VISHAY®

One of the World's Largest Manufacturers of Discrete Semiconductors and Passive Components

Comparison of Performances of Four Resistors Technologies: Bulk Metal® Foil (Classical and Z-Foil), WireWound, Thin Film, Thick Film

The first-ever LIVE demo of resistor technologies

Will transform the way you select resistors and avoid unforeseen stress factors

October 2009

Real-Time Simulation vs. PowerPoint Presentation

ESD

Current Sensing 4-terminal

Main Demo

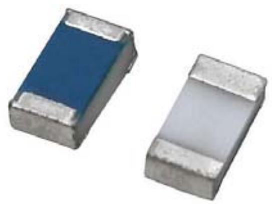
Meter

Fixtures

Fixtures

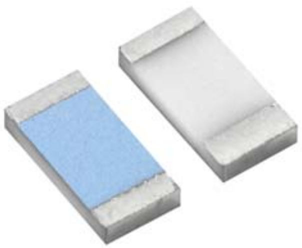
There is More to Resistor Precision than Meets the Eye

- Resistors from different technologies may seem alike on the surface, and may often have similar published specifications (initial TCR, Initial Tolerance etc).
- However, each is made of a different resistive material and produced differently. Inherent resistive material, design and processing variations strongly influence electrical performances, leading to different behaviors after mounting
- For example: resistor stability should be judged by performance under load and temperature in short-term and long-term exposure to different electrical or mechanical parameters.



There is More to Resistor Precision than Meets the Eye

- The Vishay Bulk Metal Foil Resistors division has introduced a demonstration kit that illustrates the differences between Bulk Metal foil, thin film, thick film and wirewound resistor technologies in real time.
- The purpose of the presentation is to provide a perceptible explanation of the primary factors that influence resistor stability in a real environment compared to the specifications on a datasheet.



We Bring Our Technical Seminars To You

- The Foil Resistor division offers seminars on the theory and practice of resistors, including physical and mechanical stress factors.
- We cover such subjects as temperature (known and unknown), pulse, amplifiers, CTE (coefficient of thermal expansion) of the PCB, ESD, surface tension, baking, Thermal EMF, and much more.
- We offer free seminars at preselected sites, or we can come to you and provide training and seminars at your site. We can match the seminar to your needs. Bring your own resistors to the seminar for testing and discuss your specific application with trained experts
- We promise to provide design tools to reduce your cost and at the same time maximize your circuit performances

Wirewound Resistors

- Precision wirewound resistors have the lead wires embedded in each end of the bobbin. A thin narrow ribbon is folded over the resistance wire and then welded to the lead wire so as to weld both the resistance and the lead wires at the same time.
- The result is a resistance wire sandwiched between two pieces of metal ribbon and welded all the way through to the lead wire. The assembler must find the exact point on the wire to get the correct resistance value, then sand the varnish off the wire at that point so that it could be welded.

Wirewound Resistors (Cont.)

- If not welded perfectly, long term reliability can be compromised. then, because the operator cannot find and weld the exact point for high precision, they sand off the varnish over some area of the outer layer of wire and abrade the wire, thereby reducing the cross-sectional area of a small portion of wire which increases the resistance up to the exact value and tolerance required.
- For high precision they may expose the resistor to thermal cycles of high temp to try to stabilize it before they do the final weld and calibration. The sanded wires are also point of potential failure after thermal stressing through life.

Thin Film resistors

- Thin Film (TF) are 250 Å or so of metallic deposition(vacuum deposition or sputtering) on a ceramic substrate.
- They have a temperature sensitive optimum deposit thickness, but making all values at the optimum film thickness severely limits the range of values possible. Therefore, the compromise is to use different depositions (thickness of deposit) for different ranges of values.
- The stability of the film is affected by temperature and time aging of the deposition. This time aging varies with film thickness or resistance value and so is variable throughout the resistance range. It is chemical/metallurgical in nature and includes elevated temperature oxidation of the resistive’s alloy content of the deposition. The Temperature coefficient of Resistance (TCR) is adversely affected by the shift from the optimum film thickness. A high value thin film resistor has a much greater deterioration rate due to the thinner deposition being more responsive to oxidation.

ESD sensitive

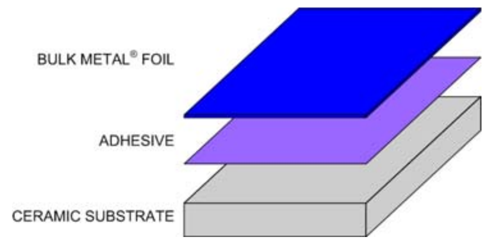
Thick Film Resistors

- Thick film resistor relies on particle-to-particle contact in a glass matrix to develop the resistive track. These points of contact develop the overall resistance but are interrupted by thermal strain during service. Since there are many of them in parallel the resistor does not go open but continuously increases in value with time and temperature combination.

