Facts at a Glance

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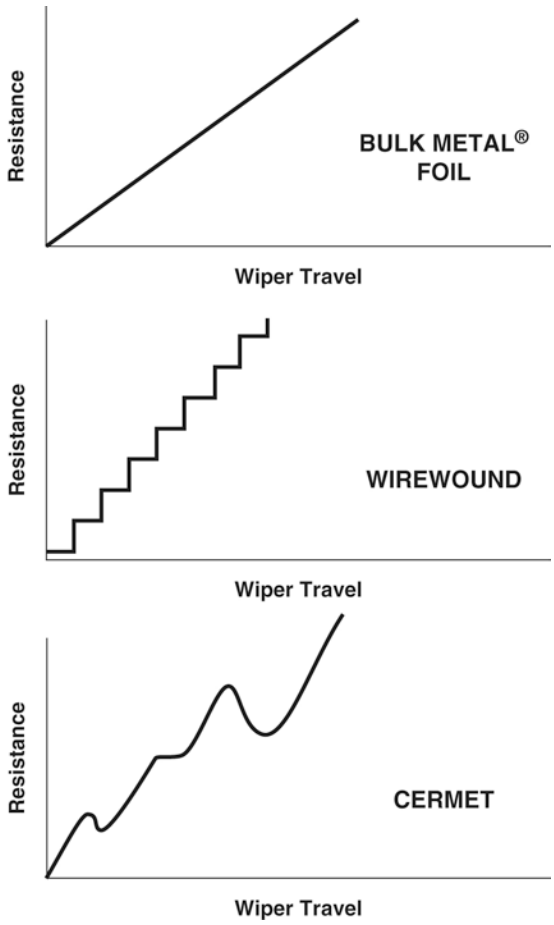
What kind of trimmer is best for my precision application?



Introduction

There are two major categories of adjustable resistors that can be used either as variable resistors or as trimming potentiometers: electromechanical pots and digital pots.

In electromechanical pots, a mechanically driven contact (the wiper) traverses a fixed resistance to tap off a resistance value that is some percentage of the total resistance element.

Digital pots are resistor arrays, sections of which are selectively linked together via CMOS switches to total a desired resistance value. The function of the point of net total resistance is the same as the moveable wiper in the electromechanical pot so it is referred to as the “wiper” even though it has no moving parts.

Either type of pot can be connected as a single two-terminal variable resistor or as two variable resistors, using three terminals to provide a variable ratio with unchangeable total net resistance. Digital pots are usually used to adjust for circuit errors at time of manufacture and are good “set-and-forget” trimmers because there are no moving parts subject to positional changes that would change the intended setting. There are several reasons why these trimmers are not used in precision applications. Most of these relate to the CMOS switches, but some are a function of the resistance elements themselves. The following are among the main reasons that digital pots are not used in precision applications.

1. Wiper current must be limited to less than 1 milliamp, preferably in the microamp range.
2. Wiper resistance is in the tens of ohms and up to more than 1 kΩ; because of this high wiper resistance, the voltage drop in the wiper circuit, depending upon wiper current, could significantly limit the dynamic range of signals carried in the wiper circuit.
3. The temperature coefficient of resistance (TCR) in the wiper circuit is in the area of 300 to 500ppm/’C, causing error voltages of 0.5% with each 10°C rise in temperature.
4. The end-to-end resistance also has a high TCR, from 35ppm/°C to over 1,000ppm/°C depending upon total resistance.

Electromechanical trimmers preferable for precision applications, but not all electromechanical trimmers are equally precise. The degree of precision of which they’re capable can vary widely depending on the technology used for the trimmer’s resistive elements and, to some extent, upon the mechanical stability of the wiper system. Users who have questioned the use of electromechanical trimmers as a consequence of their experience with lower-precision technologies

thus owe it to themselves to consider the capabilities of trimmers based on high-precision Bulk Metal Foil technology, which has a long-term history of reliability and precision in the most demanding applications, such as missiles and avionics.

Vishay's new-generation Accutrim™ trimming resistors provide all the benefits of high-precision foil technology: a smooth and unidirectional output, unprecedented wiper stability, and very low TCR, end–to-end and through the wiper. In this article we discuss their advantages compared to electromechanical trimmers based on other resistor technologies.

