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Facts at a Glance

Linearity and Noise Capabilities of Ultra-High-Precision Bulk Metal® Foil Resistors

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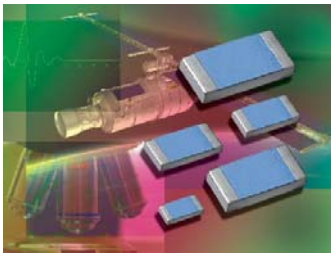
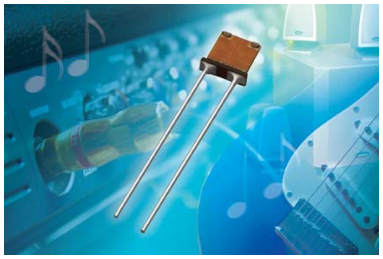
Many manufacturers and users of precision electronic equipment suffer needlessly from unexplained instabilities and drifts due to noise effects. They resign themselves to making constant adjustments and troubleshooting. But in fact these can be avoided.

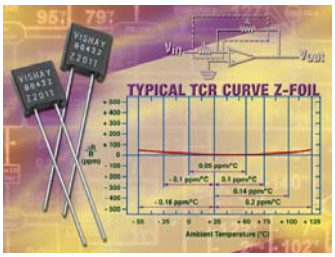
Instability is often traceable to a few supposedly "fixed" resistors which are not really fixed at all. If these resistors would only retain their original values, there would be no need for costly controls and other compensating circuitry. That's why the only resistor for applications such as these is Vishay Bulk Metal® Foil.

Vishay Bulk Metal Foil Resistors possess a set of the features that cannot be found (at once) in any other type of resistor:

- Low temperature coefficient of resistance (TCR): down to ±0.2 ppm/°C and even less
- Resistance tolerance (down to ± 0.001 %)
- Low reactance (that shows up in negligible distortion of pulse signals and in immunity to circuit self-oscillation)
- Load life stability of ± 0.005 % (50 ppm) at + 70 °C, rated power for 2000 hours
- ESD protected up to 25, 000 V
- Thermal stabilization time < 1 second (nominal value achieved within 10 ppm of steady value)
- Low thermal EMF of 0.1 µV/°C
- Low excess noise. (to be explain later)
- High linearity or low voltage coefficient of resistance (VCR)







Bulk Metal Foil resistors owe their low excess noise and high linearity to the type of material they're made of: a metal cold rolled alloy foil with a thickness of several microns.

Every real-world resistor possesses certain nonlinearity of its electrical resistance (nonlinearity of volt-ampere characteristic). The degree of nonlinearity depends on two factors:

- Micro factors: internal microstructure of resistive material.
- Macro factors (laser trimming cuts cleanness, microcracking in resistive element resulting from laser trimming, quality of contacts between resistive element and terminals, etc.).

As for the microstructure, the most linear materials are pure metals and metal alloys in bulk, such as the foil in Bulk Metal® Foil resistors. When the same materials are deposited in the form of very thin (nanometer range) films, they are less linear. Even less linear are composite materials like resistive cermets in thick-film resistors or carbon compositions in carbon composition resistors.

The macro factors that cause nonlinearity in other types of resistors aren't relevant to foil resistors. Indeed, laser trimming of foil resistors consists of cutting shorting jumpers and does not damage current carrying portions of resistive element. Terminals in foil resistors are an integral part of the foil resistive element. This insures high-quality contact between resistive element and terminals.

Several types of noise are found in resistors (Fig. 1):

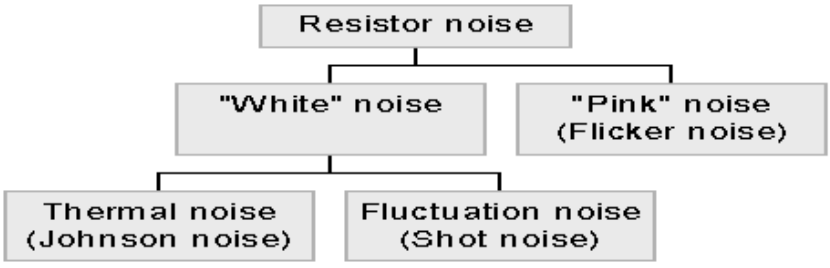


Fig.1

- Thermal noise is caused by thermal movement of electrons in resistive material and gets worse as resistance and temperature increase. Thermal noise can be reduced by reducing resistance, temperature, or signal bandwidth.
- Shot or fluctuation noise is caused by the discrete nature of charge carriers and fluctuation of their number in the unit of volume. Shot noise can be reduced by reducing bandwidth or increasing current.

The spectral density of voltage in both thermal and shot noises is uniformly distributed in entire range of frequencies ("white" noise). The level of these types of noise does not depend on resistor type (resistive element material).

- Flicker (excess) noise has 1/*f* type spectral density of voltage ("pink" noise). Its level essentially depends on resistor material. Excess noise can be reduced by a) avoiding use of the low frequency band, b) reducing current, c) increasing the volume of resistive material, i.e. by using resistors with higher rated power than is needed for proper power dissipation), or d) using less noisy resistive materials.

Carbon composition resistors are the noisiest such device type followed by thick film and thin film resistors. The least noisy are bulk metals and metal alloys (foil, wire). This is why Bulk Metal® foil resistors are such a good choice for low-noise applications.

A tight resistance tolerance, which is an inherent characteristic of Vishay Bulk Metal® foil resistors, can provide many benefits in applications involving low-noise differential amplifiers, which tend to suffer from common mode noise. The common mode noise rejection ratio (CMRR) of a differential amplifier is measured in dB. It depends on amplifier gain and resistance matching in the resistor dividers used in feedback circuits of the amplifier. Let us compare CMRR values in 3 identical amplifiers with unity gain. Suppose that resistor dividers in one of them comprise 1% thick-film resistors, in second - 0.1% thin-film resistors, in third - 0.01% foil resistors. CMRR calculation results are respectively 46 dB, 66 dB and 86 dB. By other words the amplifier based on precision foil resistors will have the best common mode noise rejection ratio.