VCR Characteristics of High Voltage Thick Film Resistors

Resistor Business Unit – TT electronics Welwyn

1.0 Introduction

Voltage coefficient of resistance (VCR) is an important characteristic of high voltage thick film resistors. It can be defined as the change in resistance of a component with respect to the voltage applied over a specific voltage range.

In general thick film ink consists of conductive material suspended in an insulating matrix. As the voltage across the ink is increased new conducting paths are opened resulting in a drop in resistance. Hence VCR is always negative in value and is expressed in parts per million per volt (ppm/V):

$$VCR = \frac{R_2 - R_1}{R_1 (V_2 - V_1)} \times 10^6$$

Where:
R_2 = Resistance @ test voltage (ohms)
R_1 = Resistance @ reference voltage (ohms)
V_2 = Voltage @ test voltage (volts)
V_1 = Voltage @ reference voltage (volts)

Hence for high voltage applications VCR can have a significant impact on the accuracy of a component. In order to try and reduce this effect, component manufacturers are continually striving to improve resistor designs and materials.

2.0 Factors Influencing VCR

Figure 1 shows the typical construction of a high voltage thick film resistor.

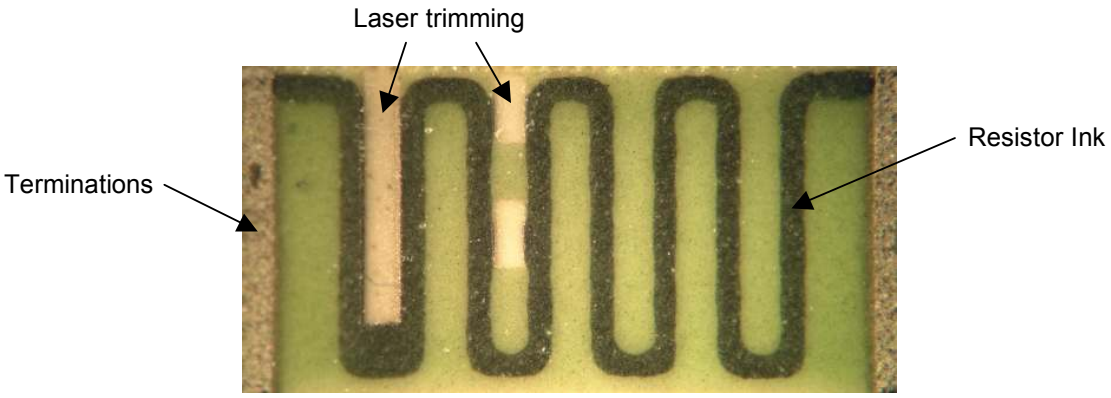

Figure 1: Typical high voltage thick film resistor construction (unprotected)

There are many factors which can influence the VCR:

- Ink resistivity - the less resistivity, the lower is VCR
- Layout and size – increasing the resistor length reduces the voltage per unit of length.
- Termination material – Must be correctly matched with resistor ink
- Trimming geometry – hot spots can be produced

VCR reported for a variety of different parameters is given in Figures 2a to 2d [1-2].

