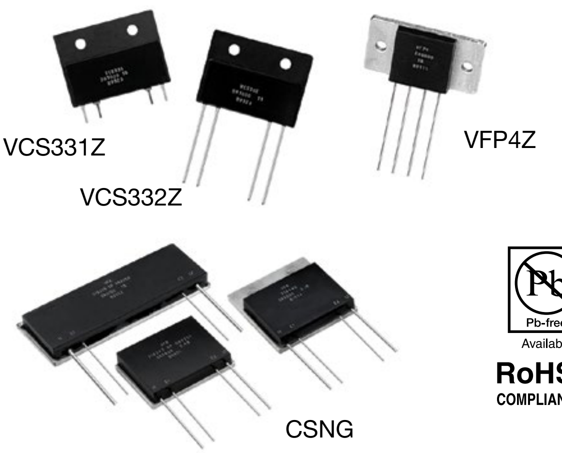
Bulk Metal® Z-Foil Technology Ultra High-Precision 4-Terminal Power Current Sensing Resistors with TCR as Low as 0.05 ppm/°C, Power up to 10 Watts and Thermal Stabilization of <1s



Pb-free Available

RoHS* COMPLIANT

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 (0R25 to 500R)

This series should be selected where rapid ΔR 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°C to +125°C or 0°C to +60°C, +25°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 100Ω (see Figure 6).

CSNG — New Generation of Power Current Sense Resistors (>0R005)

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 ±0.5 ppm/°C maximum (see page 5).

For more information, please contact Application Engineering Department at foil@vishaypg.com.

*Pb containing terminations are not RoHS compliant; exemptions may appy

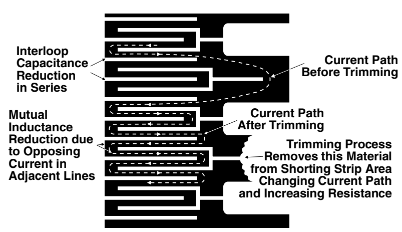
FEATURES

- Low temperature coefficient of resistance (see figure 4):
  - 0.05 ppm/°C typical (0°C to +60°C)
  - 0.2 ppm/°C typical (–55°C to +125°C, +25°C ref.)
- Resistance range: 0R25 to 500R
- Resistance tolerance: to ±0.01%
- **Power rating: 10W on heatsink(1) at +25°C; 3W in free air at +25°C (see Table 2)**
- Load life stability:
  - ±0.005% (50 ppm) typical, 3W on heatsink at +25°C, 2000h
  - ±0.01% (100 ppm) typical, 3W in free air at +25°C, 2000h
  - ± 0.01% typical (100 ppm), 10W on heatsink at +25°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 ΔR stabilization under transient loads (see Figure 2)**
- **Thermal resistance: 6°C/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 <1s (nominal value achieved within 10 ppm of steady state value)
- Voltage coefficient: <0.1 ppm/V
- Current noise: 0.010 μV_{RMS}/V of applied voltage (<–40 dB)
- Inductance: 0.1 µH maximum; 0.08 µH typical
- Thermal EMF: 0.1 µV/°C (see Table 3)
- Non-inductive, non-capacitive design
- Pattern design minimizing hot spots

Note

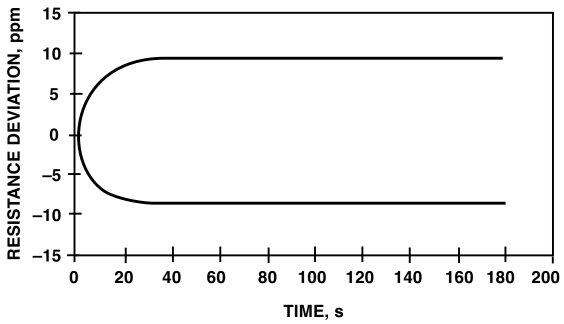
(1) Heatsink—aluminum (6” L x 4” W x 2” H x 0.04” THK)

FIGURE 1—TRIMMING TO VALUES
(conceptual illustration)



