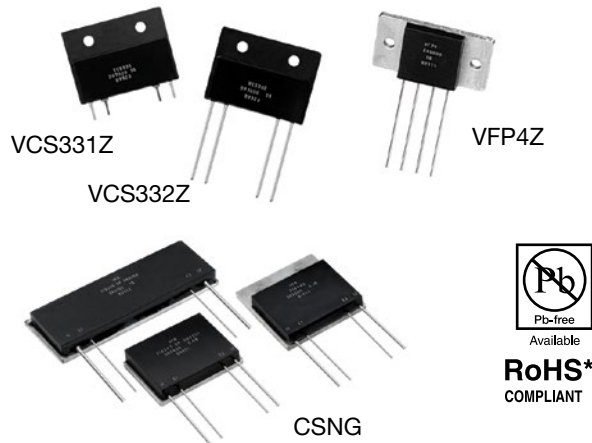


**Bulk Metal® Z-Foil Technology Ultra High-Precision 4-Terminal Power Current Sensing Resistors with TCR as Low as 0.05 ppm/°C, Power up to 10 Watts and Thermal Stabilization of <1s**



**INTRODUCTION**

The most precise measuring of electrical current is achieved by the current sensing resistor method. The precision and speed of response to changing current depend on thermal stability of the resistor, as determined by its low temperature coefficient of resistance (TCR) and related power coefficient of resistance (PCR), as well as its net reactance.

**VCS331Z, VCS332Z, and VFP4Z**

This series should be selected where rapid  $\Delta R$  stabilization and resistance stability under transient power conditions is required. These products achieve optimum performance when mounted on a chassis or cooled heat sink. The Z-Foil technology provides extremely low PCR under defined conditions (see Figure 2 and Figure 3). The low absolute TCR provided by the Z-Foil technology is measured over the temperature range of  $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  or  $0^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$ ,  $+25^{\circ}\text{C}$  reference (see Figure 4).

All of these devices utilizing the Z-Foil technology are provided with a true 4-terminal Kelvin connection. This is a must for precise current sensing when the resistance value is less than  $100\Omega$  (see Figure 6).

**CSNG — New Generation of Power Current Sense Resistors**

Custom high power designs can be developed for your specific applications. Vishay Foil Resistors (VFR) recently introduced New Generation of Power Current Sense Resistors (CSNG) with short thermal setting time, long-term stability, high power to 20W and absolute TCR to  $\pm 0.5 \text{ ppm}/^{\circ}\text{C}$  maximum (see page 5).

For more information, please contact Application Engineering Department at [foil@vishaypg.com](mailto:foil@vishaypg.com).