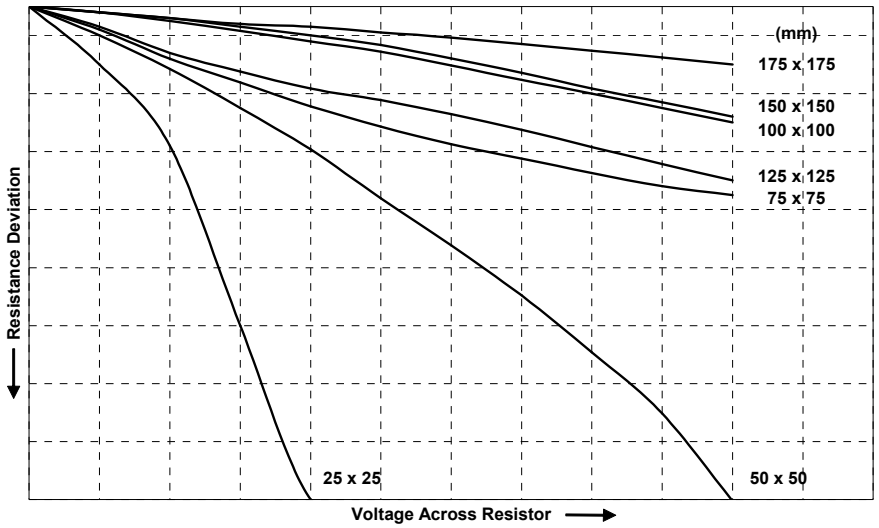

Figure 2a: VCR dependence on resistor geometry

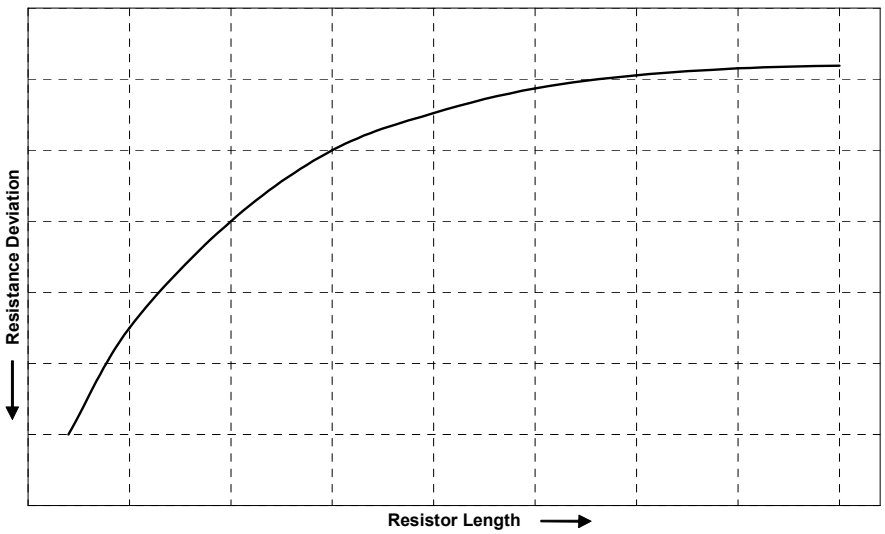

Figure 2b: VCR dependence on resistor length

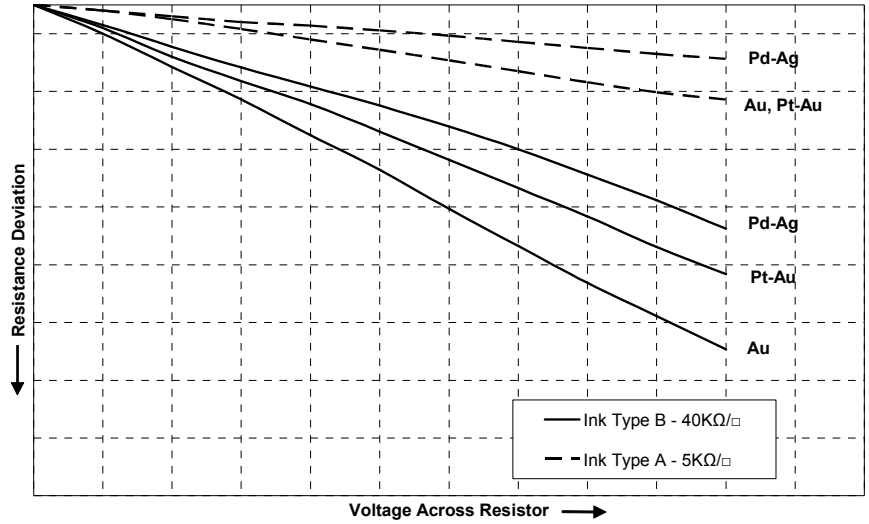

Figure 2c: VCR dependence on resistor ink and termination material combination

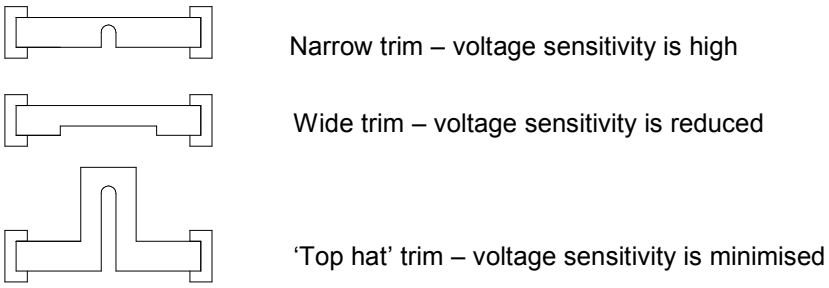

Figure 2d: VCR dependence on trimming geometry

From the above figures it is obvious that the effect of voltage can be significant under certain conditions. Only a few volts can be enough to produce considerable resistance changes, both temporary and permanent, in many situations. Any combination of high ohms per square compositions, small resistors and voltages over a few volts are situations where the effect of voltage can be significant. In order to minimise this effect it is essential that correct component design and materials selection are employed.

3.0 Welwyn Components 439050-30M High Voltage Chip Resistors

The 439050 high voltage chip resistor is specifically designed to minimise the effects of VCR. By combining an improved resistor design with optimum materials selection, VCR effects have been substantially reduced, giving a repeatable batch to batch performance of better than -2ppm/V over a working voltage of 2500V, see Figures 3a to 3b.

