Product Group: Vishay Foil Resistors / April 2010

Facts at a Glance

Author: Yuval Hernik
Tel: 972-355-70852
E-mail: Yuval.Hernik@vishay.com

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From Purchased Tolerance to End-of-Life Tolerance: You May Be Buying Tighter-Tolerance Precision Resistors Than You Really Need

The precision of any resistor once it is working in an application usually has little relation to its initial or "purchased" tolerance, i.e. the tolerance listed in specifications and price sheets. The device's purchased tolerance will likely become invalid during the resistor's first few hours' of life, since the effects of storage, assembly, load, and environmental stress can change a ±0.05% resistor very quickly into a ±0.1% or even a ±1% resistor. This is why a designer must take into account a resistor's ability to withstand all the normal and extraordinary stresses which it will undergo before deciding how tight its initial tolerance must be in order to provide sufficient accuracy throughout the life of the equipment in which it is installed.

Once the allowable end-of-life system error is established, a portion of this error is allocated to the resistors and this, in turn, indicates the allowable end-of-life accuracy limits of the resistors. Working backward from the end-of-life tolerance limits, and allowing for all the shifts to be expected from the effects of materials fabrication, assembly, load-life, and environmental stresses, the necessary purchased tolerance or initial accuracy is established, as shown in figure 1.

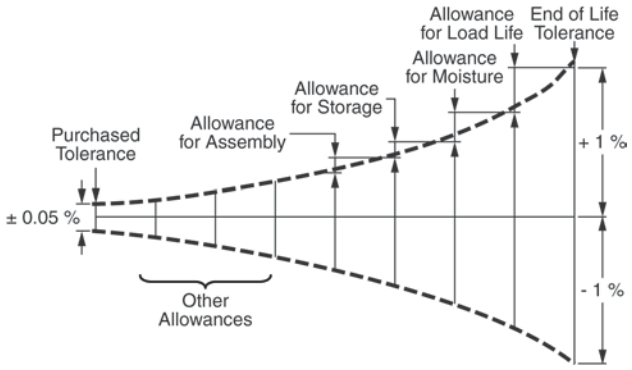


Fig.1

It quickly becomes apparent that end-of-life tolerance cannot be determined and finalized until all the other contributive measures of accuracy have been established. While tolerance itself is of extreme importance, the stability required to maintain that tolerance overshadows the original purchased tolerance when it comes to assessing ultimate end-of-life limits.

The degree to which environmental stresses can cause temporary or permanent changes in resistance depends on the inherent stability of the resistor, which in turn depends on the technology of its design and manufacture. With Vishay Bulk Metal® Foil resistors, only a minimal shift in resistance value will occur during the device's entire lifetime. Most of this shift takes place during the first few hundred hours of operation, and subsequent change is negligible.

The role played by resistor technology is illustrated in Figure 2, which shows the change in resistance (ΔR/R) of three resistors at 500 hours and after 10,000 hours at rated load. The graph shows a precision thin film resistor and a Bulk Metal Foil resistor, both of initial ±0.05% tolerance, and also a Bulk Metal Foil resistor whose initial tolerance is ±0.5%.

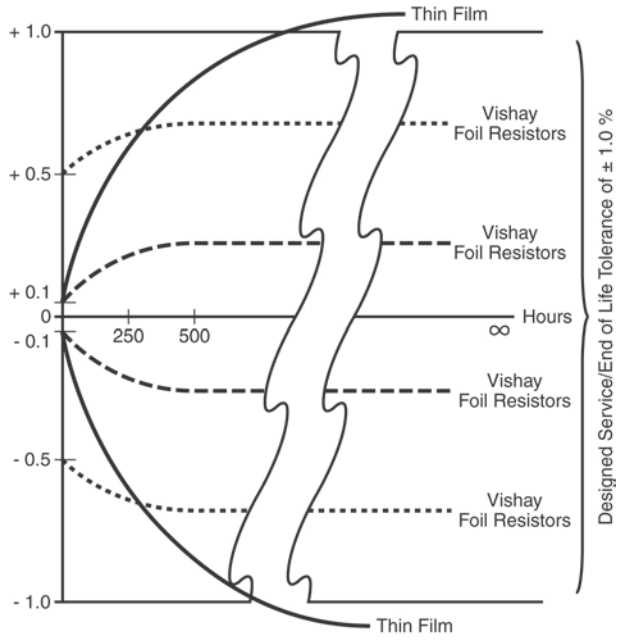


Fig.2

By the zero-hour point shown on the graph, the resistor has been placed in service in the end equipment. Up to this point, a number of degrading factors (such as those shown in Figure 1) will already have occurred and exacted a toll on the purchased tolerance. These contribute to the rapidly rising curve, but probably would not be "seen" until turn-on time.

