Resistance Trimmers

Introduction

Resistance trimmers are required when the value of resistance or voltage division in a circuit must be adjusted to compensate for environmental influences, when the desired circuit performance cannot be procured and retained through manufacturing, or it is unknown what precision is required. This applies to precision applications, among others, but in this paper, the selection and use of the trimmer focuses on available performance.

Description

Trimmers are mechanically driven, variable resistors. A wiper is moved across the resistance element, picking off an intermediate voltage in the potentiometer mode, or adding resistance in the rheostat mode. Some models employ a lead screw, while others drive a gear. All models have a clutch at either end of travel to avoid mechanical damage. These mechanical aspects have caused some users to avoid designing with trimmers and are of special concern when selecting trimmers for precision applications. This paper will describe the various types of trimmers available, and how the selection of foil-based trimmers compensates for the deficiencies of other types.

Selection

Trimmers are made with elements comprised of different materials, each with its own set of characteristics.

Wirewound - Trimmers made of wirewound elements are the original trimmers. They have a relatively good end-to-end temperature coefficient of resistance, but are limited in resistance range and display a step function output that is particularly objectionable in the lower values.

Cermet - Trimmers made of screened and fired inks extend the range of values over wirewounds, and have introduced the claim of infinite resolution. However, users have learned that the curve trace is not a smooth and unidirectional change of resistance, and the end-to-end TCR is 100 to 300 ppm/°C.

Other - Several other elements have been tried, but each has its own disadvantages. For example, thin film provides a relatively good TCR, but poor rotational life. Carbon impregnated plastic provides a good rotational life, but high TCR and poor tolerance.

In all the above cases, the TCR through the wiper is not specified (yet extremely important) because it is very high and inconsistent.

Bulk Metal® Foil - With the foil technology, there is a smooth and unidirectional, infinite resolution adjustment for lower ohmic values, and somewhat lesser resolution for values 5 kΩ and above. The foil also achieves a very low TCR end-to-end, and the TCR though the wiper can be specified (and is also relatively low). Further, the contact resistance variation is now reduced through the use of a multi-fingered wiper on a planer surface. Finally, the unique element resistive pattern design minimizes the capacitive and inductive reactance levels. All in all, this has become the trimmer of choice for precise adjustment.

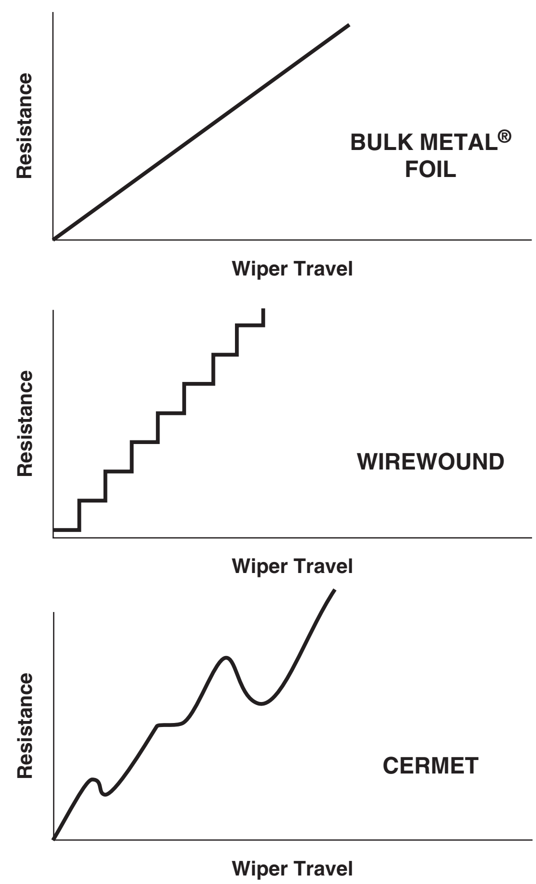

Figure 1.