\*Pb containing terminations are not RoHS compliant; exemptions may apply

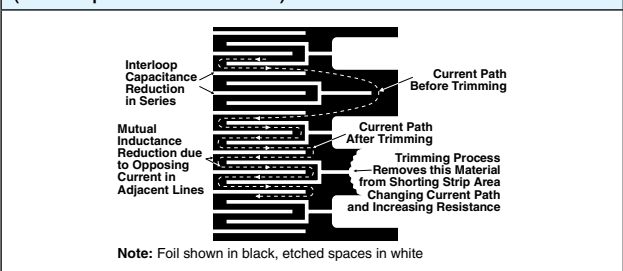
**FEATURES**

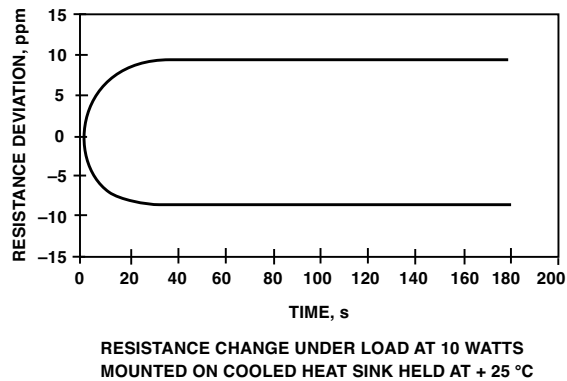
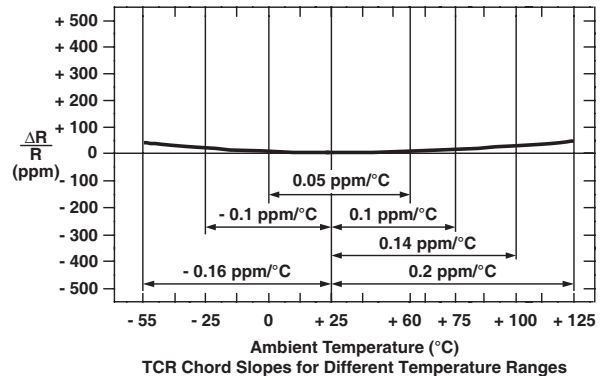
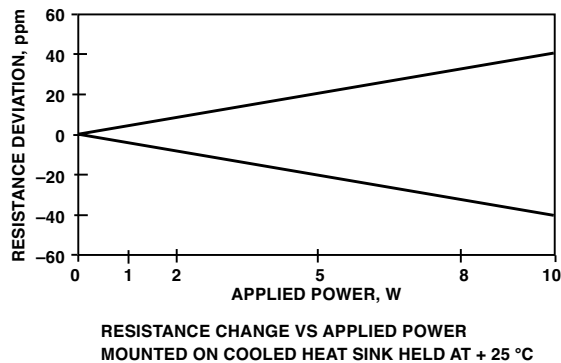
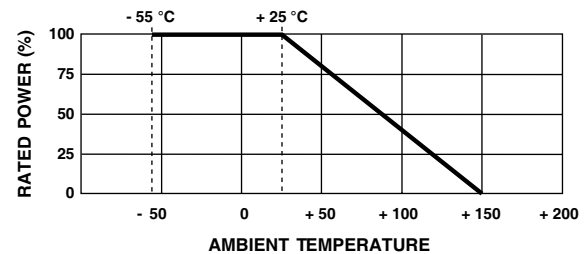
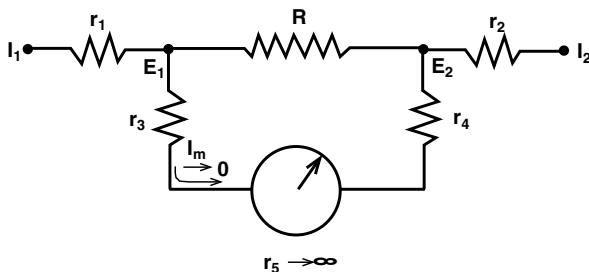
- Low temperature coefficient of resistance (see figure 4):
  - 0.05 ppm/°C typical ( $0^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$ )
  - 0.2 ppm/°C typical ( $-55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ,  $+25^{\circ}\text{C}$  ref.)
- Resistance range: 0R25 to 500R
- Resistance tolerance: to  $\pm 0.01\%$
- **Power rating: 10W on heatsink(1) at  $+25^{\circ}\text{C}$ ; 3W in free air at  $+25^{\circ}\text{C}$  (see Table 2)**
- Load life stability:
  - $\pm 0.005\%$  (50 ppm) typical, 3W on heatsink at  $+25^{\circ}\text{C}$ , 2000h
  - $\pm 0.01\%$  (100 ppm) typical, 3W in free air at  $+25^{\circ}\text{C}$ , 2000h
  - $\pm 0.01\%$  typical (100 ppm), 10W on heatsink at  $+25^{\circ}\text{C}$ , 2000h
- Vishay Foil Resistors are not restricted to standard values; specific “as required” values can be supplied at no extra cost or delivery (e.g. 1R2345 vs. 1R)
- **Rapid  $\Delta R$  stabilization under transient loads (see Figure 2)**
- **Thermal resistance:  $6^{\circ}\text{C}/\text{W}$**
- Electrostatic discharge (ESD) at least to 25 kV
- Rise time: 1 ns, effectively no ringing
- **Tenfold improvement of power coefficient of resistance (PCR): 4 ppm/W (see Figure 3)**
- Thermal stabilization time  $<1\text{s}$  (nominal value achieved within 10 ppm of steady state value)
- Voltage coefficient:  $<0.1 \text{ ppm}/\text{V}$
- Current noise:  $0.010 \mu\text{V}_{\text{RMS}}/\text{V}$  of applied voltage ( $<-40 \text{ dB}$ )
- Inductance: 0.1  $\mu\text{H}$  maximum; 0.08  $\mu\text{H}$  typical
- Thermal EMF: 0.1  $\mu\text{V}/^{\circ}\text{C}$  (see Table 3)
- Non-inductive, non-capacitive design
- Pattern design minimizing hot spots