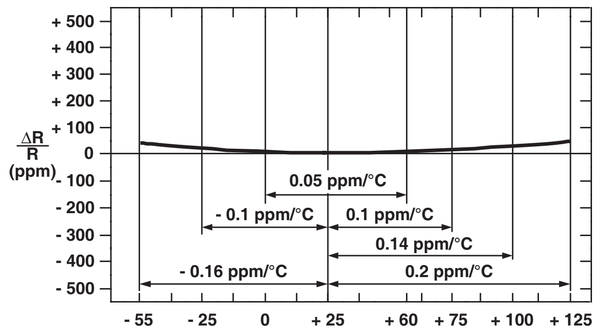
Note: Foil shown in black, etched spaces in white

FIGURE 2 – RAPID STABILIZATION



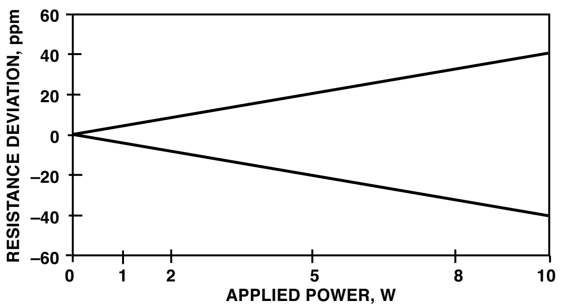
RESISTANCE CHANGE UNDER LOAD AT 10 WATTS
MOUNTED ON COOLED HEAT SINK HELD AT + 25 °C

FIGURE 4 – TYPICAL RESISTANCE/ TEMPERATURE CURVE (Z-FOIL)



Ambient Temperature (°C)
TCR Chord Slopes for Different Temperature Ranges

FIGURE 3 – POWER COEFFICIENT (PCR)



RESISTANCE CHANGE VS APPLIED POWER
MOUNTED ON COOLED HEAT SINK HELD AT + 25 °C

FIGURE 5 – POWER DERATING CURVE

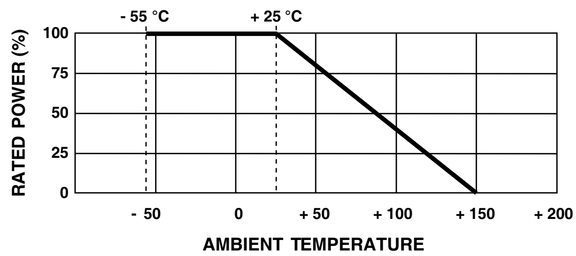
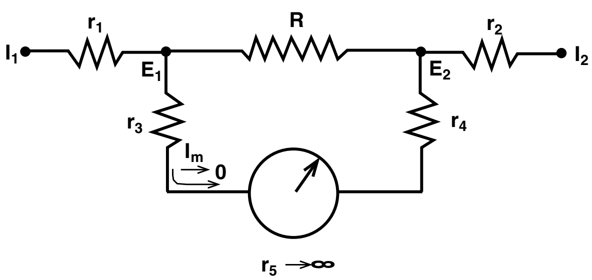


