 max. 20.83 max. 10.49 max. 0.889 ±0.13 1.27 ±0.13 25.4 ±3.18 16.51 ±0.51
Z206	5 Ω to 600 kΩ	500 V	2.0 W up to 400K 1.0 W over 400K	1.0 W up to 400K 0.5 W over 400K	3.7 g	W: 0.260 max. L: 1.200 max. H: 0.413 max. ST: 0.035 ±0.005 SW: 0.050 ±0.005 LL: 1.000 ±0.125 LS: 0.900 ±0.020	6.60 max. 30.48 max. 10.49 max. 0.889 ±0.13 1.27 ±0.13 25.4 ±3.18 22.86 ±0.51

Note

[1] 0.200 in (5.08 mm) lead spacing available – specify Z201L instead of Z201.

[2] For non standard values please contact Application Engineering at foil@vpgsensors.com

FIGURE 5 – STANDARD IMPRINTING AND DIMENSIONS



Note

1. The standoffs shall be so located as to give a lead clearance of 0.010 in minimum between the resistor body and the printed circuit board when the standoffs are seated on the printed circuit board. This is to allow for proper cleaning of flux and other contaminants from the unit after all soldering processes.

TABLE 3 – ENVIRONMENTAL PERFORMANCE COMPARISON	MIL-PRF-55182 CHAR J	Z SERIES TYPICAL ΔR	Z SERIES MAXIMUM ΔR (1)
Test Group I			
Thermal shock, 5× (–65°C to +150°C)	±0.2%	±0.002% (20 ppm)	±0.01% (100 ppm)
Short time overload, 6.25× rated power	±0.2%	±0.003% (30 ppm)	±0.01% (100 ppm)
Test Group II			
Resistance temperature characteristics	±25 ppm/°C	±0.2 ppm/°C	see table 1
Low temperature storage (24 h at –65°C)	±0.15%	±0.002% (20 ppm)	±0.01% (100 ppm)
Low temperature operation (45 min, rated power at –65°C)	±0.15%	±0.002% (20 ppm)	±0.01% (100 ppm)
Terminal strength	±0.20%	±0.002% (20 ppm)	±0.01% (100 ppm)
Test Group III			
DWV	±0.15%	±0.002% (20 ppm)	±0.01% (100 ppm)
Insulation resistance	≥10⁴ MΩ		≥10⁴ MΩ
Resistance to solder heat	±0.10%	±0.005% (50 ppm)	±0.01% (100 ppm)
Moisture resistance	±0.40%	±0.010% (100 ppm)	±0.02% (200 ppm)
Test Group IV			
Shock	±0.2%	±0.002% (20 ppm)	±0.01% (100 ppm)
Vibration	±0.2%	±0.002% (20 ppm)	±0.01% (100 ppm)
Test Group V			
Life test at rated power/+125°C			
2 000 h	±0.5%	±0.005% (50 ppm)	±0.015% (150 ppm)
10 000 h	±2.0%	±0.015% (150 ppm)	±0.050% (500 ppm)
Test Group Va			
Life test at 2× rated power/+70°C, 2 000 h	±0.5%	±0.005% (50 ppm)	±0.015% (150 ppm)
Test Group VI			
High temperature exposure (2 000 h at +175°C)	±2.0%	±0.02% (200 ppm)	±0.05% (500 ppm)
Test Group VII			
Voltage coefficient	5 ppm/V		3 ppm/V

(1) Measurement error allowed for ΔR limits: 0.01 Ω

STANDARD OPERATIONS AND TEST CONDITIONS

A. Standard Test Operations

By 100% Inspection:

- TCR
- Short-time overload (6.25× rated power for 5 s)
- Resistance – tolerance check
- Visual and mechanical

By Sample Inspection:

- Environmental tests per table 3 on a quarterly basis to establish performance by similarity

B. Test Conditions

- Lead test point: 0.5 in (12.7 mm) from resistor body
- Temperature: +23°C ±2°C
- Relative humidity: per MIL-STD-202

LONG-TERM STABILITY

Some process controls are not very critical but many, many are – particularly when a process is operating near a tipping point where it could get out of control quickly if not well monitored.

In process control applications, entire production batches have been lost or suffered reduced reliability when critical parameters were not kept within narrow limits. One thing that can cause this to happen is changes in the precision resistor over time. Reference points in the control process thus become less and less reliable. Repeatability of the process from batch to batch begins to drift. The process is changing while the monitors appear to be holding it within specified limits because the sense resistor is producing a different output voltage than it was in previous runs for the same sensor output. So the process appears to be under control when, in reality, it is experiencing an undetected drift.

Long-term stability is thus one of the considerations that drive the selection of which resistor technology to use in the application.

But the typical permanent resistance drift of a Bulk Metal Foil resistor is less than 60 ppm (0.006%) after 10 years running at 0.1 W at 70°C.