**Note**

(1) Heatsink—aluminum (6" L x 4" W x 2" H x 0.04" THK)

**FIGURE 1 — TRIMMING TO VALUES**  
(conceptual illustration)

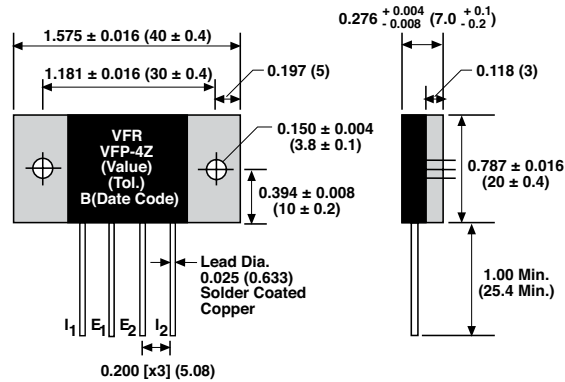


**FIGURE 2 – RAPID STABILIZATION****FIGURE 4 – TYPICAL RESISTANCE/TEMPERATURE CURVE (Z-FOIL)****FIGURE 3 – POWER COEFFICIENT (PCR)****FIGURE 5 – POWER DERATING CURVE****FIGURE 6 – KELVIN CONNECTION**

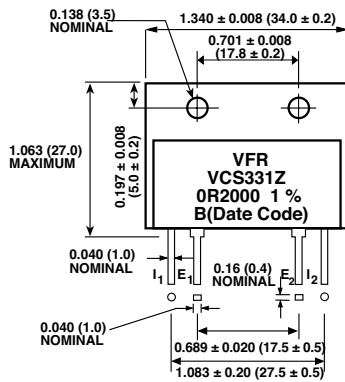
Kelvin, 4-terminal, connections are utilized for these low ohmic value products to measure a precise voltage drop across the resistive element. In these applications the contact resistance, lead resistance, and their TCR effect may be greater than that of the element itself and could cause significant errors if the standard 2-terminal connection is used. Figure 6 shows a high impedance measurement system where  $r_5$  approaches infinity and  $I_m$  approaches zero resulting in negligible IR drop through  $r_3$  and  $r_4$  which negates their lead resistance and their TCR effect. With the voltage sense leads  $E_1$  and  $E_2$  inside of  $r_1$  and  $r_2$  the resistance and TCR effect of the current leads,  $I_1$  and  $I_2$  are negated and only the resistance and TCR of the element  $R$  are sensed. This method of measurement is essential for precise current sensing.

**FIGURE 7—STANDARD IMPRINTING AND DIMENSIONS** in inches (millimeters)

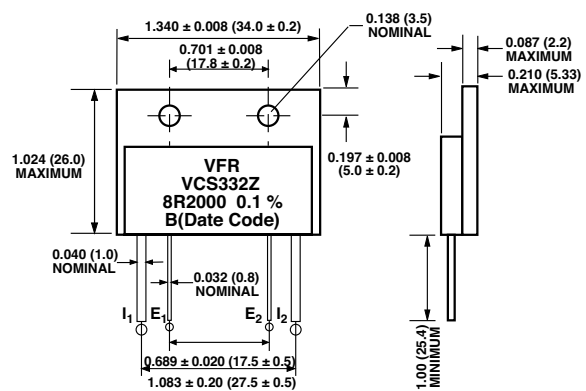
**VFP4Z**



**VCS331Z**



**VCS332Z**



**TABLE 1 – RESISTANCE VALUE VS. TOLERANCE**

RESISTANCE RANGE ( $\Omega$ )	STANDARD TOLERANCE (%)
10 to 500	$\pm 0.01\%$
5 to <10	$\pm 0.02\%$
2 to <5	$\pm 0.05\%$
1 to <2	$\pm 0.10\%$
0.5 to <1	$\pm 0.25\%$
0.25 to <0.5	$\pm 0.50\%$