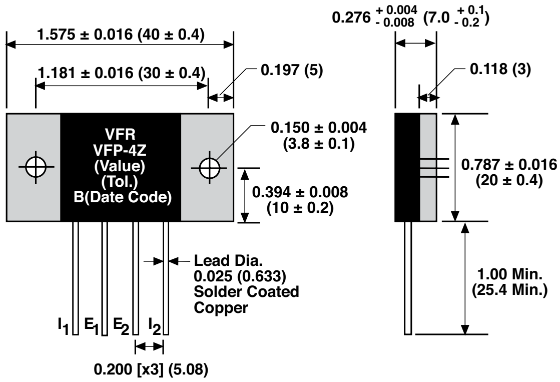
FIGURE 6 – KELVIN CONNECTION



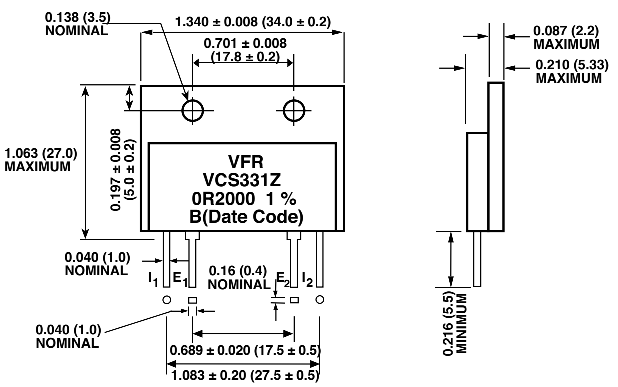
Kelvin, 4-terminal, connections are utilized for these low ohmic value products to measure a precise voltage drop across the resistive element. In these applications the contact resistance, lead resistance, and their TCR effect may be greater than that of the element itself and could cause significant 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

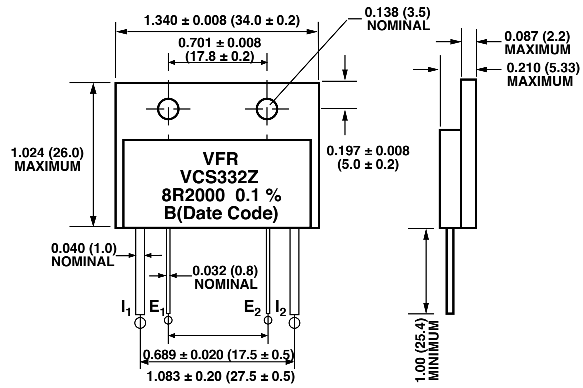


TABLE 1 – RESISTANCE VALUE VS. TOLERANCE

RESISTANCE RANGE (Ω)	STANDARD TOLERANCE (%)
10 to 500	±0.01%
5 to <10	±0.02%
2 to <5	±0.05%
1 to <2	±0.10%
0.5 to <1	±0.25%
0.25 to <0.5	±0.50%

TABLE 2 – SPECIFICATIONS		
TEST OR CONDITION		**PERFORMANCE**
Power Coefficient of Resistance (PCR)		4 ppm/W maximum [1]
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 [1]
Power Rating at +25°C	**VFP4Z**	10W or 3A maximum (heatsink) [2][3] 3W or 3A maximum (free air) [3]
	VCS331Z, VCS332Z	10W or 5A maximum (heatsink) [2][3] 3W or 5A maximum (free air) [3]

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[1] (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)

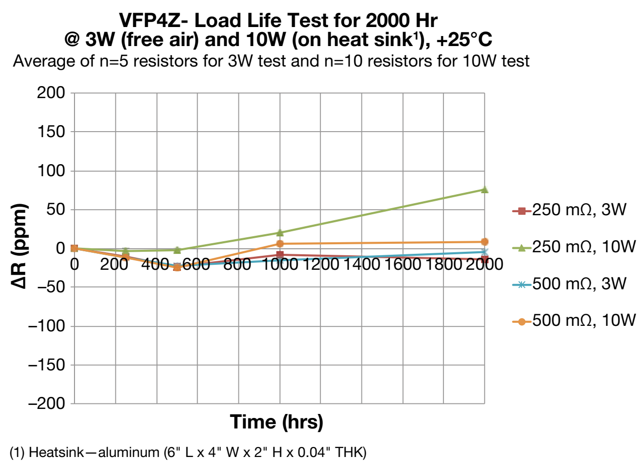


FIGURE 4 – GLOBAL PART NUMBER INFORMATION [(1)]

NEW GLOBAL PART NUMBER: Y1468400R000T9L (preferred part number format)

