WHITE PAPER

Tight Ratio Tolerance Resistor Networks

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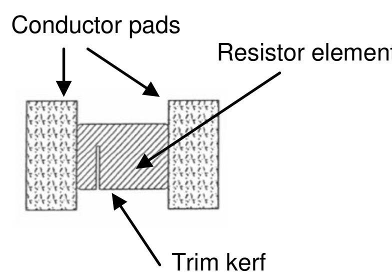
Introduction

As currently practiced, thick film resistor technology is based on the use of relatively simple block designs as shown in the example of a chip resistor to the right, where primary dependence for achieving different resistance values is placed upon selection of an appropriate ink composition. This approach does not easily allow for the fabrication of close tolerance resistors, because the usual means of trimming, which involves continuous laser cutting into major current carrying sections of the resistor, may leave significant areas of damaged film adjacent to the kerf, generally in the immediate region of highest current concentration. Subsequent physical or chemical changes in the damaged film can lead to significant changes in resistance, possibly several times greater than the initial tolerance level itself. For this and other reasons, thick film resistors are generally regarded as capable of holding tolerance of the order of only 1% on an absolute basis.



Example of conventional Block Style Resistor Design

On a relative basis, it might be possible to trim matched resistors to close ratio tolerances; however, this will be limited to resistors prepared with identical design and ink, thereby assuring close tracking. Multi-value networks composed of differing geometrical patterns and/or ink compositions typically do not track closely, which offsets the value of achieving close initial tolerance. For instance, the TCR of resistors in a given network made with different inks may easily differ by as much as 50 ppm/°C. Thus, over a 50°C excursion, this would result in a change in relative values of 0.25%. Ageing characteristics would differ similarly. Overall, it would probably be unreasonable to expect such resistors to perform and therefore justify trimming, to tolerances of within 0.5% even on a relative basis.

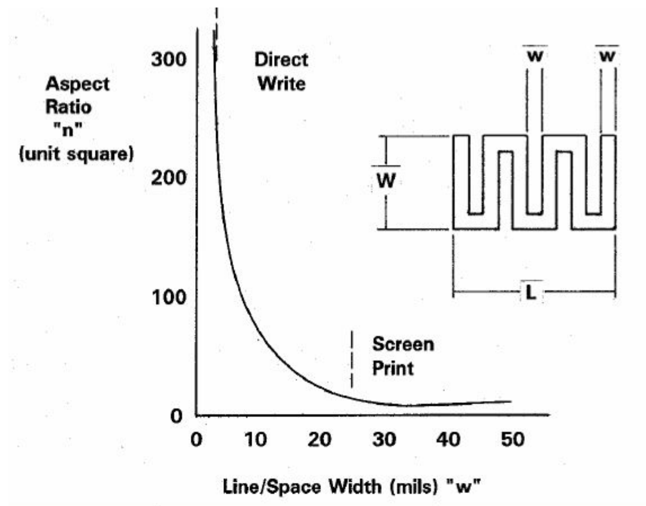
The introduction of fine line patterning of thick film resistor compositions has significantly increased our capability with respect to both absolute and relative rim tolerances. This is because fine line patterns of high aspect ratio can incorporate shorting links and ladder networks for coarse and intermediate level adjustment of resistance, which totally circumvents the problem of kerf damage, and side-bars equivalent sections having low sensitivity to achieve fine continuous trim adjustment value. Moreover, fine line traces of higher aspect ratio generally have a much greater overall length than conventional designs, which greatly reduces instabilities related to termination phenomena. These features enable meaningful trimming to tolerance of the order of 0.1%. This ability is most useful with respect to ratio tolerances, because of the designs made possible by fine line traces, for depositing wide-ranging multi-value networks in a single ink composition. Because they are composed of a single ink, such networks possess excellent tracking characteristics, thereby further justifying their adjustment to close relative values.

Design provisions for stable adjustment to close tolerances such as with links cuts and low sensitivity sections, could be done using any line width, however, the substrate area required for these more complex patterns of high aspect ratio would be inordinately large for wider lines. For a single serpentine pattern, the following relationships apply:

n = aspect ratio
w = line width
w = interline spacing
A = substrate area = W*L

$$n = \frac{L*W}{2*w^2}$$

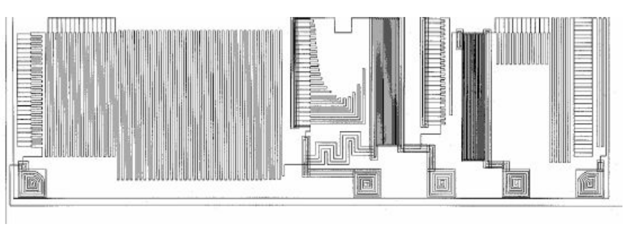
For instance, depositing a given pattern design based on line and space dimensions of 5 mils each could correspondingly be done with lines and spaces of 20 mils each, but would require 16 times the substrate area, which would be totally impractical in most applications.

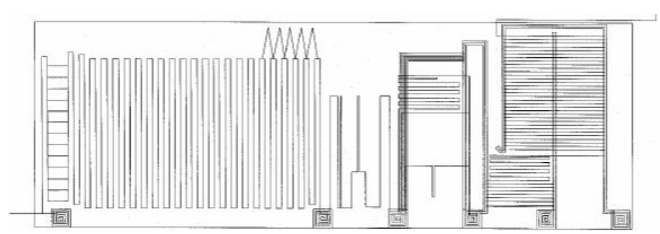


Maximum Aspect Ratio versus line / space width

Implementation

Although in principle it would be possible to fabricate fine line patterns in any one of several techniques, the examples presented below were all done using the direct-write technique wherein an ink is extruded through a fine orifice under hydraulic pressure using computer controlled positive displacement control of the flow rate. This technique provides traces as narrow as 4 mils in width with exceptional edge acuity, and with great versatility. Patterns can be designed and prototypes prepared within matter of hours. Subsequent adjustments in the design to improve yields or performance are easily and quickly made. Since close tolerance resistor networks are most often of a custom nature, the design flexibility of this technique is of special advantage in such applications. All of these things can be done with resistor inks of any sheet resistivity, which make their use in higher value situations especially valuable. Please refer to the examples below.





Examples of Fine Line, high aspect ratio designs with ladder and plunge trim sections