ESD sensitive

Foil Resistors

- 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 photoetched into a resistive pattern. Furthermore, 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.
- Foil resistors achieve maximum stability and near Zero TCR. These performances are built-in for every unit, and do not rely on screening or other artificial means for uniform performances.



Four Temperature Factors

There are four main factors which should be considered when designing a board:

- **TCR**
- **PCR**
- **Thermal EMF**
- **ESD**

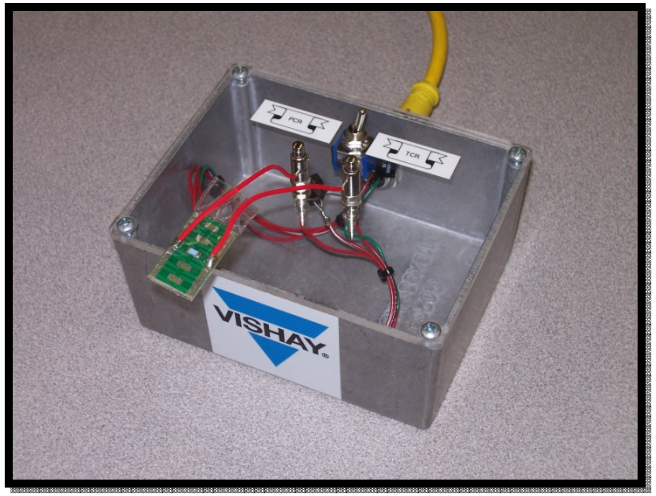
$\Delta T \longrightarrow \Delta R$

Reversible
(TCR, PCR)

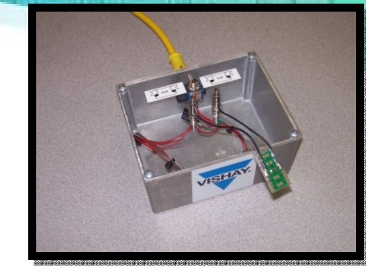
Irreversible
(ESD, Load Life)

Temperature Coefficient of Resistance (TCR)

- Temperature Coefficient of Resistance (TCR) is the best known parameter used to specify a resistor's stability, and is used to depict the resistive element's sensitivity to temperature change due to ambient temperature variations. Temperature Coefficient of Resistance (TCR) will show how resistors behave under cold operating temperatures and high operating temperatures



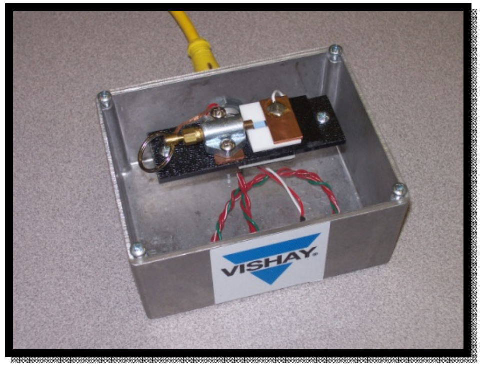
Power Coefficient of Resistance (PCR)



- Power Coefficient of Resistance (PCR) is a lesser-known, but still an extremely important parameter. This parameter quantifies the resistance change due to self-heating when power is applied. All the tested resistors are same size/value and tested under the same conditions.
- Test 1: Power Coefficient of Resistance for discrete resistor. During the test we apply power and measure the ΔR. The demonstration will illustrate the behavior of the resistors under applied power.
- Test 2: Tracking Power Coefficient of Resistance for resistor networks.
  We apply power to a voltage divider with two equal value resistors on the same substrate and measure the ΔR2-ΔR1 ratio tracking.