Resistance Trimmers

Stability - Smooth and Unidirectional Output is Preferred

Figure 1 displays the output to be expected from each of the three major technologies. Notice that the wirewound trimmer provides a step function, with each step increase being the resistance of a single turn-of wire on the wound mandrel. The wiper bumps along from one turn to the next, making an intervening adjustment impossible. This is particularly objectionable in the lower values. The cermet trimmer, on the other hand, displays a somewhat erratic output, causing the user to see increases and decreases while turning the screw in the same direction.

The foil trimmer gives a smooth and unidirectional output with each turn of the screw, and while it is not a perfectly straight line, it is straight enough to defy human detection.

Setting Stability - Once Set, the Output Should Not Change

The wirewound trimmer relies on a single point of wiper contact on a turn of wire, adjacent to another round-wire turn. If the screw is adjusted, leaving the wiper ready to depart from the first turn, in the presence of vibration the wiper will likely engage the adjacent turn for an instability of one resolution (the resolution being the reciprocal of the number of turns of wire from one end of the mandrel to the other). The cermet trimmer may rely on a contact shoe that has some degree of freedom longitudinally, and in the presence of vibration, will "settle in" for a value different than the operator intended.

The foil trimmer has a multi-fingered wiper engaging a planar surface. This construction allows for an interference fit between the lead screw and the wiper block, and the many fingers thus remain in position through vibration. With stability being one of the primary objectives in precision applications, the foil trimmer should be used for a stable setting.

Temperature Coefficient of Resistance - Stability With Temperature

A wirewound trimmer has a fair TCR end-to-end, but cannot be relied upon to demonstrate an acceptable TCR through the wiper. The TCR end-to-end may be 70 ppm/°C, but when adding the potential for a wiper shift of one turn of wire, the TCR through the wiper could be as much as 1 % in a 100 Ω trimmer. The cermet trimmer has the same potential for wiper shift in addition to the TCR, and therefore the TCR is not even specified. The TCR through the wiper is not a practical specification for these devices, yet the user must know what to expect from temperature changes - what the true TCR is through the wiper.

The foil trimmer has a multi-fingered, noble metal wiper engaging a planar surface of etched foil, and the TCR end-to-end is 10 ppm/°C. With some allowance for contact resistance, the TCR through the wiper is 25 ppm/°C. The TCR through the wiper is an important element in the precise adjustment of circuits subject to temperature fluctuations.

Power Coefficient of Resistance

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 ambient conditions, he may not consider the effect of TCR. But when power is applied to the trimmer, the resistor element is heated - this is known as the Joule effect. This self-heating will cause a shift in the resistance, even at ambient external temperatures.

The cermet trimmer, with its TCR of 100 to 300 ppm/°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 allows 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.

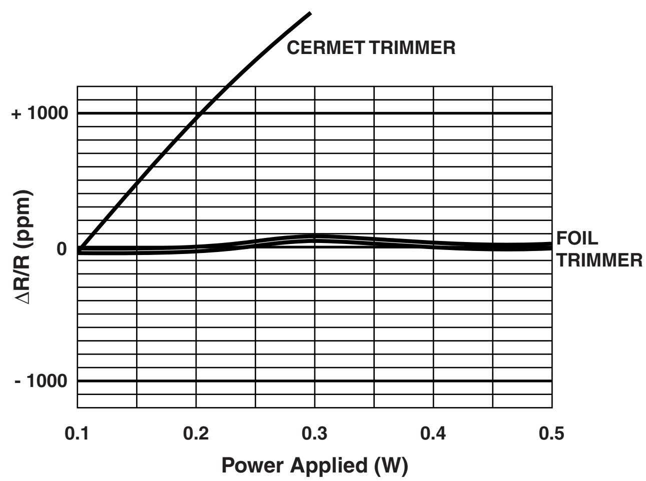

Figure 2.