The Language of Trimming Resistors

If the device uses three terminals with the center tap picking off the voltage somewhere along the length of the resistance element, it is in the potentiometric mode and is a trimming potentiometer. If it uses two terminals (the wiper terminal being connected to one of the other terminals) and the position of the center tap adds or subtracts resistance, it is in the rheostat mode and is a rheostat. Almost all adjustable resistors are interchangeably called trimmers potentiometers, or rheostats and can be used for either function. Some larger devices are specific to each category.

Construction Details of Trimming Potentiometers

Trimmers today are made in generally standardized sizes with few dimensional variations and only a few technological variations. However, those variations are extremely important because they significantly affect the overall performance of the trimmers. In the following sections we discuss aspects of trimmer construction that represent potential vulnerabilities or strengths, depending on the technology we're talking about.

Moisture Resistance:

The ingress of moisture during board washing has long been a production problem. At one time all trimmers had O-ring seals around the lead screw, but cost pressures drove some manufacturers to use less expensive labyrinth seals and certain temporary sealing methods, none of which were found satisfactory by military and industrial customers. Vishay Bulk Metal Foil trimmers continue to use O-ring seals as the safest protection against ingress of moisture. Vishay Precision Group performs a 100% seal test on all products during manufacturing.

Adjustment Screw Ratio:

The number of turns that a screw has available for adjustment speaks to the intended accuracy of the adjustment. Some trimmers have a coarse thread of only 12 turns of the lead screw to move the wiper across the full length of the resistance element. Vishay Precision Group foil-based trimmers provide 26 turns

for end-to-end adjustment, thereby improving the resolution of adjustment. The foil-based trimmer provides a two-fold advantage in adjustability accuracy.

Adjustment Screw Backlash:

At one time all trimmers had the lead screw spring loaded in the housing, but several manufacturers cut costs by dropping the tensioning spring. Vishay Precision Group Foil continues to tension the lead screw so that backlash is minimized and the product has a higher order of setting stability.

Wiper Noise or CRV (Contact Resistance Variation):

All trimmers introduce noise as the wiper traverses the resistance element. This is particularly objectionable when trying to fine tune an instrument. In the case of wirewound trimmers the noise comes from the single-point contact of a wiper engaging each turn of oxidized wire. To improve this, the industry calls for the CRV to be measured after several passes of the wiper and thus the oxide on the wire breaks down and the noise level eventually improves. The industry therefore insists on several passes before determining noise but this is not practical in real applications where simple tweaking adjustments are required.
In wirewounds, the output is a step function as the wiper moves from one turn of wire to the next. Cermet trimmers have a much higher CRV (as much as 3%) because the cermet element is composed of conducting particles and non-conducting particles in a non-homogeneous matrix formed with a glassy over-glaze that adds high resistance into the wiper contact circuit (CR). As the wiper traverses the element the wiper current shifts back and forth through the matrix, an effect that yields high CRV. (Fig. 1)

Foil trimmers have the advantage of a flat cold rolled foil on a ceramic substrate being engaged by a multi-fingered wiper. While there may be some discontinuities under one finger, the many other contacts even this out and the detectable result is low CR and no measurable CRV. (Fig. 2)

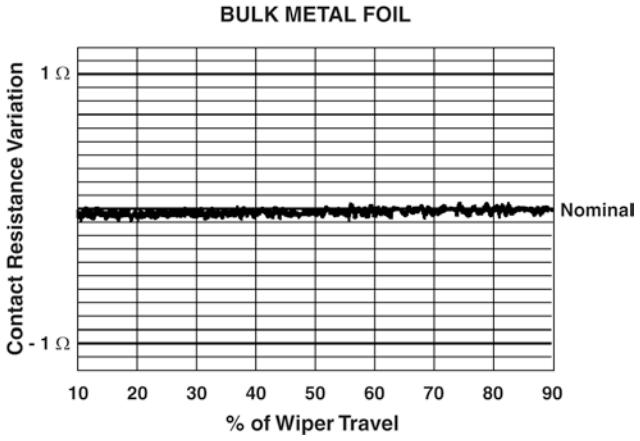


Fig. 2

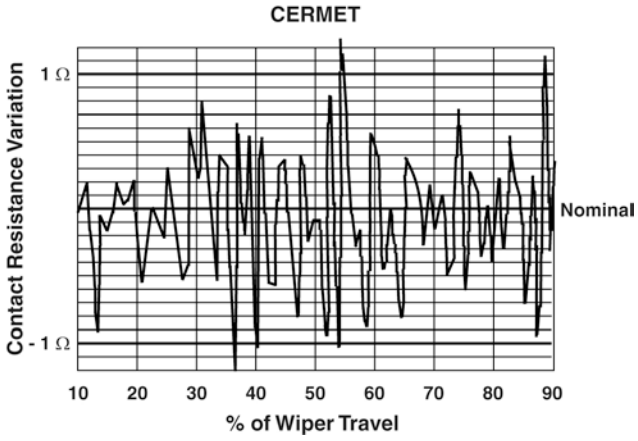


Fig. 1

Thermal Stability:

Most trimmers are built with thermoplastic materials which become softened and deformed when exposed to the high temperatures that are needed to make the labyrinth seals work. Foil based trimmers are made using diallyl phthalate which is a thermo-set material with substantial stability under temperature. The increased stability makes the foil trimmer a preferred choice in down-hole oil exploration and other high-temperature applications.

Other Factors:

The end-to-end **TCR** of foil trimmers (10ppm/°C from -55°C to +150°C) is the best in the industry. Likewise, the very low absolute TCR of foil, and its multi-fingered precious metal wiper making many contacts with the flat resistive element, result in a TCR through the wiper that is even better than the TCR end-to-end of other technologies.

A function of TCR, the **power coefficient of resistance (PCR)** is an important factor to consider when designing circuits with precision requirements. If a designer considers that his circuit will be operating at otherwise constant temperature conditions, he may not consider the effect of TCR. But when power is applied to the trimmer, the resistor element is self-heated in a “Joule effect” that causes a shift in the resistance, regardless of constant external temperatures. The cermet trimmer, with its TCR of 100 to 300ppm/°C, will be affected by small changes in temperature as a result of self-heating. The foil resistor has a lower TCR, therefore it will be affected much less by the same self-heating. Additionally, the bulk properties of the foil element allow it to dissipate more heat, keeping the element temperature lower. This combination of low TCR and lower self-heating leads to very low PCR for the foil trimmer, see Fig. 3

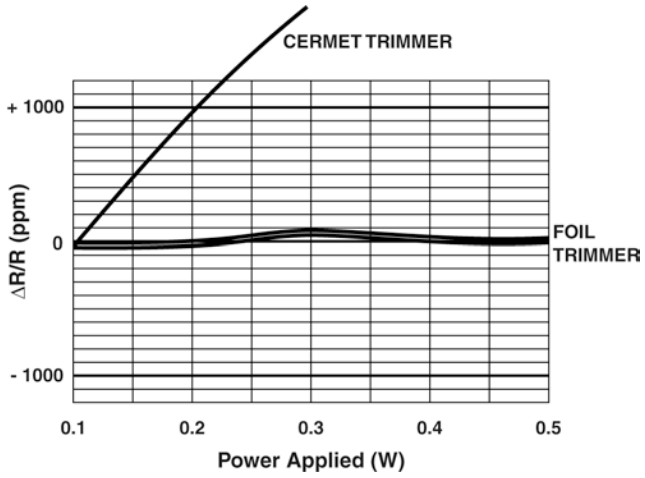


Fig. 3

Vishay foil trimmers have a very low **inductance** (.08 µH). By contrast, a wirewound trimmer is characteristically inductive because its resistive element must necessarily be one continuous length of coiled wire. Foil elements have multiple redundant parallel current paths in a planar formation to reduce inductance.

Vishay foil trimmers are the most **accurate** end-to-end (5%). End terminations are by precisely placed welded contacts, as opposed to the uncertain solder connection in wirewounds or in cermets.

Vishay Foil trimmers withstand a very high number of wiper excursions because of the multifingered wiper employed and thus have an exceptionally long **rotational life** of up to 1000 cycles. Because the cermet trimmer must maintain high contact pressure to reduce the CR through the glassy over-glaze of the cermet element, the rough surface of the cermet introduces exception wear on the wiper. Similarly, the wirewound wiper must maintain high contact pressure to break through the wire oxidation and through the debris that accumulates between the turns of wire.

What are the disadvantages by technology?

Wirewounds

Connection to the outside world: Soldering is the only practical way to connect to a wire that is 0.0004 inches in diameter. Solder is not precisely controllable so the wirewound trimmer has to have a much greater tolerance.

Oxidation of the bare wire: A segment of the wire has to be exposed to permit wiper contact. But when exposed it oxidizes creating an insulation that must be pierced by the wiper resulting in high noise (>100ppm).

Single point contact: The wiper can only touch the wire at one point. The contact is thus susceptible to debris or other causes of noise in addition to wire oxidation (opens).