**TABLE 2 – SPECIFICATIONS**

TEST OR CONDITION		PERFORMANCE
Power Coefficient of Resistance (PCR)		4 ppm/W maximum <sup>(1)</sup>
Temperature Coefficient of Resistance (TCR) (-55°C to +125°C, +25°C Reference)		≥1.0Ω to 500Ω, ±0.2 ±1.8 ppm/°C maximum 0.25Ω to <1.0Ω, ±0.2 ±2.8 ppm/°C maximum
Thermal Resistance		6 °C/W <sup>(1)</sup>
Power Rating at +25°C	VFP4Z	10W or 3A maximum (heatsink) <sup>(2)(3)</sup> 3W or 3A maximum (free air) <sup>(3)</sup>
	VCS331Z, VCS332Z	10W or 5A maximum (heatsink) <sup>(2)(3)</sup> 3W or 5A maximum (free air) <sup>(3)</sup>

**Notes**

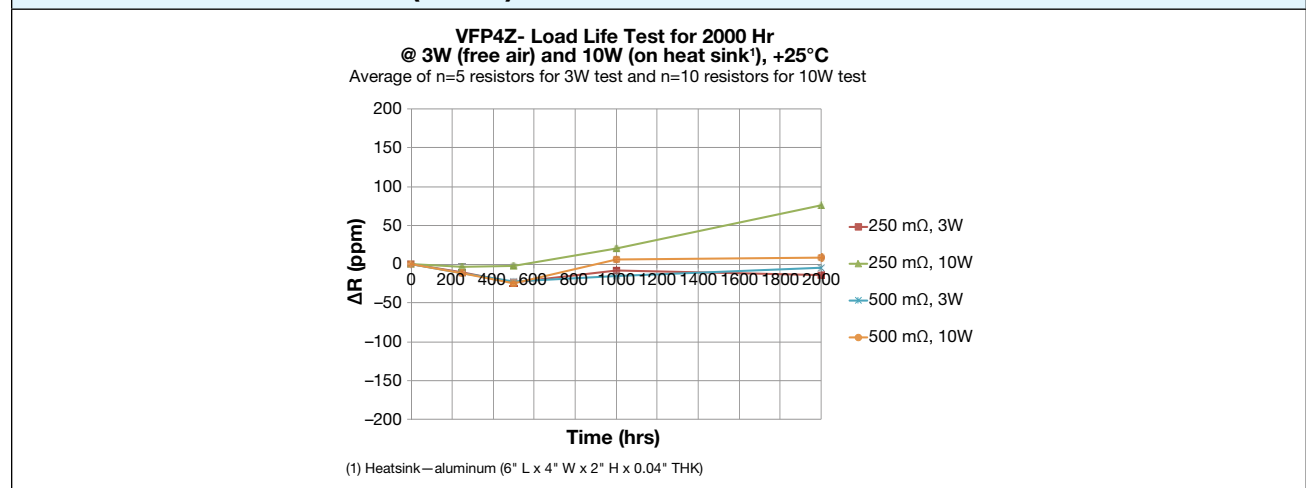
- (1) Mounted on a cooled heat sink held at +25°C  
(2) Heatsink—aluminum (6" L x 4" W x 2" H x 0.04" THK)  
(3) Whichever is lower