Low Noise - No Unwanted Signal Generation

Noise generation within a trimmer is generally associated with the contact resistance of the wiper. A potentiometer being adjusted can be seen to have not only the change in resistance due to wiper position, but also the variation in the contact resistance as the wiper is moved over the element. An unadjusted wirewound potentiometer in a steady state can experience spurious signal generation as the oxide on the wire breaks down. The debris under the shoe of a cermet trimmer disperses under the application of voltage with no wiper movement.

The foil-based trimmer, with its noble metal, multi-fingered wiper exponentially reduces the potential for wiper contact noise due to the many fingers in contact at all times with the element.

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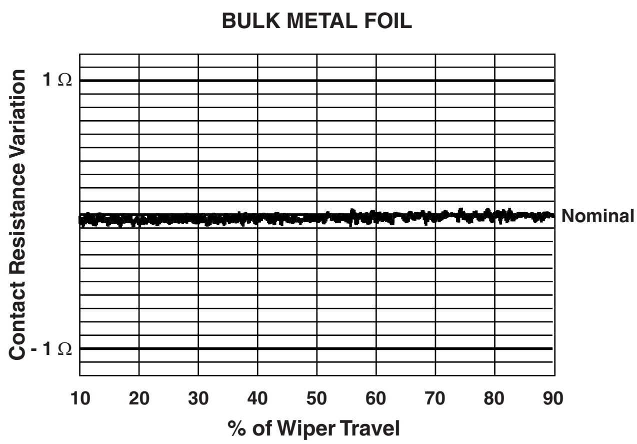

Figure 3.

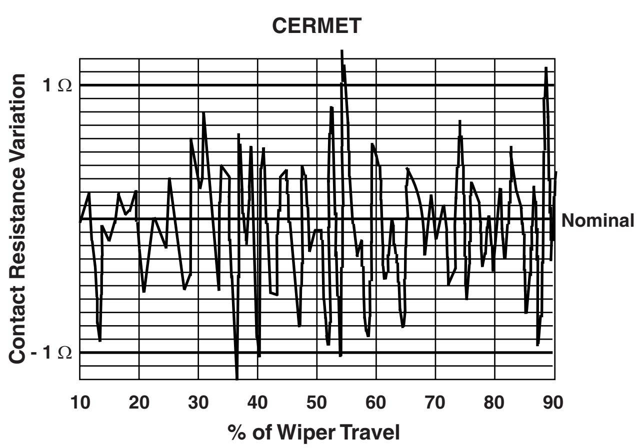

Figure 4.

Low Reactance - No Signal Retardation From Inductance or Capacitance

Like all foil-based resistance elements, the resistive pattern is flat and etched into the foil to produce different values of resistance end-to-end. This affords the opportunity to lay the pattern out in opposing transverse directions, so that the inductance from one line is opposed by the adjacent line (unlike a wirewound element that has current in adjacent turns, creating a field of mutual inductance). Also, the current paths represent capacitors in series, so the lumped capacitance is very low.

Moisture Sealed

All trimmers are hollow and subject to pressure increases when heated and pressure decreases when cooled. As a consequence, the hot liquids in which the board is washed may be drawn into the product when the board is removed into cooler air. Vishay foil based trimmers are equipped with an O-ring that retards this ingress and egress of contaminants, making them safe for board washing.

Summary of Attributes

Collectively, the foil-based trimmer is superior to any other type, and Table 1 shows the comparison in each model range.

Value Range - Lower Values are Preferred

Some users are accustomed to improving the output linearity by paralleling the trimmer with another resistor (Figure 5). The cost of the two additional resistors (or one additional depending on the case) by themselves are not much, 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.

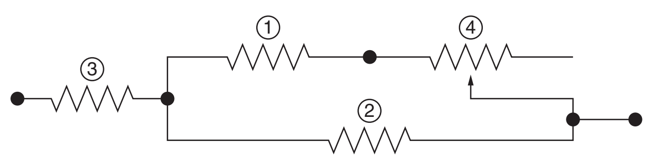

Figure 5. - Conventional Circuit

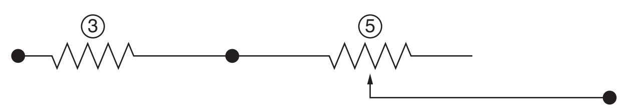

Figure 6. - Circuit with VISHAY Bulk Metal Foil Trimmer

Conclusions

1. Foil trimmers are preferred for precise adjustment.
2. Foil trimmers are preferred when the adjustment must be stable with mechanical vibration and temperature excursion.
3. Foil trimmers introduce the least noise.
4. An O-ring seal is the surest protection against contaminants.