Y	1	4	6	8	4	0	0	R	0	0	0	T	9	L

DENOTES PRECISION
Y

VALUE
R = Ω

CHARACTERISTICS
0 = standard
9 = lead (Pb)-free
1 to 999 = custom

PRODUCT CODE
1468 = VFP4Z
1481 = VCS331Z
1467 = VCS332Z

RESISTANCE TOLERANCE
T = ±0.01%
Q = ±0.02%
A = ±0.05%
B = ±0.1%
C = ±0.25%
D = ±0.5%

PACKAGING
L = bulk pack

FOR EXAMPLE: ABOVE GLOBAL ORDER Y1468 400R000 T 9 L:
TYPE: VFP4Z
VALUE: 400Ω
ABSOLUTE TOLERANCE: ±0.01%
TERMINATION: lead (Pb)-free
PACKAGING: bulk

HISTORICAL PART NUMBER: VFP4Z 400R T B (will continue to be used)

VFP4Z	T	400R	T	B
MODEL	TERMINATION	RESISTANCE VALUE	TOLERANCE	PACKAGING
VFP4Z **VCS331Z** **VCS332Z**	**T** = lead (Pb)-free None = tin/lead alloy	400Ω	**T** = ±0.01% **Q** = ±0.02% **A** = ±0.05% **B** = ±0.1% **C** = ±0.25% **D** = ±0.5%	**B** = bulk pack

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.

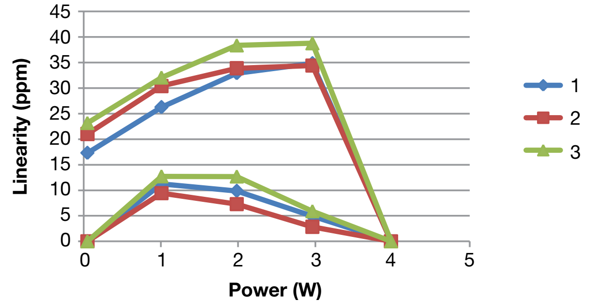


FIGURE 6—TEMPERATURE COEFFICIENT

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 48C. 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

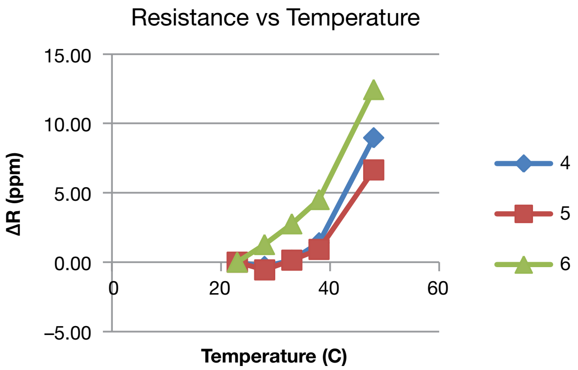
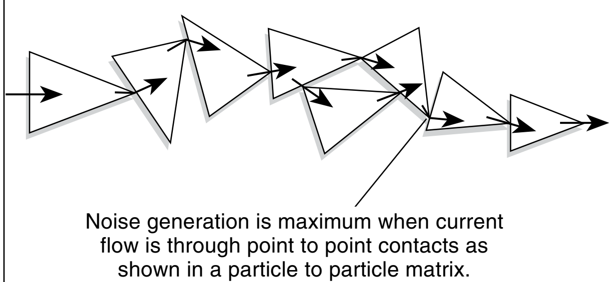
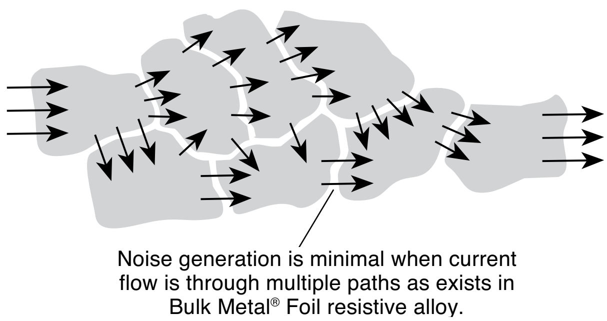