FIGURE 6 – LOAD LIFE TEST FOR 10 000 HRS @ 0.3 W +125°C; Z201, N=24

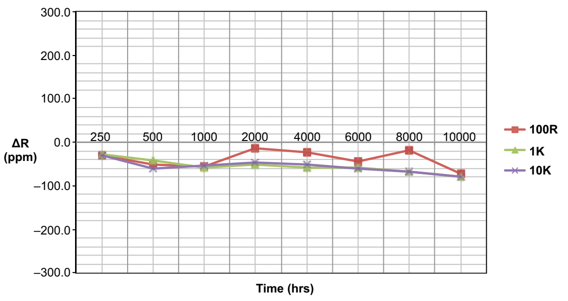
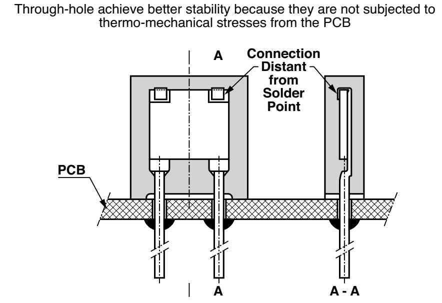


FIGURE 7 – IMPROVED STABILITY WITH THROUGH-HOLE



THERMAL EMF

In a resistor, the resistance is composed of a resistance element of one material and two terminations of a different material. When the junction of the element and the termination is heated in a closed circuit, there is a DC voltage generated in the circuit (see Seebeck and Peltier Effects). Hence, if both termination junctions of the resistor are at exactly the same temperature across terminations there is no net thermal EMF voltage generated in the circuit due to thermal EMF error voltages in the resistor.

In fact, however, the terminals are very seldom at the same temperature because their temperatures are influenced by uneven power dissipation within the resistor, differential heating from other components on the board, and heat conducted along the board itself. Obviously, in a sense resistor that's supposed to accurately convert a current to a voltage, the presence of an extraneous thermal EMF voltage could constitute a significant error source in the system. That is why it's important that Bulk Metal Foil resistors have a thermal EMF voltage of less than 0.1 mV/°C difference across the element to termination junction.

POST MANUFACTURING OPERATIONS (PMO)

Many analog applications can include requirements for performance under conditions of stress beyond the normal and over extended periods of time. This calls for more than just selecting a standard device and applying it to a circuit. The standard device may turn out to be all that is needed but an analysis of the projected service conditions should be made and it may well dictate a routine of stabilization known as post manufacturing operations or PMO. The PMO operations that will be discussed are only applicable to Bulk Metal® Foil resistors. They stabilize Bulk Metal Foil resistors while they are harmful to other types. Short time overload, accelerated load life, and temperature cycling are the three PMO exercises that do the most to reduce drifts down the road. VFR Bulk Metal Foil resistors are inherently stable as manufactured. These PMO exercises are only of value on Bulk Metal Foil resistors and they improve the performance by small but significant amounts. Users are encouraged to contact Vishay Foil Resistors' applications engineering for assistance in choosing the PMO operations that are right for their application.

TABLE 4 – "Z" SERIES SPECIFICATIONS

Stability (1) Load life at 2 000 h Load life at 10 000 h	±0.015% (150 ppm) ±0.005% (50 ppm) ±0.050% (500 ppm) ±0.015% (100 ppm)	Maximum ΔR at 0.3 W/+125°C Maximum ΔR at 0.1 W/+70°C Maximum ΔR at 0.3 W/+125°C Maximum ΔR at 0.1 W/+70°C
Current Noise	0.010 μV_{RMS}/V of applied voltage (<–40 dB)	
High Frequency Operation Rise time Inductance (L) (2) Capacitance (C)	1.0 ns at 1 kΩ 0.1 µH maximum; 0.08 µH typical 1.0 pF maximum; 0.5 pF typical	
Voltage Coefficient	<3 ppm/V (3)	
Thermal EMF (4)	0.05 µV/°C typical 1 µV/W (Model Z201)	

Notes

(1) Load life ΔR maximum can be reduced by 80%, please contact applications engineering.
(2) Inductance (L) due mainly to the leads.
(3) The resolution limit of existing test equipment (within the measurement capability of the equipment.)
(4) µV/°C relates to EMF due to lead temperature difference and µV/watt due to power applied to the resistor.

TABLE 5 – GLOBAL PART NUMBER INFORMATION [1]

NEW GLOBAL PART NUMBER: Y145380K5000V9L (preferred part number format)

Y	1	4	5	3	8	0	K	5	0	0	0	V	9	L

DENOTES PRECISION
- **Y**

PRODUCT CODE
- **1453** = Z201
- **1454** = Z201L
- **1441** = Z204
- **1443** = Z205
- **1447** = Z206

VALUE
- **R** = Ω
- **K** = kΩ
- **M** = MΩ

RESISTANCE TOLERANCE
- **V** = ± 0.005%
- **T** = ± 0.01%
- **Q** = ± 0.02%
- **A** = ± 0.05%
- **B** = ± 0.1%
- **C** = ± 0.25%
- **D** = ± 0.5%
- **F** = ± 1.0%

CHARACTERISTICS
- **0** = tin/lead
- **9** = lead (Pb)-free
- **1 to 999** = custom

PACKAGING
- **L** = bulk pack

FOR EXAMPLE: ABOVE GLOBAL ORDER Y1453 80K5000 V 9 L:

TYPE: Z201
VALUE: 80.5 kΩ
ABSOLUTE TOLERANCE: ± 0.005%
TERMINATION: lead (Pb)-free
PACKAGING: bulk pack

HISTORICAL PART NUMBER: Z201 T 80K500 V B (will continue to be used)

Z201	**T**	**80K500**	**V**	**B**
MODEL	TERMINATION	RESISTANCE VALUE	TOLERANCE	PACKAGING
Z201 **Z201L** **Z204** **Z205** **Z206**	**T** = lead (Pb)-free None = tin/lead alloy	**250R00** = 250.00 Ω **5K2310** = 5.231 kΩ **1M000** = 1 MΩ	**V** = ± 0.005% **T** = ± 0.01% **Q** = ± 0.02% **A** = ± 0.05% **B** = ± 0.1% **C** = ± 0.25% **D** = ± 0.5% **F** = ± 1.0%	**B** = bulk pack

Note
[1] For non-standard requests, please contact application engineering.

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