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TABLE 1 - SPEC COMPARISON OF VISHAY BULK METAL FOIL TRIMMERS TO COMPETITIONORS

CHARACTERISTIC	VISHAY 1202	ALTERNATIVE INDUSTRY WIREWOUND TRIMMER	ALTERNATIVE INDUSTRY CERMET TRIMMER	VISHAY 1240	ALTERNATIVE INDUSTRY WIREWOUND TRIMMER	ALTERNATIVE INDUSTRY CERMET TRIMMER
Size		1 1/4"			1/4" Square	
MIL style	RJ12	RT12	RJ12	RJ26	RT26	RJ26
Element	foil	wirewound	cermet	foil	wirewound	cermet
Resistance range	2 Ω to 20 kΩ	10 Ω to 50 kΩ	10 Ω to 2 MΩ	5 Ω to 10 kΩ	10 Ω to 25 kΩ	10 Ω to 1 MΩ
TCR end to end	10 ppm	50 ppm	100 ppm	20 ppm	70 ppm	100 ppm
TCR through the wiper	25 ppm	not specified	not specified	50 ppm	not specified	not specified
Setability, 10K value	0.05 %	0.34 %	0.05 %	0.005 %	0.29 %	0.05 %
Contact resistance variation, 10K value	3 Ω	100 Ω	100 Ω	3 Ω	100 Ω	300 Ω
Load life stability	0.001	0.02	0.03	0.005	0.02	0.03
Linearity	infinite	steps	dither	infinite	steps	dither
Power rating	0.5 W	1.0 W	1.0 W	0.25 W	0.25 W	0.25 W
Adjustment turns	25	22	22	21	11	12
"O" Ring sealed[1)]	Yes	No	No	Yes	No	No
CHARACTERISTIC	VISHAY 1260	ALTERNATIVE INDUSTRY WIREWOUND TRIMMER	ALTERNATIVE INDUSTRY CERMET TRIMMER	VISHAY 1280G	ALTERNATIVE INDUSTRY WIREWOUND TRIMMER	ALTERNATIVE INDUSTRY CERMET TRIMMER
Size		3/8" Square			3/4"	
MIL style	RJ24	RT24	RJ24			
Element	foil	wirewound	cermet	foil	wirewound	cermet
Resistance range	5 Ω to 10 kΩ	10 Ω to 50 kΩ	10 Ω to 2 MΩ	10 Ω to 20 kΩ	10 Ω to 50 kΩ	10 Ω to 2 MΩ
TCR end to end	10 ppm	50 ppm	100 ppm	15 ppm	50 ppm	100 ppm
TCR through the wiper	25 ppm	not specified	not specified	50 ppm	not specified	not specified
Setability, 10K value	0.05 %	0.17 %	0.05 %	0.005 %	0.30 %	0.05 %
Contact resistance variation, 10K value	3 Ω	100 Ω	100 Ω	3 Ω	100 Ω	100 Ω
Load life stability	0.001	0.02	0.03	0.005	0.03	0.04
Linearity	infinite	steps	dither	infinite	steps	dither
Power rating	0.25 W	1.0 W	0.5 W	0.75 W	1.0 W	0.75 W
Adjustment turns	21	25	25	26	20	15
"O" Ring sealed[1)]	Yes	No	No	No	No	No

Notes

1. Potentiometers are hollow and an "O" ring prevents the ingress of fluids during any board cleaning operation

- Foil's multifingered wiper has a very high natural frequency allowing the pot to retain its setting under vibration much better than other devices