Ultra High Precision Resistors
Vishay Foil Resistors - Overview

• More than five decades after its invention by physicist, Dr. Felix Zandman in 1962, Bulk Metal® Foil (BMF) technology still outperforms all other resistor technologies available today for applications that require precision, stability, and reliability.

• Used in the highest quality instruments for which the resistor performance (TCR, stability) is the most important requirement.

• Develop and manufacture, military-established-reliability components (EEE-INST-002, DSCC, CECC, ESA, ER, QPL, etc).

• Customized chip resistor networks and resistor arrays can also be manufactured.
VPG Brands

VPG Foil Resistors

VPG Micro Measurements

VPG Load Cells

VPG Process Weighing

VPG On-board Weighing
**Typical Applications**

- Measurement systems
- Current sensing
- High-precision amplifiers
- Weighing systems
- Force balance scales
- Differential amplifiers
- Switching power supplies
- Electron microscopes

- Gyro navigation controls
- Pressure sensors
- Motor speed controls
- Telecommunications
- Bridge networks
- Standard Box & Decade
- Tailored solutions per customer specifications
VPG Foil Resistors

Tailored Solutions

The Foil resistors can be provided even with better specification than written in the standard datasheets. There are specific cases where some parameters can be maximized/Improved beyond the standard performances to suit the customer requirements.

- Examples of such parameters are:
  - Total Error Budget (TEB) or End Of Life (EOL)
  - Long term stability
  - Ultra precision
  - Matched resistors
  - Resistance Value
  - Tolerance - Absolute and matched
  - TCR - Absolute and tracking

For more information please contact Application Engineering department: foil@vishaypg.com
# Diversified Customer Base

## Distributors/EMS
- AVNET
- DALE
- B+BRAEYAC
- ANNAY
- Texas Components Corporation
- REXON
- Benchmark
- Jabil
- FLEXTRONICS
- Celestica
- Mouser
- Premier Farnell
- Newark

## AMS
- AEROSPACE
- Liton
- AIRBUS
- Alenia Aeronautica
- Boeing
- McDonnell Douglas
- Sagem Avionics Inc.
- SAFRAN Group
- Honeywell
- Lockheed Martin
- EADS
- ATRIUM
- NASA
- Harris
- Raytheon
- British Aerospace
- Space Systems
- Loral
- Northrop Grumman

## Medical
- PHILIPS
- SIEMENS
- St. Jude Medical
- Biosense Webster
- Sorin Group
- Agilent Technologies
- Texas Instruments

## Precision Instrumentation
- FLUKE
- HP
- KEITHLEY
- Datron
- Guildline
- JMEC
- METTLER TOLEDO
- PRECIA ITALIANA

## Industrial
- Rockwell Automation
- Caterpillar
- Schlumberger
- BAKER HUGHES
- ZERA
- Schneider Electric
- Tyco

## Metrology
- Solartron
- PerkinElmer

## Weighing
- Sartorius
- WIPOTEC

## Standards
- JEMIC
- NIST

## Hardware
- IBM
- Google
- Apple

## Academy
- University of Warwick
- Massachusetts Institute of Technology
- University of Cambridge

## ATE/EM
- KLA-Tencor
- FEI
- Applied Materials
- Zeiss
What Factors Do Design Engineers Look For When Choosing Resistors?
Resistors Evolution

TCR
Tolerance
Stability
Power Stability
ESD
NI
Long terme Stability
Reliability
Low Noise

Foil Z Foil Z1Foil

Thin Film
Métal Film
Wirewound
Thick Film
Carbon

±0.0025% Stability,
±0.05 ppm/℃ TCR, ESD >25 kV

MOQ: 1
RV: 1K1234
Tol.: 0.001%
TCR: 0.2ppm/℃
ESD: >25KV
High Temp.: 240℃
Samples in 5 days
Comparison of Resistor Technologies

![Diagram showing a comparison of TCR and long term stability for different resistor technologies: Foil, Wire Wound, Thick Film, and Thin Film. Each technology type is represented by a circle with varying degrees of overlap, indicating different performance characteristics.]