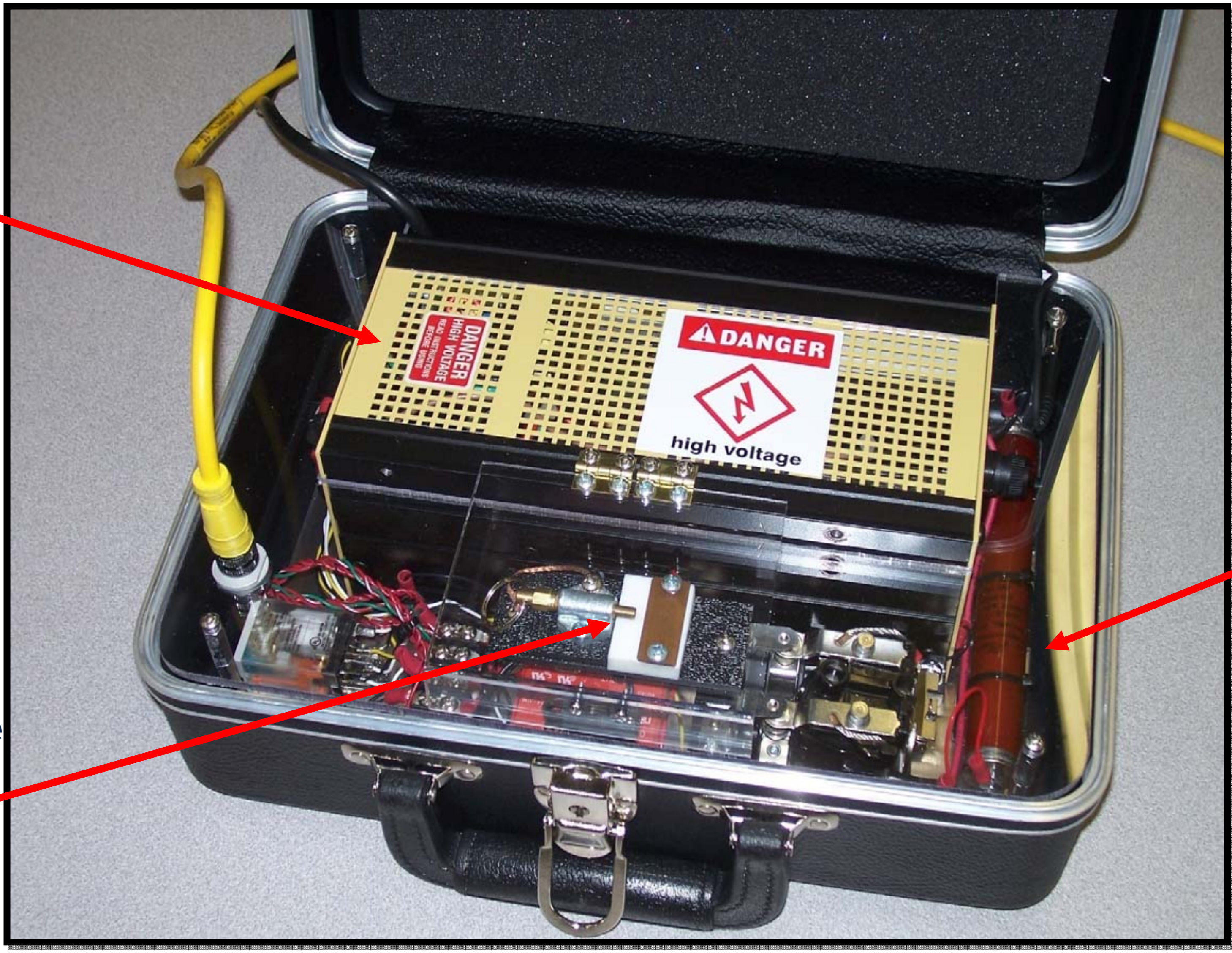
Short Time Overload (Load Life Acceleration)

- Short Time Overload (STO) occurs when a circuit is subjected at one point in time to a temporary, unexpected high pulse (or overload) that can result in device failure. Simulation of load life stability as a function of Power, Temperature and time. Short Time Overload (STO) is an accelerated simulation of load life stability.
- We apply high power for a short time, measure the ΔR, and correlate it to load life stability.



Electrostatic Discharge (ESD)

