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Low Current Noise Resistors

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Introduction

One of the most distinguishing characteristics between thin film and thick film resistors is their current noise. Thin films are markedly superior in this respect, in general, because of the homogeneous nature of thin film materials. The higher noise levels usually associated with thick films are a consequence of their heterogeneous structure, resulting from the particulate nature of the conducting phase. Experience indicates that minimum current noise is closely associated with a smooth, uniform constriction-free flow of current. These conditions are not as well met in composite, thick film materials. However, there are great variations among different thick film resistors. The most readily apparent relationship is between noise level and the amount of conductor phase present. Everything else being equal, compositions with higher concentrations, that is, lower sheet resistivity, have lower noise levels. The capability of depositing thick film inks in very fine lines presented an opportunity to fabricate resistor using much lower resistivity than would otherwise be the case, and thereby, possibly achieving significantly lower noise levels. Although this concept appears straight forward, its implementation has some potential difficulties. The most serious is related to the physical irregularity of the edge of the trace. Such irregularity, resulting in non-uniform current flow, should increase current noise. The effect should be proportionately greater, the narrower the line. Another drawback is the fact that in converting from a low aspect ratio block type design to a serpentine type, the total area occupied by conductive film is reduced by the amount of the space between lines. This by itself should result in higher current noise since current noise is a statistical phenomena which is related to total number of charge carriers available within a resistor element; the fewer the total number of carriers present, the more apparent will be a given amount of statistical fluctuation. Although the use of fine line-low resistivity combinations by itself should lower current noise, other factors act in such a way as to raise the current noise.

Experimental Design

The concept was tested using a series of decade-value inks deposited in a series of patterns having aspect ratios (length/width) which differ by decades. A 6-mil orifice was employed to produce lines of different width (single, triple and sevenfold). Each resistor pattern occupied approximately the same overall area (160 x 200 mil) between terminations printed on 200 mil centers, and was approximately 330, 33 and 3.3 unit squares respectively. The 330 unit square element consisted of a single, 6 mil wide serpentine. The 33 square pattern was composed of three 6 mil lines in parallel. The 330 square pattern was composed of seven 6-mil lines in parallel. All samples were fired using the standard 850°C profile and measurements of resistance and current noise index were made. Commercial, ruthenium-based thick film inks were used. The patterns are shown in figure 1.

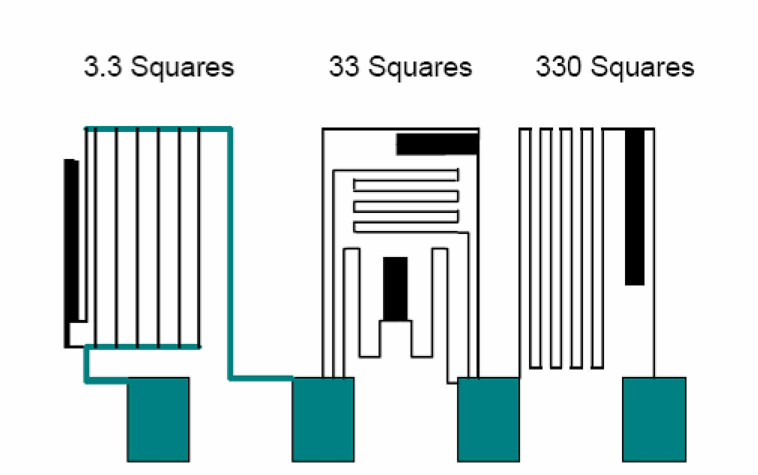

Figure 1
Patterns of 3.3, 33 and 330 square resistors on 200-mil centers

The resistance values obtained with various combinations of sheet resistivity and effective line width are shown in Table 1.

Aspect ratio (unit squares) ► **Total line width (mils) ►** **Sheet resistivity (Ω/□)**	3.3 40	33 18	330 6
30Ω/□			9KΩ
300Ω/□		6.6KΩ	77KΩ
3KΩ/□	9 KΩ	73KΩ	870KΩ
30KΩ/□	93KΩ	735KΩ	9.5MΩ
300KΩ/□	647 KΩ	6.2MΩ	

Table 1
Resistance value for different combinations of sheet resistivity and aspect ratio

Resistors of roughly equivalent value (positioned diagonally in Table 1, highlighted in like colors) were compared based on current noise index and this information is shown in Table 2 and Figure 1. As hypothesized, elements made with the finer line, in a higher aspect ratio design and lower sheet resistivity, had a substantially lower current noise index than elements of similar resistance made with wider lines and higher sheet resistivity.

The trace deposited by direct-write is very uniform in cross section and has very smooth edges. Equivalent results may not be obtained in fine lines produced by screen-printing.

Aspect ratio (unit squares) ▶ Total line width (mils) ▶ Sheet resistivity (Ω/□)	3.3 40	33 18	330 6
30Ω/□			-38db
300Ω/□		-26db	-28db
3KΩ/□	-18db	-20db	-20db
30KΩ/□	-10db	-11db	-8db
300KΩ/□	+1db	+2db	

Table 2
Current noise index (db) for combinations shown in Table1

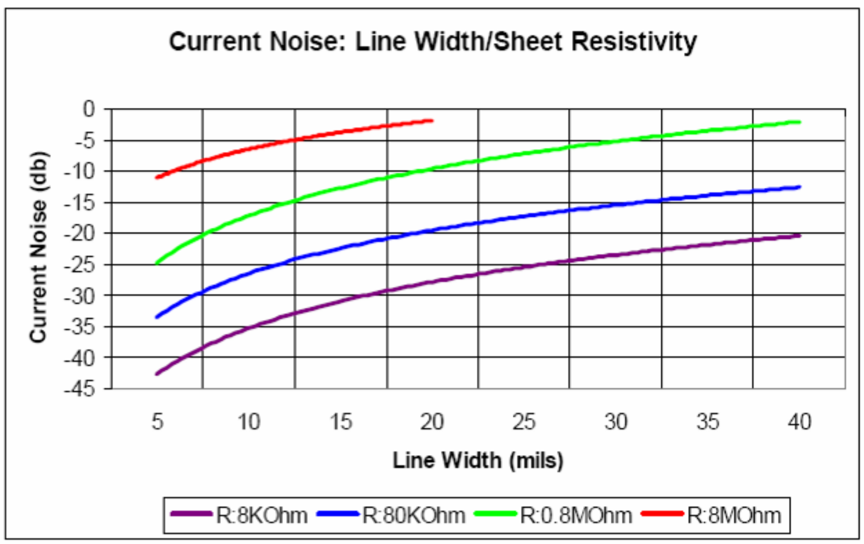

Figure 2
Variation of current noise with different line width/sheet resistivity

Conclusion

Although data were not collected in this experiment, it is expected that the voltage coefficient of resistance, which often acts in a similar manner as current noise, will be improved in elements made with the combination of fine line and low resistivity, due to:

1. More linear voltage current relationship of lower resistivity compositions.

- AND-

2. Lower operational internal electric field experienced because of the much greater length of the fine line patterns.