Given the great stability and very small early resistance shift of the Vishay resistors, it is evident that a ±0.5% Vishay resistor will quickly pay its own way in a design calling for a ±1% end-of-life tolerance, in comparison with a metal-film resistor which must be purchased with a ±0.05% initial tolerance. The apparent initial tolerance advantage of the thin film component is wiped out after only a few hours of service. On the other hand, the Vishay resistor's small initial shift and almost zero shift after burn-in actually assures a tighter and more reliable end-of-life accuracy.

Users of Vishay Bulk Metal Foil resistors get the additional advantages of improved system performance through their unique combination of these optimum resistor characteristics:

- TCR (temperature coefficient of resistance) of ±0.05ppm/°C over the range of 0°C to 60°C, +25°C ref.
- TCR tracking: to 0.1ppm/°C
- Power TCR (Power coefficient of resistance or change of resistance due to self heating – Joule effect): 5 ppm at rated power.
- Tolerance (absolute and match) to 0.001% (10ppm)
- Load life stability to 0.005 % (50ppm) after 2000 h, at +70°C, rated power. (The load-life stability of Vishay Foil resistors can be improved even further using post manufacturing operations.)
- Ideal high-frequency and pulsing characteristics (no inductance or capacitance, rise time as low as 1ns, effectively no ringing)
- Fast thermal stabilization, less than 1 second (nominal value achieved within 10 ppm of steady value)
- Low reactance (that shows up in negligible distortion of pulse signals and in immunity to circuit self-oscillation)
- ESD immunity up to 25,000 V
- Low excess noise
- High linearity: 0.1 ppm /Volt ,voltage coefficient of resistance (VCR)

Shelf-life stability

In designing precision electronic products which may lie unused for many months in un-airconditioned warehouses, the problem of shelf-life stability becomes especially important. Vishay's unique manufacturing process imposes no stresses on the Bulk Metal Foil resistive element that might relax during storage and thus cause shifts in the resistance value. To prove the point, Vishay has kept groups of resistors in un-airconditioned storage for over 10 years. The small changes observed were due almost entirely to moisture pickup during the high humidity summer season, and were almost completely reversed during the cooler low-humidity months. On the basis of such tests and customer feedback, Vishay can guarantee the remarkable shelf-life stability typified by figure 3, showing the consistent ΔR/R envelope in parts per million maintained over 10 years on tested products. Furthermore Vishay Foil Hermetically sealed resistors remove this variable to almost no change to ΔR/R.