FIGURE 7—NOISE GENERATION—VISHAY FOIL RESISTOR VS. OTHER TECHNOLOGIES

The Current Path in a Particle-to-Particle Matrix



The Current Path in a Resistive Alloy



ORDERING INFORMATION

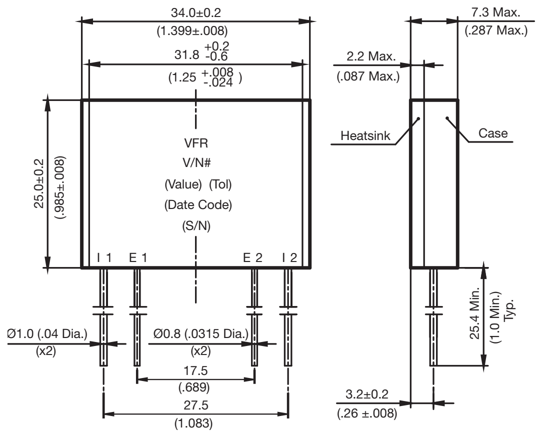
New Generation of Power Current Sense Resistors is tailored made products built to your requirements. Send your electrical specifications to the Applications Engineering Department (foil@vishaypg.com).

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.

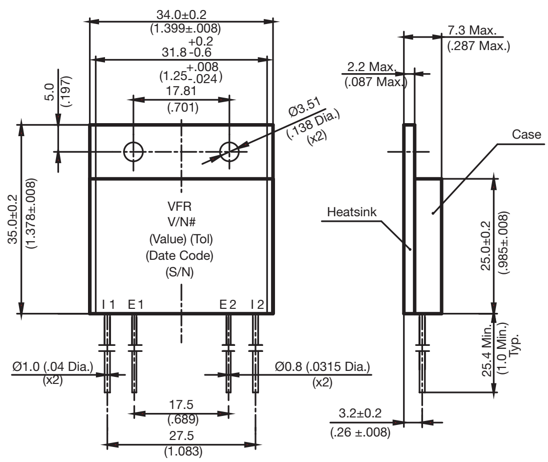
Example 1— Three-chip configuration; heat sink without mounting holes



Notes:

1. Leads: Tinned Copper
   - Current Leads: Ø1.0 (.04 Dia.) x 2.
   - Voltage Leads: Ø0.8 (.315 Dia.) x 2.
2. All Dimensions are in mm (inches).
3. Tolerances: If not otherwise stated ±0.2 (±.0C

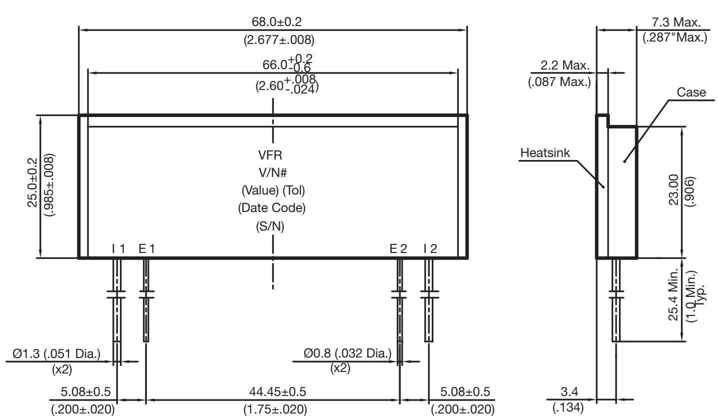
Example 2— Three-chip configuration; heat sink with mounting holes



Notes:

1. Leads: Tinned Copper
   - Current Leads: Ø1.0 (.04 Dia.) x 2.
   - Voltage Leads: Ø0.8 (.031 Dia.) x 2.
2. All Dimensions are in mm (inches).
3. Tolerances: If not otherwise stated ±0.2 (±.008).

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



Notes:

1. Leads: Tinned Copper
   - Current Leads: Ø1.3 (.051Dia.) x 2.
   - Voltage Leads: Ø0.8 (.032 Dia.) x 2.
2. All Dimensions are in mm (inches).
3. Tolerances: If not otherwise stated ±0.2 (±.008).

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