VPG Foil Resistors
## Comparison of Resistor Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Temperature Coefficient of Resistance (TCR)</th>
<th>Initial Tolerance</th>
<th>End of Life Tolerance</th>
<th>Load Life Stability at +70°C, Rated Power 2000 Hours and 10,000 Hours</th>
<th>ESD (V)</th>
<th>Thermal Stabilization</th>
<th>Noise (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Metal® Foil</td>
<td>±0.2 ppm/°C</td>
<td>From 0.001%</td>
<td>&lt;0.05%</td>
<td>0.005% (50 ppm) 0.01% (100 ppm)</td>
<td>25,000</td>
<td>&lt;1 second</td>
<td>-42</td>
</tr>
<tr>
<td>High-Precision Thin Film</td>
<td>±5 ppm/°C</td>
<td>From 0.05%</td>
<td>&lt;0.4%</td>
<td>0.05% (500 ppm) 0.15% (1500 ppm)</td>
<td>2500</td>
<td>&gt;few minutes</td>
<td>-20</td>
</tr>
<tr>
<td>Precision Thick Film</td>
<td>±50 ppm/°C</td>
<td>From 0.5%</td>
<td>&lt;5%</td>
<td>0.5% (5000 ppm) 2% (20,000 ppm)</td>
<td>2000</td>
<td>&gt;few minutes</td>
<td>+20</td>
</tr>
<tr>
<td>Wirewound</td>
<td>±3 ppm/°C</td>
<td>From 0.005%</td>
<td>&lt;0.5%</td>
<td>0.05% (500 ppm) 0.15% (1500 ppm)</td>
<td>25,000</td>
<td>&gt;few minutes</td>
<td>-35</td>
</tr>
</tbody>
</table>
Resistor Technologies

- **Thick Film**
  - Screen Printed Conducting Paste + Laser Trimming
  - Typical TCR Range: 100 to 400 ppm/K

- **Thin Film**
  - Sputtering + Laser Trimming
  - Typical TCR Range: 50 to 200 ppm/K

- **Precision Thin Film**
  - Sputtering + Photo Etching + Laser Trimming
  - Typical TCR Range: 5 to 25 ppm/K

- **Bulk Metal Foil**
  - Metal Rolling + Photo Etching + Laser Trimming or Manual Trimming
  - Typical TCR Range: 0.2 to 5 ppm/K
Why Bulk Metal Foil Resistor?

**Stability**
- Time=The Lowest Long Term Stability (2 ppm/year for 6 years)
- Temperature=The Lowest TCR (0+/−0.05 ppm/℃)

**Reliability**
- Reliability Tests= According to MIL-PRF-55182/9 & MIL-PRF-55342

**Accuracy**
- The Tightest Tolerance (±0.001%)
Main reasons for selecting Foil as a precision resistor

* VPG Foil Resistors estimates
The Foil development over the years

![Graph showing Foil development over the years with different alloys and temperature coefficients.]

- **C Alloy**: 2 ppm/°C (1962)
- **K Alloy**: 1 ppm/°C (1982)
- **Z Alloy**: 0.2 ppm/°C (2002)

Temperature coefficients indicated:
- ±1 ppm/°C
- ±0.2 ppm/°C
- ±2 ppm/°C
Vishay Foil Resistors Unique Stability

Long –Term Stability over 30 years (0.1 W at 70 °C 50 samples (S102C, 10KΩ)

Shelf Life test results of hermetically sealed VHP 101 Foil Resistors over 10 years
What is Behind
The Foil Technology
Company’s Key Technology

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.
Company’s Key Technology
Trimming

In Parallel

To Series

Increase Resistance Value
Technology Comparison
Bulk Metal Foil vs. Thin Film Resistor

Vishay Foil Resistors

25,000 Å (2.5μm)

Ni-Cr Foil
Bonding Layer
Alumina Alloy

250 Å

Alumina Alloy

Protection Layer
Resistive Layer
Electroplated Termination
Base Contacts
Ceramic Substrate
Laser Trimming

HOT SPOTS
Company’s Key Technology
TCR & PCR

Inherent Resistivity of Free Metal® Foil

Resulting R/T Curve

Coefficient of Thermal Expansion

T - Thickness

13 ppm/°C

6 ppm/°C

T×100

Decrease due to Compression
Unique Trimming Method

The Bulk Metal® Foil is photo etched into a resistive pattern (no mechanical stress introduced). Later, it is laser (or manually) adjusted to any desired value and tolerance.