Insulated/varnished wire is wrapped around a mandrel and the varnish is sanded off along one line at the top where the wiper must make contact. This means that the output resistance can only be sensed in fixed increments related to the resistance of each turn of wire. This is the characteristic step-function resolution of the wirewound technology. The resolution is expressed in percentage and represents the percentage of the total resistance in each turn of wire. The lower the total resistance, the thicker the wire needed along the fixed-length mandrel, the less number of turns along the length of the mandrel, and the worse the resolution.

TCR end to end is 50 ppm/C. TCR through the wiper is not specified. PCR (Power TCR) is also not specified.

Cermets

Contact Resistance Variation (CRV): A carbon shoe (wiper) wobbles up and down the element creating debris and gathering debris. The contact is sometimes at the front of the shoe and sometimes at the back of the shoe. This action is not only a source of noise but also of non-linearity.

Non-linearity: The user attempting to adjust a circuit with a cermet trimmer will find that rotation of the adjustment screw in one direction suddenly produces a change of resistance associated with rotation in the opposite direction. These current reversals make precision setting difficult and add expensive adjustment time to the cost of equipment manufacture.

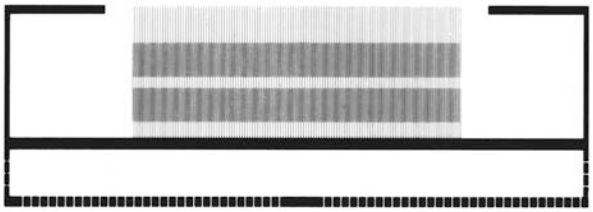
Cermet trimmers also have very high TCRs and PCR and have the highest current noise of any precision trimmer. TCR and PCR through the wiper are not specified.

Mechanical construction: These trimmers are built for price rather than performance and as such use the least expensive materials and designs. Temperature limits and vibration sensitivity are affected.

Bulk Metal Foil (advantages and disadvantages)

Value range: While some may regard the value range of the foil trimmers (5 Ω to 10 KΩ) as a limitation, this is the range for practical adjustment, and circuits requiring higher values bring along a host of other problems. It is better to determine the adjustment range within the total range and use stable Vishay foil trimmers for the adjustment portion of the range.
Price: Viewed as individual components, foil-based trimmers are more expensive than other types, but they save costs down the road compared to trimmers that require more frequent adjustments. A total “solution cost” includes not just the components but also the technician time to adjust the circuit to value initially and then the readjust cost if the instrument is jarred and has to be brought back in for recalibration. Foil trimmers offer the best level of rugged service. Foil trimmers also have the lowest TCR and PCR and maintain their settings better than any other trimmer technology.

Foil Trimmers elements:



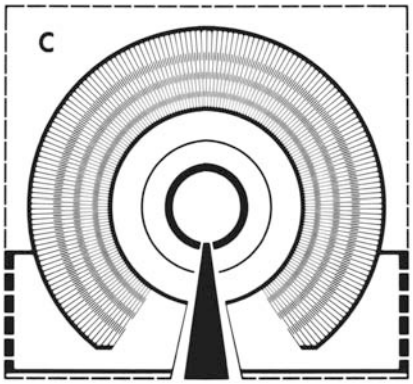


Table 1: Specification comparison of three trimmer types

Performances	Bulk Metal Foil	WireWound	Cermet
MIL style	RJ12/24/26	RT12/24/26	RJ12/24/26
Resistive element	Bulk Metal Foil	Wirewound	Cermet
Resistance range	2Ω to 20kΩ	10Ω to 50kΩ	10Ω to 2MΩ
Tolerance	±5% to ±10%	±5% to ±10%	±10% to ±20%
TCR, end to end	± 10ppm/°C	± 50ppm/°C	±100ppm/°C
TCR, through the wiper	± 25ppm/°C	>>50ppm/'C	>>100ppm/'C
Settability, 10K value	0.05%	0.20%	0.05%
Contact resistance variation, 10K value	3Ω	100Ω	3%
Load life stability, 2000 hours @ +70°C at rated power	0.10%	0.30%	1.00%
Resolution	Infinite	Steps	Dither
Power rating	0.25W to 0.75W	0.25W to 1W	0.25W to 1W
Mechanical travel	22±4 turns	22±4 turns	18 turns ±5
O-ring sealed	Yes	No	No
Rotational life	>1000 cycles	200 cycles	200 cycles
Temperature range	-55°C to +150°C	-65°C to +150°C	-55°C to +125°C