Power Supply



Capacitor

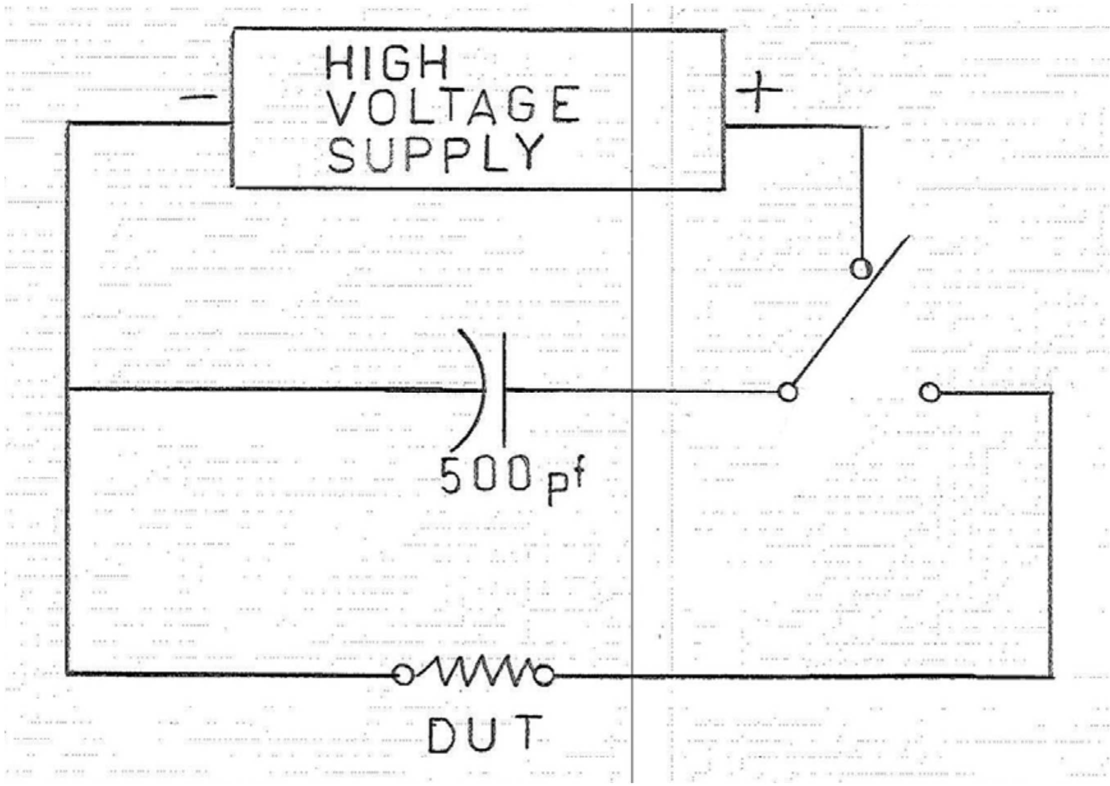
Device Under Test

ESD - Silent Killer of The Electronics Industry

- Electrostatic Discharge (ESD) damage to electronic devices can occur at any point in the component's life cycle, from manufacturing to field service. Generally, ESD damage is classified as either a catastrophic failure or latent defect. A catastrophic failure can be detected when the resistor is tested prior to shipment, but in the case of a latent defect, the damage will go undetected until the device fails in operation.
- A latent defect is more difficult to identify because a resistor that is exposed to an ESD event may be partially degraded, yet continue to perform its intended function. Premature failure can occur after the resistor is already functioning in the finished product for a period of time

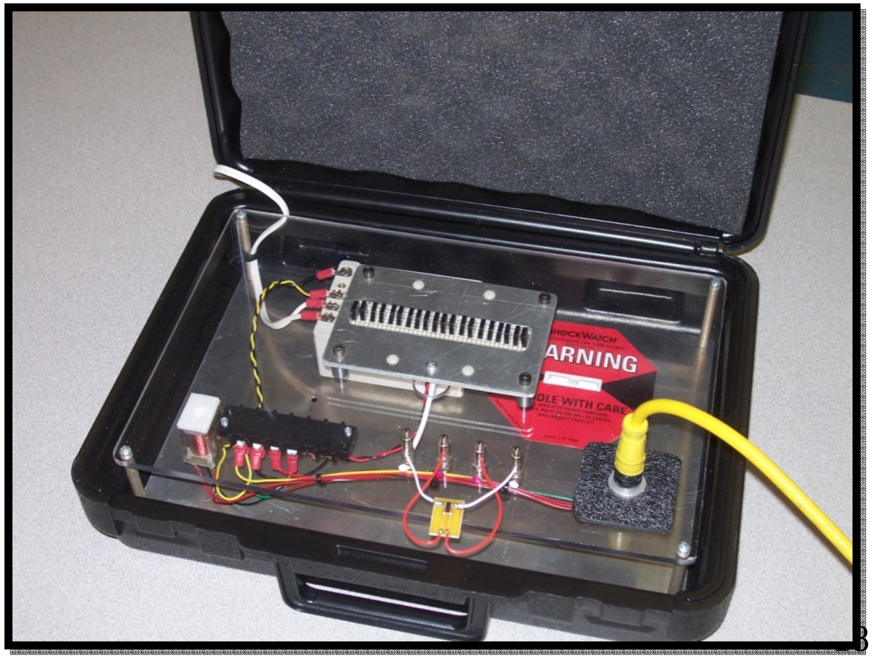
ESD Test

- Electrostatic Discharge (ESD) Test:
  We apply up to 4500 Volts for 500 nano-seconds and measure the ΔR (test data up to 25000 Volts is available)