**TABLE 3 – ENVIRONMENTAL PERFORMANCE<sup>(1)</sup> (PER MIL-PRF-39009)**

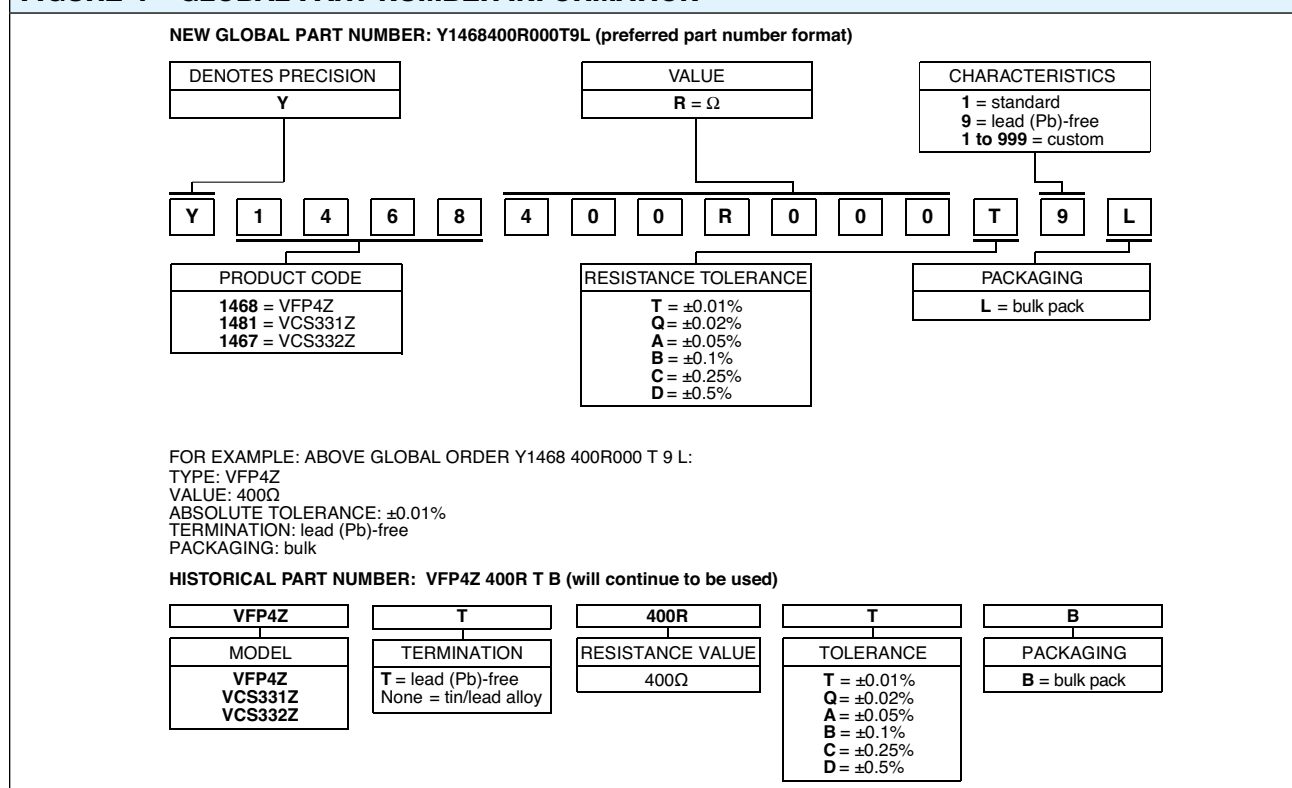
TEST OR CONDITION		TYPICAL ΔR LIMITS	MAXIMUM ΔR LIMITS
Thermal Shock		0.01%	0.02%
Short Time Overload (5 x rated power for 5s)		0.01%	0.02%
Terminal Strength		0.02%	0.05%
High Temperature Exposure (2000h at +150°C)		0.02%	0.05%
Moisture Resistance		0.03%	0.05%
Low Temperature Storage (24h at -55°C)		0.005%	0.01%
Shock (specified pulse)		0.01%	0.02%
Vibration (high frequency)		0.01%	0.02%
Load Life (rated power, +25°C, 2000h)		0.01%	0.02%
Thermal EMF	VFP4Z	0.5 μV/°C maximum (lead effect) 4.0 μV/W maximum (power effect)	
	VCS331Z, VCS332Z	0.2 μV/°C max. (E terminal)	

**Note**

- (1) ΔR's plus additional 0.0005Ω for measurement error

**FIGURE 8 – LOAD LIFE TEST (VFP4Z)**

**FIGURE 4 – GLOBAL PART NUMBER INFORMATION <sup>(1)</sup>**



**Note**

(1) For non-standard requests, please contact application engineering

## CSNG – NEW GENERATION OF POWER CURRENT SENSE RESISTORS

### Custom Tailored Design and Construction

The most precise measuring of electrical current is achieved by the current sensing resistor method. The precision and speed of response to changing current depend on thermal stability of the resistor, as determined by its low temperature coefficient of resistance (TCR) and related power coefficient of resistance (PCR), as well as its net reactance. Vishay Foil Resistors' new-generation Bulk Metal® Foil resistor technology and internal design reduce maximum TCR to less than 0.5 ppm/°C, while a special construction reduces thermal distortion, resulting in a current detector with a precision of a few parts per million (PPM) within a fraction of a second after application of rated power.

These new resistors include multiple Bulk Metal® Foil chips and are uniquely designed and tailor-made for the customers' specific applications.