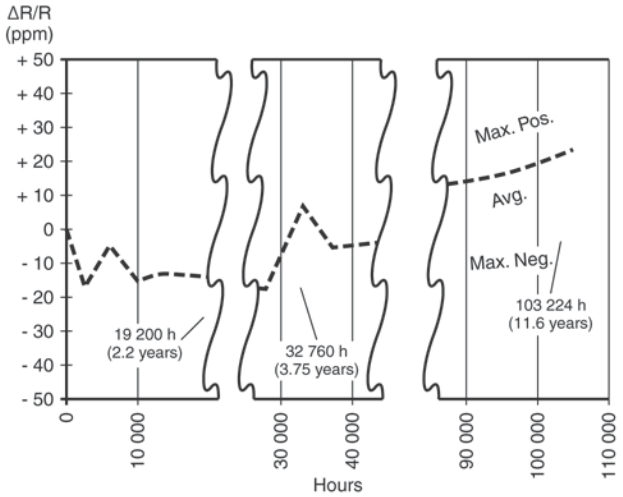
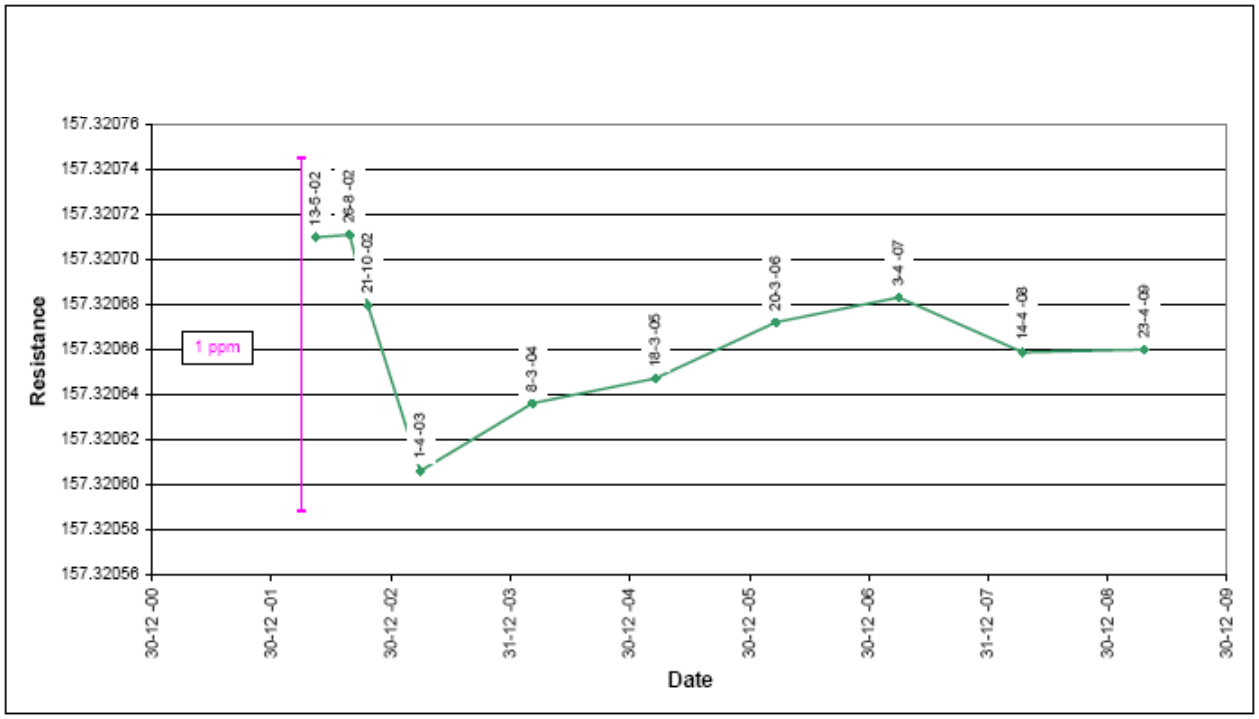
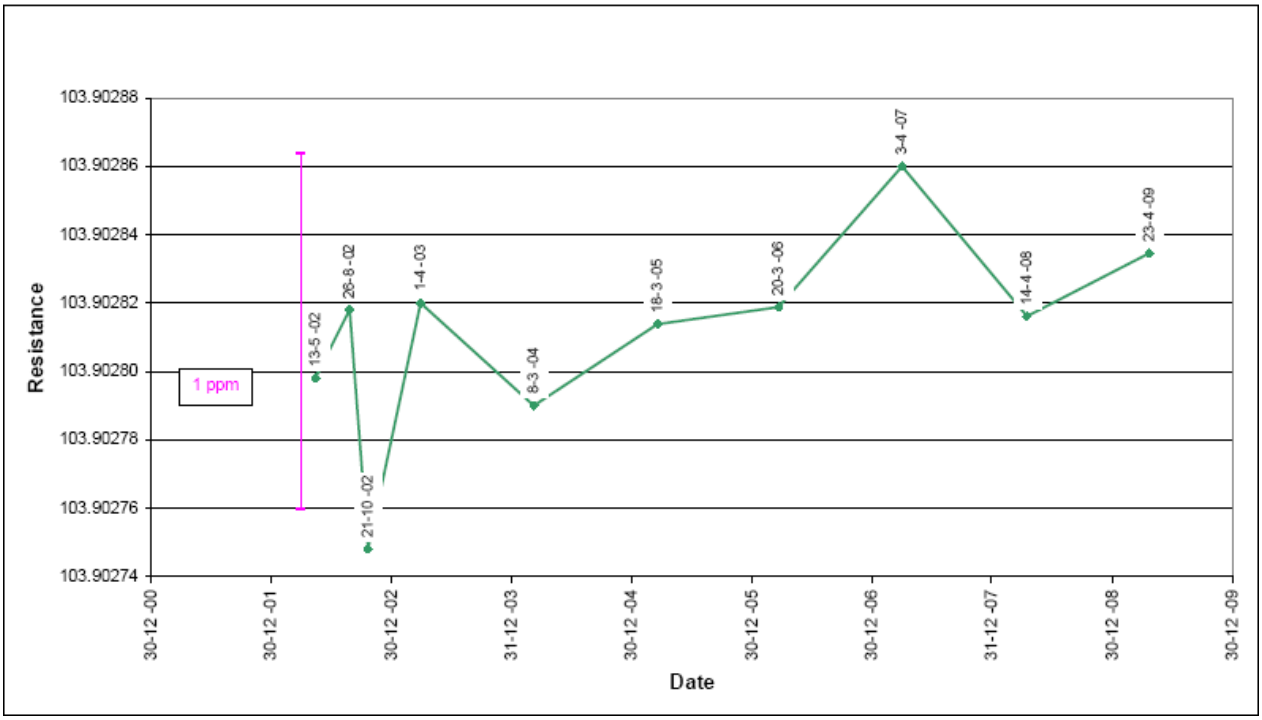


Fig.3: S102C (Foil Resistor) 1kΩ over 10 years, actual tests.