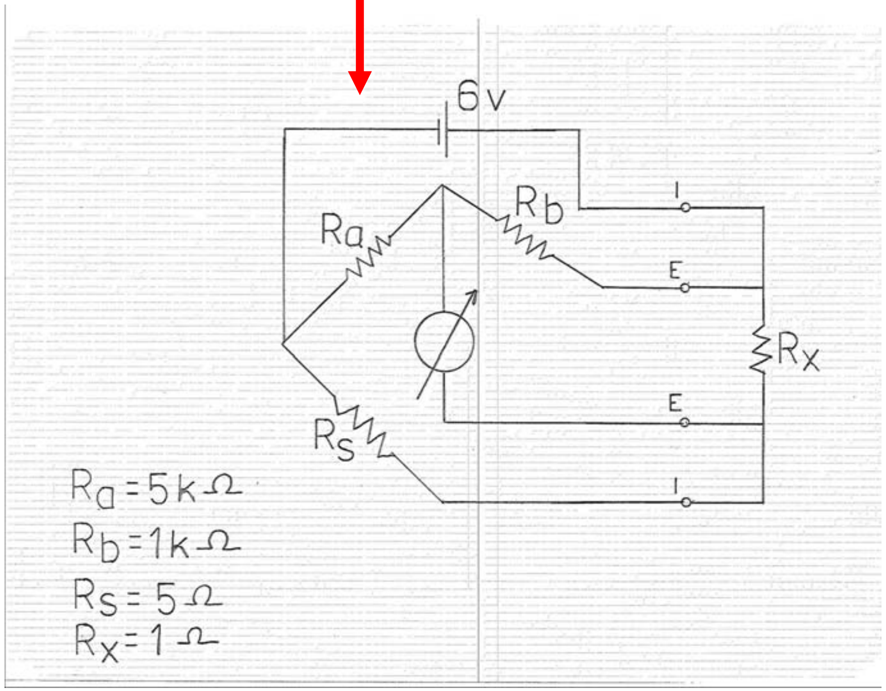
Current Sense: Do I need 2 or 4 Terminals (Kelvin connections)?

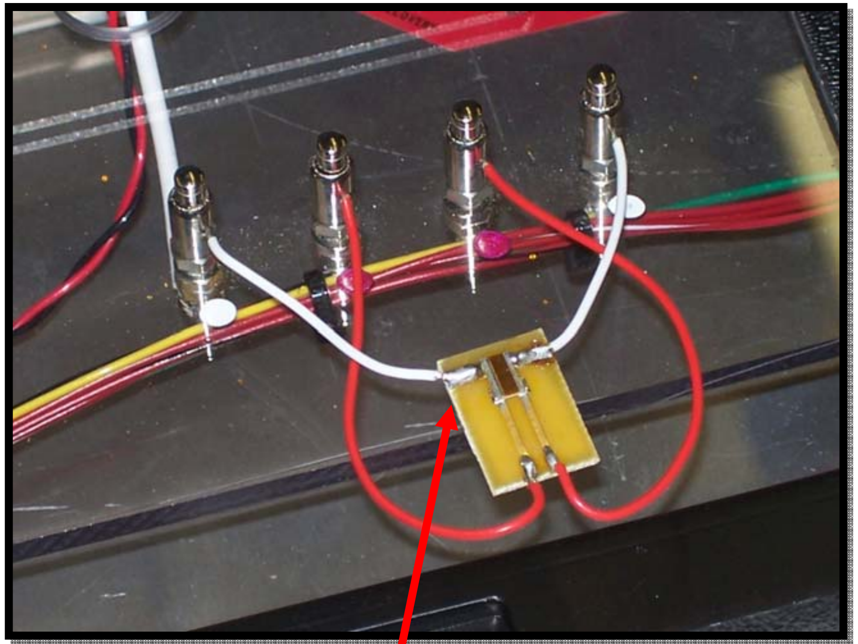
- Power pulse stability for low values typically used in current sensing applications
- We test 4 terminal Kelvin connection resistors and read the resistance change (ΔR) every 25 milliseconds with increasing applied power up to 1 Watt



Power Coefficient of Resistance for Low Values

Circuit diagram





Kelvin connections

Save Money

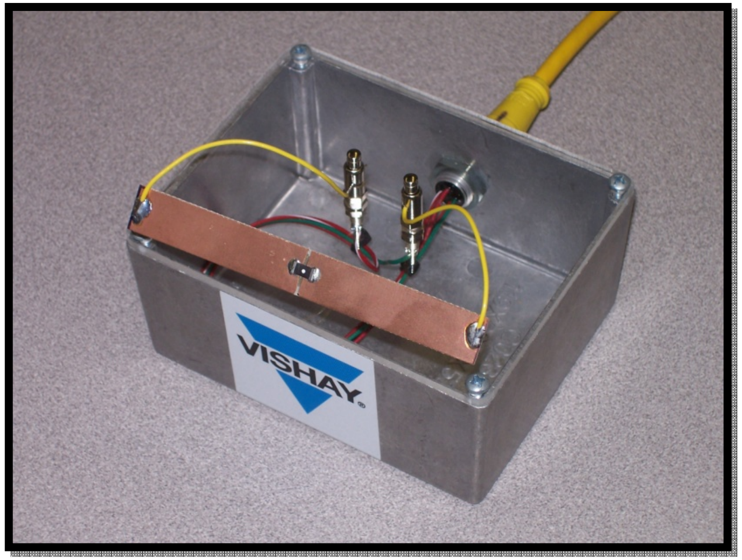
- Save your prototype costs ordering just a few Foil resistors in any value
- Preserve your R&D cash in these hard economic times. There is no need to stock a wide array of precision resistors at minimum order prices when you can buy only what you need and get them within days. And, because this resistor is the most precise resistor available, it will satisfy all your R&D requirements.
- For lesser precision applications on your board, convert back to lesser precision resistors at the production phase when your purchasing dollars can buy the larger quantities at a more economical net cost
- **Foil.@vishay.com**