Value Range - Lower Values are Preferred

Some users are accustomed to improving the output linearity and resolution by paralleling the trimmer with one or two resistors (Figure 5). The cost of the additional resistor(s) by itself is insignificant, but the installation cost and the loss of board space can be a factor. Taking advantage of the foil technology, a low-valued foil trimmer in series with a higher-valued fixed resistor (preferably a foil resistor) is the best tradeoff of cost to performance (Figure 6). Viewed this way, the selection of a high-valued cermet trimmer can be a source of noise, instability, and high TCR changes. The cost advantage is not worth the performance risk in most precision applications.

Fig. 5:

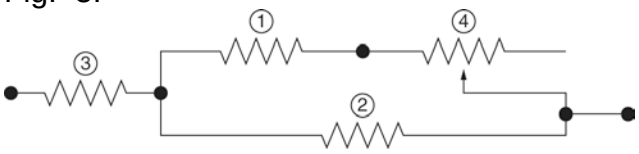
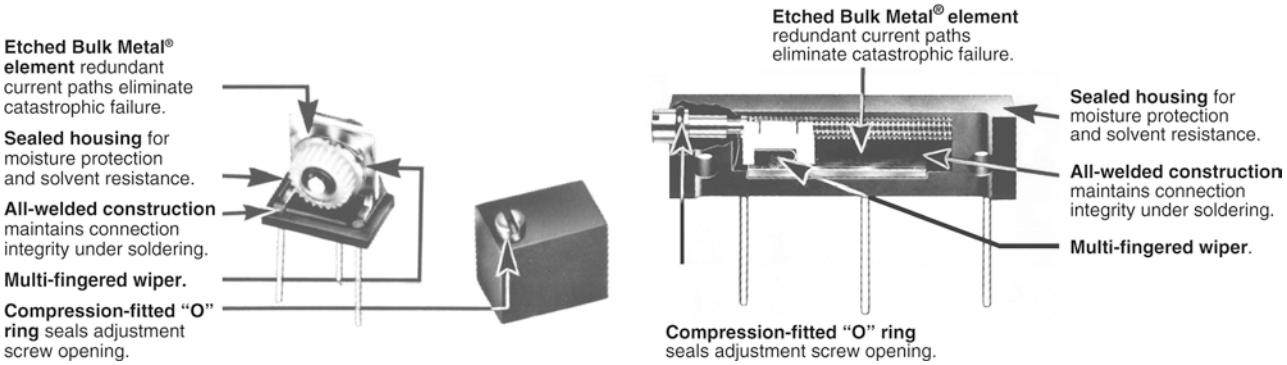


Fig. 6:



All Vishay trimmers are inspected 100% for:

- Short-time overload (6.25 x rated power for 5 seconds on; and for 30 seconds off — 3 cycles)
- Immersion
- Resistance tolerance check
- End resistance
- Visual-mechanical
- Dynamic tests for continuity, CRV

By sample for:
- TCR
- DWV

Conclusions

- Low-value foil trimmers are preferred for precise adjustment (infinite resolution).
- Foil trimmers are preferred when the adjustment must be stable with mechanical vibration and temperature excursion.
- Foil trimmers introduce the least noise.
- An O-ring seal is the surest protection against humidity and contaminants.
- The foil trimmer is the better performing device in most performance categories.
- The value range is appropriate for all rheostat applications because of infinite resolution of low values foil trimmers.
- A selection of styles is available (¼ square, 11/4 rectilinear).
- The designer must specify a “foil trimmer” for superior performance and not leave it to purchasing to select a trimmer by size, configuration, resistance, power, supplier and price if performance is critical in terms of temperature, stability and resolution.
- Samples and technical support are available from Vishay Applications Engineering:

For more information on the AccutrimTM trimming potentiometers, please visit the website to review the following datasheets:

- 1202 (RJ12 Style), please visit http://www.vishay.com/docs/63055/1202.pdf
- 1240 (RJ26 Style), please visit http://www.vishay.com/docs/63053/1240.pdf
- 1242 (QPL), please visit http://www.vishay.com/docs/63052/1242.pdf
- 1260 (RJ24 Style), please visit http://www.vishay.com/docs/63054/1260.pdf
- 1280, 1285G, please visit http://www.vishay.com/docs/63056/12801285.pdf

For further questions, please contact Vishay Foil Resistors at Foil@vishay.com