In-Process and Post Manufacturing Operations (PMO) tests are performed for high-end industrial, metrology, and instrumentation applications. Prestigious scientific and research institutes like: CERN, PTB, MEATEST, JUELICH, DALHAUSIE University, etc., are among the users of these CSNG.

## TECHNOLOGICAL BREAKTHROUGHS

- Highly efficient thermally-conductive resin to bond the Bulk Metal® Foil to ceramic
- Highly efficient thermally conductive resin to bond the chips to heat sink
- Special chip trimming method to ensure uniform heat dissipation
- Special concept of TCR adjustment for almost zero TCR even at low values
- Different lead diameters (cross section) for different current specs, e.g.:
  - 1 mm (18 AWG) for 15A
  - 1.3 mm (16 AWG) for 20A

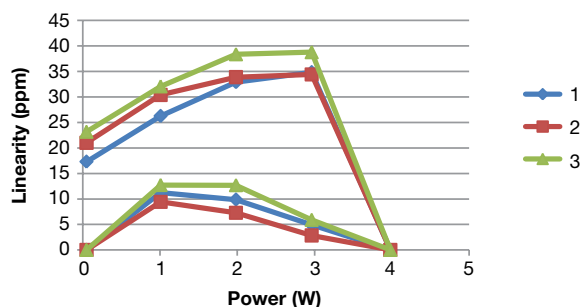
## FLEXIBILITY OF CONSTRUCTION TAILORED PER CUSTOMER'S SPEC

- Size and type of heat sink: with or without mounting holes
- Size of resistor
- Mounting method with screws or bonded with thermo conductive epoxy and clamps
- Wide range of resistive elements may be used to adapt the resistor to customer specification
- Terminations: lead (Pb)-free or tin/lead

**FIGURE 4—LINEARITY TEST**

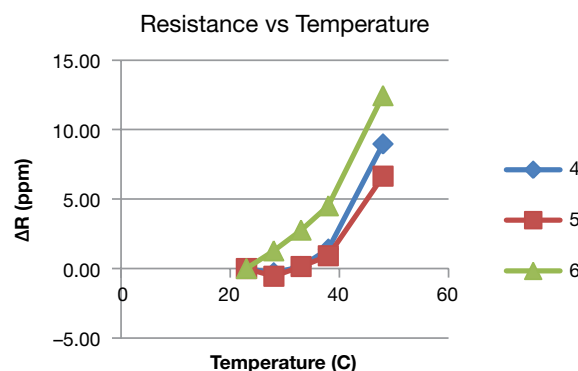
Perfect linearity is when a straight line can be drawn between the low and high power values. Linearity error is the deviation from this straight line. Three resistors of 17 mΩ were measured at various power levels between 10 mW and 4W (starting at 10 mW up to 4W and then back down to 10 mW to indicate any hysteresis). The resistor was allowed to settle at each point.

The graph shows that including the hysteresis, the linearity is less than 40 ppm.

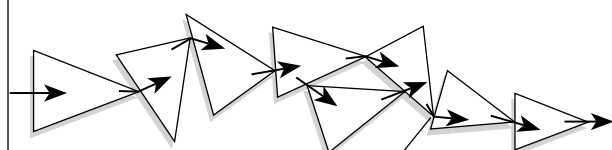
**FIGURE 6—TEMPERATURE COEFFICIENT**

The graph represents an example of TCR graph based on 3 resistors (value: 50 mΩ) with 6 chips configuration. These specific resistors were measured at 1A (50 mW) at 23, 28, 35, 38 and 48°C. Each resistor was allowed to settle at each temperature point for at least 2 hours. The table shows the TCR results accordingly.

Resistor #	Temperature Coefficient (ppm/C)
1	+0.29
2	+0.21
3	+0.44

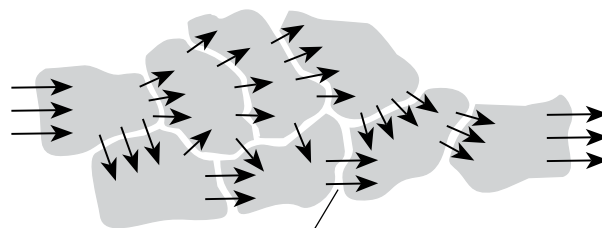
**FIGURE 7—NOISE GENERATION—VISHAY FOIL RESISTOR VS. OTHER TECHNOLOGIES**

#### The Current Path in a Particle-to-Particle Matrix



Noise generation is maximum when current flow is through point to point contacts as shown in a particle to particle matrix.