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.
Capacitance & Inductance

• In spiraled and wire wound resistors, the Capacitance and Inductance are created by the loops and spaces formed by the spirals or turns of wire (Fig A).

• In planar resistors such as the Bulk Metal® Foil resistors, the geometry of the lines of the resistor patterns is intentionally designed to counteract these reactance’s.

• Figure B shows a typical serpentine pattern of a planar resistor. Opposing current directions in adjacent lines reduces mutual inductance while geometry-related inter-line capacitances in series reduces overall capacitance.

• Both inductance and capacitance produce reactance proportional to the operating frequency and it changes the effective resistance and the phase between the current and voltage in the circuit.
Product Life Cycle

Color Key for Certificates
- DLA DWG Available
- DLA + EPPL European Preferred Parts List, Issue 11
- DLA + EEE INST 002 test program
- EEE INST 002 test program
- Established Reliability (ER)
- QPL

Recent and Forthcoming Product Developments
- Implementation of Z1-Foil technology in all products
- Introduction of new products for high-temperature applications (up to 240°C)
- Smaller SMD case sizes (including 0402 and 0603)
- Current sense with higher power

Vishay Foil Resistors

Bulk Metal® Foil Resistors in Precision Instrumentation

New Generation Custom Designed Current Sensor is used in High End Voltage/Current Calibrator
Value: 10mΩ, TCR <1 ppm/°C
VHD200 for high temperature up to +200°C is used in Brakes Control System of Commercial Airplanes

New Generation Current sensor is used to enable handling of 40A and accuracy of 0.005% in Submarine Repeater Station
**Vishay Foil Resistors**

Bulk Metal® Foil Resistors in Space Application

*Space Level Resistor per EEE – INST-002*

- **CSM Series (current sensors)**
- **VSMP Series (warp around SMD)**
- **SMR series (Molded SMD)**
- **PRND (Hermetically Sealed Networks)**
Vishay Foil Resistors

Bulk Metal® Foil Resistors in Precision Instrumentation

Hermetically sealed Ultra High Precision Z-Foil Technology Resistors – H-Series for
Electron Beam Microscope

Ultra high-precision Z-Foil flip chip resistor for
DC Test Instrument
Vishay Foil Resistors

**Bulk Metal® Foil Resistors in Precision Weigh Scale**

VFPCP2512 are used as current sense resistors at the new series of **High Performance Laboratory Scales**

Alpha’s thermo sensitive resistors are used as temp. compensator for load cell of **Weigh Scales**
Bulk Metal® Foil Resistors in Down Hole Drilling Tool (High Temperature)

HTHG series is used for measurement inside of a drilling tool.
Withstand temperature up to $+270^\circ C$
Three Manufacturing Facilities

Israel

Japan

Germany
## Vishay Foil Resistors

### Bulk Metal® Foil Resistors Categories

<table>
<thead>
<tr>
<th>Surface Mount</th>
<th>Through Hole</th>
<th>Voltage Dividers and Networks</th>
<th>Power Current Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Surface Mount" /></td>
<td><img src="image2.jpg" alt="Through Hole" /></td>
<td><img src="image3.jpg" alt="Voltage Dividers and Networks" /></td>
<td><img src="image4.jpg" alt="Power Current Sensors" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hermetically Sealed</th>
<th>Trimmers</th>
<th>Hybrid Chips and PRND</th>
<th>Military and Space</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5.jpg" alt="Hermetically Sealed" /></td>
<td><img src="image6.jpg" alt="Trimmers" /></td>
<td><img src="image7.jpg" alt="Hybrid Chips and PRND" /></td>
<td><img src="image8.jpg" alt="Military and Space" /></td>
</tr>
</tbody>
</table>
Bulk Metal® Foil Resistors Categories

Current Sense

High Precision

Networks

Thermosensitive

Thin Film

Standard Resistor
Bulk Metal® Foil Resistors Categories

Powertron

- Current Sense (29)
- High Precision (25)
- Networks (4)
- Power Resistors (45)
- Special Resistors (11)
- Surface Mount (16)
Contact us at
foil@VPGsensors.com

Visit us

www.VPGFoilResistors.com