Thermal EMF (Noise Source)

- Thermal EMF, which is negligible in ordinary resistors, may become a significant noise source of drift or instability in high-precision resistors for low values DC applications, and is considered a parasitic effect interfering with pure resistance.
- It is often caused by the dissimilarity of the materials used in the resistor construction, especially at the junction of the element and the lead materials.
- The thermal EMF performance of a resistor can be degraded by external temperature difference between the two junctions, dissymmetry of power distribution within the element, and the dissimilarity of the molecular activity of the metals involved

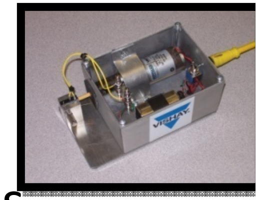
Thermal EMF Test

- Thermal EMF (TEMF): when there is a temperature difference at the junction of two dissimilar metals, such as the lead to resistive element termination, a voltage is generated
- Across the thermocouple junction: this voltage can show up as an instability in low level DC circuits. We measure the thermal EMF voltage of several types of resistors

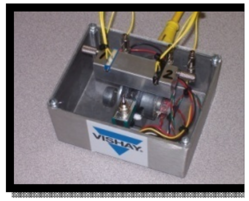


Trimmers

- Trimmer settability and stability tests are performed comparing to other resistor technologies:

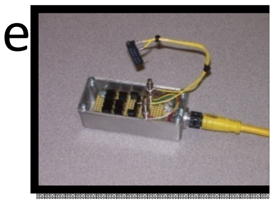


  - **Contact Resistance Variation (CRV)**
    Change in resistance is measured as the trimmer wiper is moved across the element and resistance variation from nominal is shown

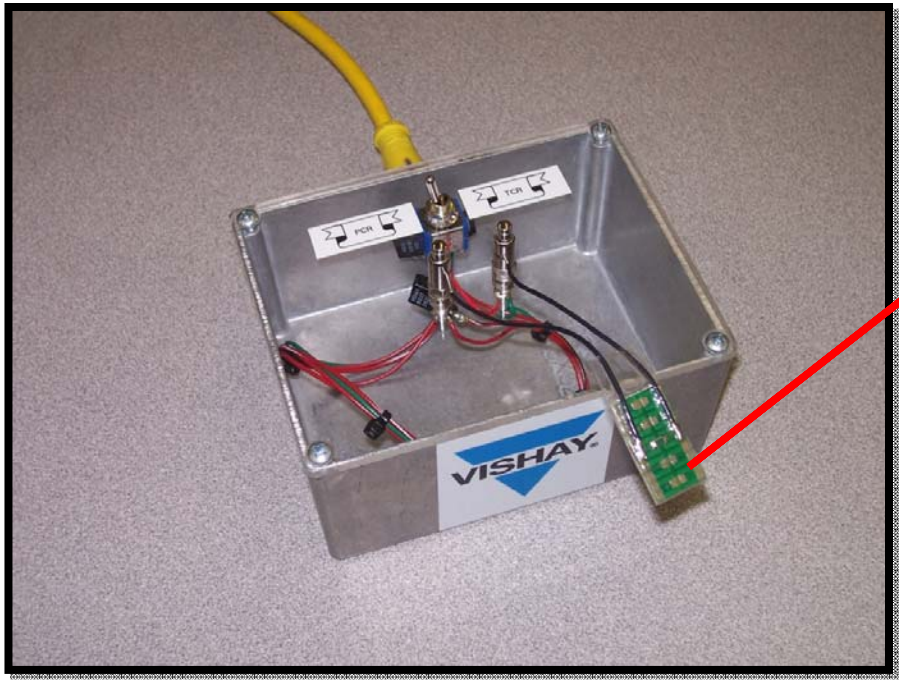


  - **Stability through the wiper**
    Trimmers are set to the middle of wiper travel then vibration is applied for 30 seconds, we measure the resistance change and display the difference

  - **Power TCR (ΔR due to power)**
    PCR is measured through the wiper by applying increasing power and displaying the change in resistance