Documented performance from a customer for hermetically sealed VHP101 Foil resistors which have been on test for over 10 years. (*)





(*):ΔR/R Data is available for 30 years shelf-life in non hermetic resistor at non controlled atmospheric conditions is in the range of 25 ppm

How total noise can impact the initial tolerance

Contrary to popular belief, resistor noise is not exclusively a thermal phenomenon. “White noise” in resistors has both thermal and electrical components, caused respectively by the thermal movement of electrons (thermal noise) and the fluctuation of electrical current (fluctuation noise). A fundamentally different type of noise, “flicker” or excess noise, may also be present. Flicker noise has a 1/f type spectral density of voltage (the so-called “pink” noise spectrum). Its level may exceed thermal noise level in the low-frequency band (commonly below 100 Hz). This noise results from interaction of electric current and the resistive element material, and its extent essentially depends on the type of material. Excess noise can be reduced by: a) avoiding use of the low frequency band, b) reducing current across the resistor, c) increasing the volume of resistive material, i.e. by using resistors with a higher rated power than is needed for proper power dissipation), or d) by using less noisy resistive materials. Bulk metals alloys, such as those used in Vishay Bulk Metal Foil resistors, are characterized by the lowest level of excess noise.

Practical implications and application examples

It is quite possible that you are paying a premium for a resistor tolerance that you are not getting in actual real-life usage. Look into all the advantages of Vishay Bulk Metal Foil resistors and you may find that their stability will let you eliminate trimmers and costly active circuitry that you have had to use to compensate for the limitations of your present resistors. You might well be able to upgrade your design and improve your product with a few Vishay resistors whose apparent initial tolerance is one or two orders of magnitude looser than that of the resistors you are now using. Please feel free to call our sales engineering department to discuss your application problems. Who knows? Vishay Foil resistor may be able to save you money while making your own product more stable and saleable.

Bridge Networks: This application calls for three resistors of the most stable technology available with the fourth being the bridge completion sensor monitoring the output from some function being measured. The resistors are matched as closely as possible and mounted in such a way that they are kept at a common temperature in service. This function is best served by Vishay Bulk Metal Foil resistors because of their remarkably low TCR and PCR.

Current Sensing: A very low-value resistor with a four-terminal connection allows the current to pass through the resistor with minimum power loss and still measure the IR drop to monitor the current. Current sensing of very large amounts of current requires a correspondingly large resistor with a suitable heat sink to dissipate the heat generated. Vishay Foil technology lends itself uniquely well to this application because the flat foil is bonded to a thin ceramic backing which can dissipate considerable heat to the sink below.

Differential Amplifiers: The gain of an amplifier needs to be as constant as possible with minimal influence from the outside world. The feedback and sense resistors used in these applications have different heat dissipation and self-heating characteristics. Four or more resistors must be balanced, and this calls for the resistor selection to include similar behavior over a wide range of values. The Vishay Foil resistor satisfies these requirements better than any other resistive technology.

Gyro Navigation Controls: Gyro controls have a mechanical input but require an electronic output to be useful. The electronics are most often in the form of networks of resistors defining the various functions of “on-off detector,” “azimuth control,” etc. These functions are critical to the transfer of information, for which airborne and outer space missions typically provide only one opportunity for success. This is just

one reason that the unequaled precision and stability of Vishay Bulk Metal Foil resistors is a must for gyro navigation applications.

Pressure sensors: Cabin pressure, atmospheric pressure, submersible pressure can all be related to life threatening issues and need accurate and dependable measurement. Generally the output is detection of movement, and if the information is to be transmitted, a bridge circuit is required. Mid-range resistance values keep the power loss to a minimum while affording a respectable level of sensitivity. Vishay Bulk Metal Foil resistors provide an added level of safety by being only marginally affected by temperature and other outside influences on pressure measurement.

Reference Standards and Decade Boxes: Resistance decade boxes were once confined, due to their size, to the laboratory, but today a handful of Vishay Foil hermetic resistors serves the purpose of secondary standards that can be specific to a customer's application. Decade boxes of reasonable size and with six digit accuracy can only be made using Vishay Bulk Metal Foil resistors.

Switching Power Supplies: A fast response to a change in demand requires a network of resistors that are absent of any reactance. Any inductive or capacitive insertion by the resistors will slow the response and could potentially cause a system failure. Vishay Foil resistors have the least reactance of any resistor type.

Telecommunications: In these applications, the paramount requirement is performance at frequency with long term stability. The resistance path in a Vishay Bulk Metal Foil resistor is planar with adjacent conductors in opposing directions. This results in bucking out of the inductance and creating capacitors in series which means very low capacitance and therefore low or no signal distortion.

Weighing Systems: System accuracy is an obviously desirable attribute of any electronic weighing system. Resistors are key to this accuracy and Vishay Foil resistors provide not only the highest level of accuracy but also the highest level of stability available today.

Contact us today for our end-of-life resistor tolerance recommendations for your application.

Foil@vishay.com

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