#### The Current Path in a Resistive Alloy



Noise generation is minimal when current flow is through multiple paths as exists in Bulk Metal® Foil resistive alloy.

## ORDERING INFORMATION

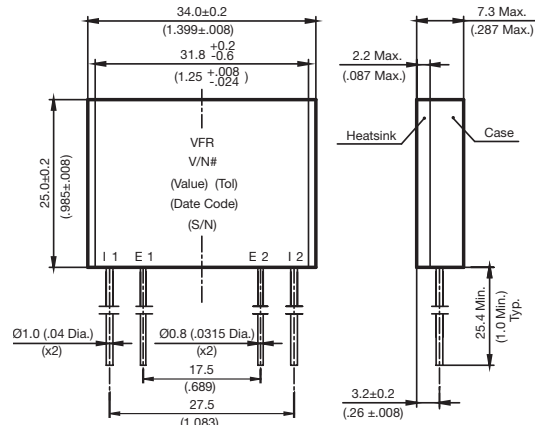
New Generation of Power Current Sense Resistors is tailored made products built to your requirements. Send your electrical specifications to the Applications Engineering Department ([foil@vishaypg.com](mailto:foil@vishaypg.com)).

A unique part number (V/N#) will be assigned which defines all the aspects of your resistor.

**FIGURE 9—EXAMPLES OF DIFFERENT CONFIGURATIONS**

For your specific requirements please contact Application Engineering Department.

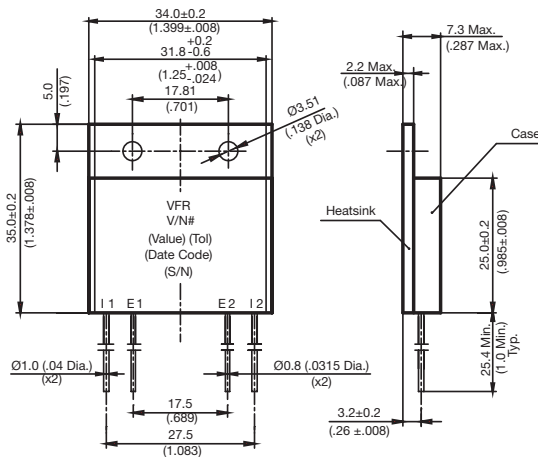
**Example 1— Three-chip configuration; heat sink without mounting holes**



**Notes:**

1. Leads: Tinned Copper
  - Current Leads:  $\varnothing 1.0$  (.04 Dia.) x 2.
  - Voltage Leads:  $\varnothing 0.8$  (.315 Dia.) x 2.
2. All Dimensions are in mm (inches).
3. Tolerances: If not otherwise stated  $\pm 0.2$  ( $\pm .00$ )

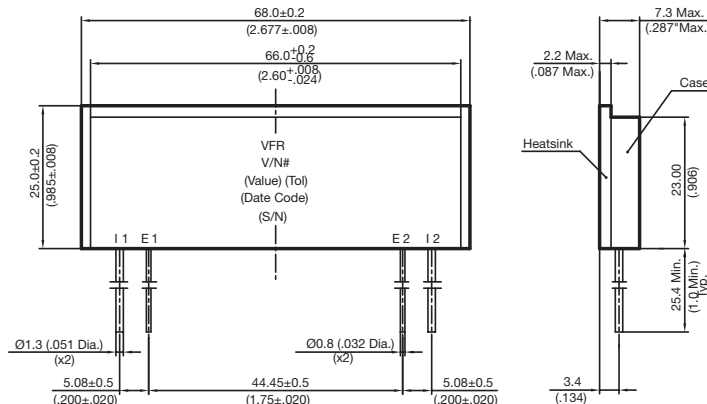
**Example 2— Three-chip configuration; heat sink with mounting holes**



**Notes:**

1. Leads: Tinned Copper
  - Current Leads:  $\varnothing 1.0$  (.04 Dia.) x 2.
  - Voltage Leads:  $\varnothing 0.8$  (.315 Dia.) x 2.
2. All Dimensions are in mm (inches).
3. Tolerances: If not otherwise stated  $\pm 0.2$  ( $\pm .008$ ).

**Example 3— Six-chip configuration; heat sink without mounting holes**



**Notes:**

1. Leads: Tinned Copper
  - Current Leads:  $\varnothing 1.3$  (.051 Dia.) x 2.
  - Voltage Leads:  $\varnothing 0.8$  (.32 Dia.) x 2.
2. All Dimensions are in mm (inches).
3. Tolerances: If not otherwise stated  $\pm 0.2$  ( $\pm .008$ ).

## Disclaimer

ALL PRODUCTS, PRODUCT SPECIFICATIONS AND DATA ARE SUBJECT TO CHANGE WITHOUT NOTICE.

Vishay Precision Group, Inc., its affiliates, agents, and employees, and all persons acting on its or their behalf (collectively, "Vishay Precision Group"), disclaim any and all liability for any errors, inaccuracies or incompleteness contained herein or in any other disclosure relating to any product.

The product specifications do not expand or otherwise modify Vishay Precision Group's terms and conditions of purchase, including but not limited to, the warranty expressed therein.

Vishay Precision Group makes no warranty, representation or guarantee other than as set forth in the terms and conditions of purchase. **To the maximum extent permitted by applicable law, Vishay Precision Group disclaims (i) any and all liability arising out of the application or use of any product, (ii) any and all liability, including without limitation special, consequential or incidental damages, and (iii) any and all implied warranties, including warranties of fitness for particular purpose, non-infringement and merchantability.**

Information provided in datasheets and/or specifications may vary from actual results in different applications and performance may vary over time. Statements regarding the suitability of products for certain types of applications are based on Vishay Precision Group's knowledge of typical requirements that are often placed on Vishay Precision Group products. It is the customer's responsibility to validate that a particular product with the properties described in the product specification is suitable for use in a particular application.

No license, express, implied, or otherwise, to any intellectual property rights is granted by this document, or by any conduct of Vishay Precision Group.

The products shown herein are not designed for use in life-saving or life-sustaining applications unless otherwise expressly indicated. Customers using or selling Vishay Precision Group products not expressly indicated for use in such applications do so entirely at their own risk and agree to fully indemnify Vishay Precision Group for any damages arising or resulting from such use or sale. Please contact authorized Vishay Precision Group personnel to obtain written terms and conditions regarding products designed for such applications.

Product names and markings noted herein may be trademarks of their respective owners.



## Disclaimer

ALL PRODUCTS, PRODUCT SPECIFICATIONS AND DATA ARE SUBJECT TO CHANGE WITHOUT NOTICE.

Vishay Precision Group, Inc., its affiliates, agents, and employees, and all persons acting on its or their behalf (collectively, "Vishay Precision Group"), disclaim any and all liability for any errors, inaccuracies or incompleteness contained herein or in any other disclosure relating to any product.

The product specifications do not expand or otherwise modify Vishay Precision Group's terms and conditions of purchase, including but not limited to, the warranty expressed therein.

Vishay Precision Group makes no warranty, representation or guarantee other than as set forth in the terms and conditions of purchase. **To the maximum extent permitted by applicable law, Vishay Precision Group disclaims (i) any and all liability arising out of the application or use of any product, (ii) any and all liability, including without limitation special, consequential or incidental damages, and (iii) any and all implied warranties, including warranties of fitness for particular purpose, non-infringement and merchantability.**

Information provided in datasheets and/or specifications may vary from actual results in different applications and performance may vary over time. Statements regarding the suitability of products for certain types of applications are based on Vishay Precision Group's knowledge of typical requirements that are often placed on Vishay Precision Group products. It is the customer's responsibility to validate that a particular product with the properties described in the product specification is suitable for use in a particular application.

No license, express, implied, or otherwise, to any intellectual property rights is granted by this document, or by any conduct of Vishay Precision Group.

The products shown herein are not designed for use in life-saving or life-sustaining applications unless otherwise expressly indicated. Customers using or selling Vishay Precision Group products not expressly indicated for use in such applications do so entirely at their own risk and agree to fully indemnify Vishay Precision Group for any damages arising or resulting from such use or sale. Please contact authorized Vishay Precision Group personnel to obtain written terms and conditions regarding products designed for such applications.

Product names and markings noted herein may be trademarks of their respective owners.