Thermal Stabilization : 3 Seconds

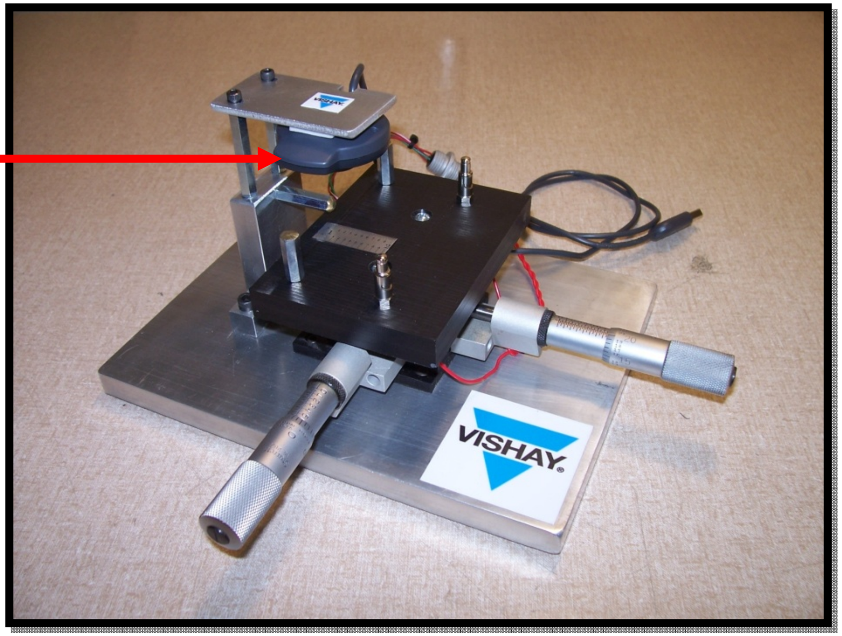


Thick Film
Thin Film
Z-Foil

- An important factor for precision circuits is how quickly a resistor stabilizes at its final value after being subjected to its full rated power
- Demonstration plots the ΔR of a test resistor under full-rated power from 0 – 3 seconds

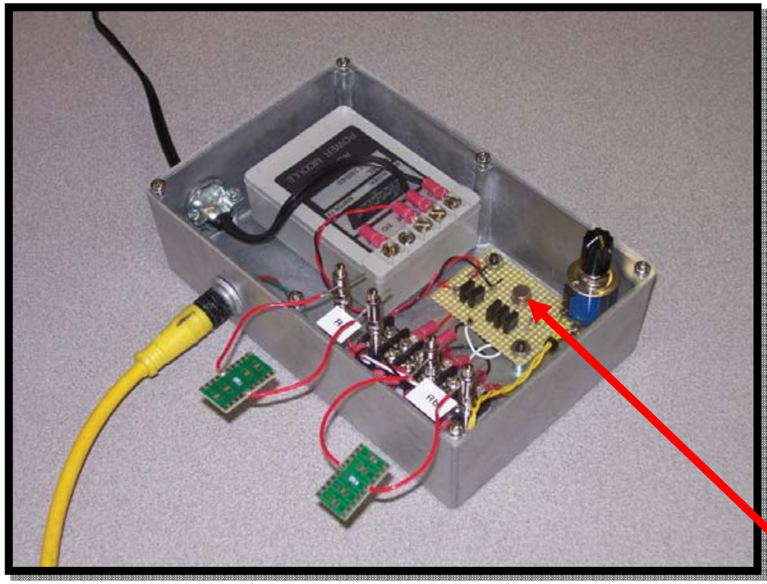
Flexible Terminations Simulator

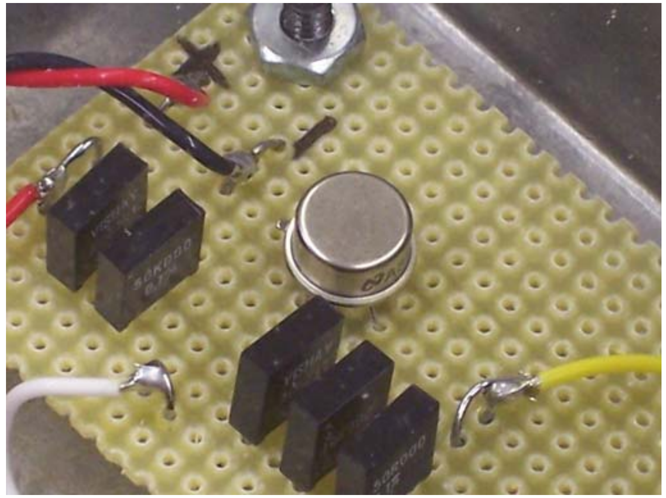
Camera



- Component failure due to PCB flexing and termination failure is a major reliability issue
- The demonstration shows the difference in resistor termination strengths by flexing and measuring mounted resistors