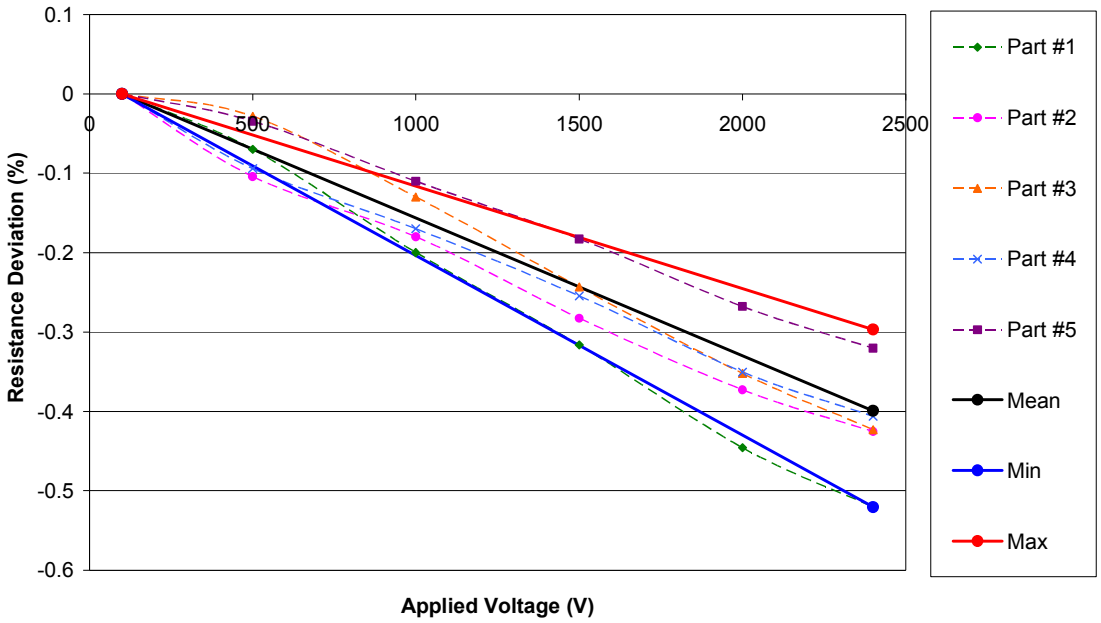

Figure 3a: VCR Characteristic of the 439050-30M resistor – Batch A

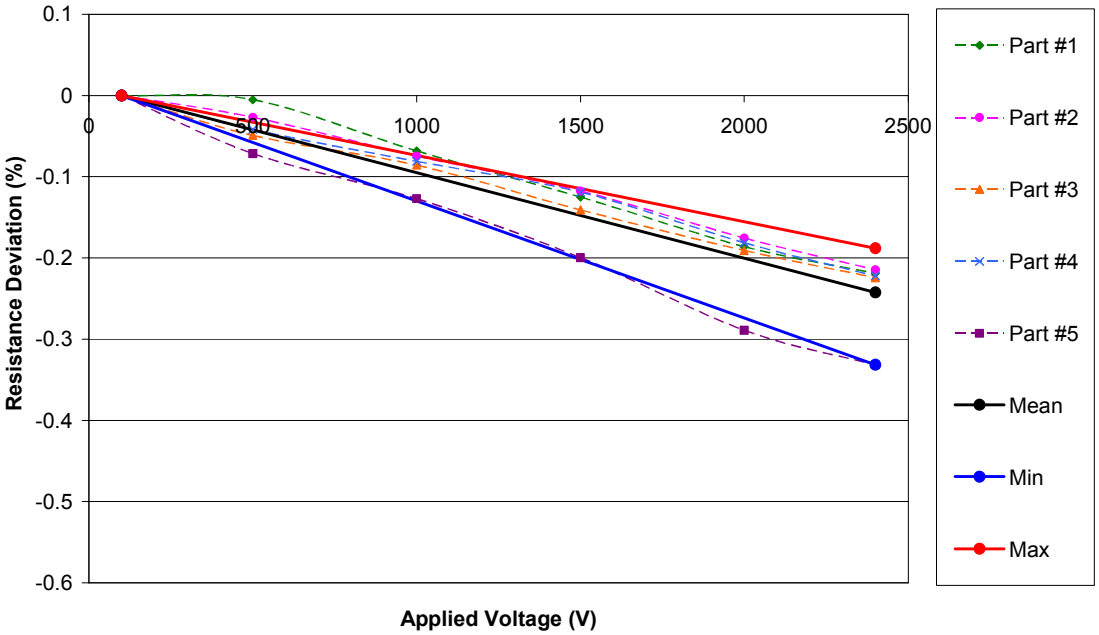

Figure 3b: VCR Characteristic of the 439050-30M resistor – Batch B

Notes:
1.) Dashed lines show the resistance deviation from the resistance value measured at 100V of 5 individual parts measured at 500V, 1000V, 1500V, 2000V and 2400V.
2.) Solid lines show the Min, Mean and Max resistance deviation from the resistance value measured at 100V for a sample of 20 parts measured at 2400V.

4.0 References

1. Isaak, O (1970) Voltage Coefficient of Resistance (VCR) of Thick Film Resistors, *Proceedings of the ISHM Symposium,* Pg 8.7.1

2. Herbst, D & Greenfield, M (1969) Voltage Sensitivity vs Geometry of Thick Film Resistors, *Proceedings of the ISHM Symposium,* Pg 345

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