Amplifier

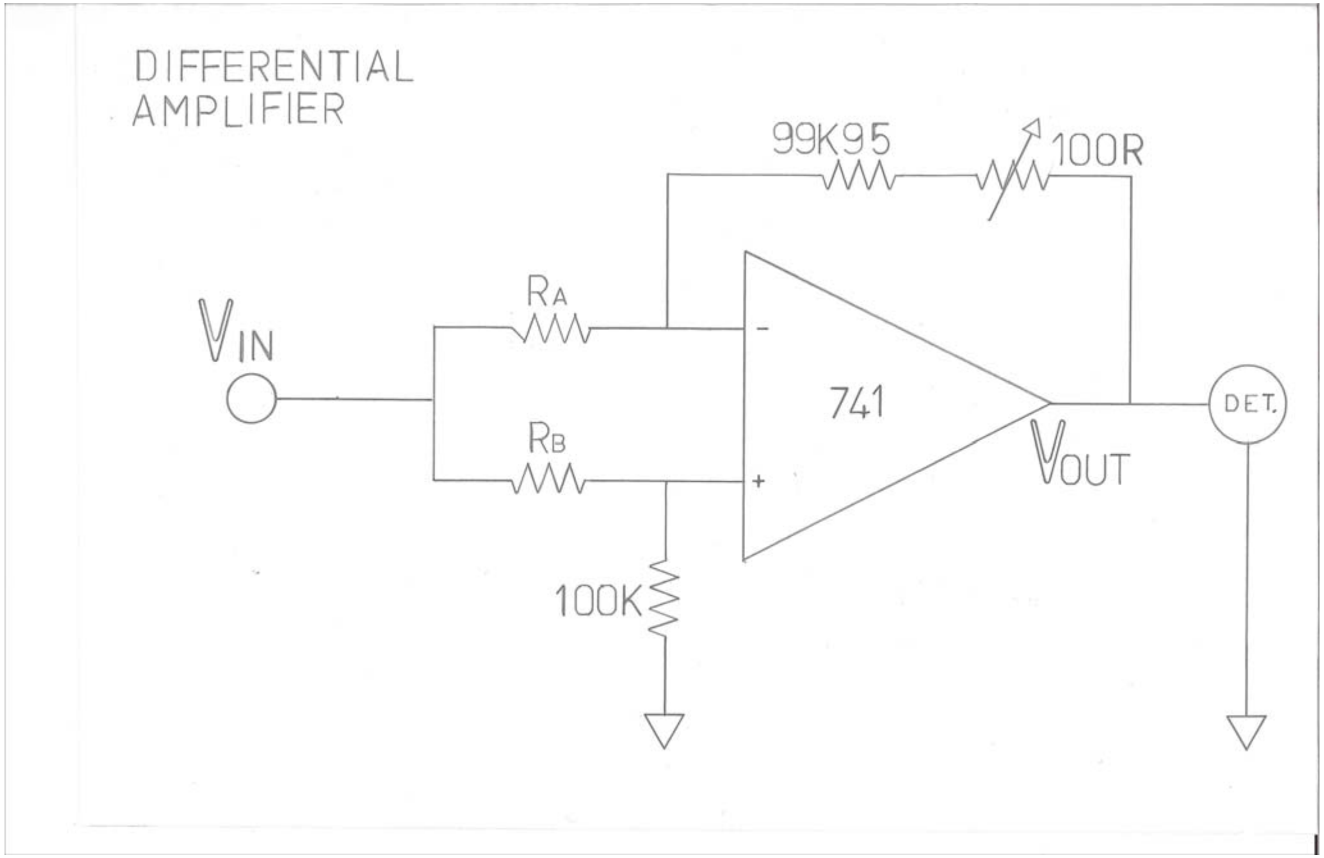




Amplifier

- Amplifier output stability is directly related to the stability of its input bias resistors
- The demonstration shows amplifier output variations when resistors of different technologies are used as bias resistors

Differential Amplifier



"Panic Button" : Prototype Service

Watch our demo kit to understand how the "Panic Button" is feasible

- When you need precision resistors for your prototype, you want them in a hurry … and now Vishay Foil resistors guarantees a 5-working day delivery on any value from 0R001 to 1M. Any tolerance down to 0.005 %.
- This is available through our new "Panic Button" service. For the prototype quantities you need, the very moderate "Panic Button" surcharge is insignificant. What's really important is that you can put your prototype system together faster than ever before … check it out … get it into production … with full assurance that your resistor solutions are completely verified. This is a Vishay spec package that eliminates resistor "trade-off" worries … the only one of its kind

Calibration Station: No minimum quantity and any value within a few seconds

Calibration Station: No minimum quantity and any value within a few seconds

The History of Precision Resistors

- The original Resistor had an ordinary structure. To double its resistance, the old solution was to double its resistive path. The resistor developed by Dr. Zandman was made of a resistive Foil cut so that it forced the current to travel a longer path.
- Vishay Foil resistors are not restricted to standard values. Specific "as required" values can be supplied at no extra cost or delivery (e.g. 100R2345 vs 100R)
- Vishay Foil's design: