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SHORT COMMUNICATION

A Thick-Film Segmented-Resistor Structure for High Trimfactors

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This communication reports the preliminary experimental results on a triple-segment thick-film resistor structure. This structure, first reported by Karlskov Jensen[1] comprises two or more partly overlapping ink segments with increasing sheet resistivities $\rho_{s1} < \rho_{s2} \ldots < \rho_{sn}$. The primary objective is to fabricate a miniaturised thick-film component whose resistance can be increased to several times the starting value by trimming, without the risk of hotspots. The resistance change is expressed in terms of the trimfactor defined as $R_{final}/R_{initial}$. In applications like active filters and audio-frequency oscillators, electrical circuits of different specifications can be fabricated using the same design and set of screens if segmented resistors are utilised.

The test vehicle was a resistor test pattern, Figure 1, designed with the help of a 'Computer-Aided Artwork Generation' program. The pattern includes rectangular segmented resistors (RSRs), along with top-hat segmented resistors (TSRs), of different geometrical parameters (see Figures 2(a) and 2(b)). The resistor-to-conductor overlap and segment-to-segment overlap are both 0.5 mm. The fabrication uses a set of five masks, one for the conductor pattern, three for the resistor segments and one for overglazing; 2-in x 1-in 96% alumina substrates from Kyocera were used. The Pd-Ag conductor (Du Pont 9308) was printed and fired first. For resistor segments, Birox 1400

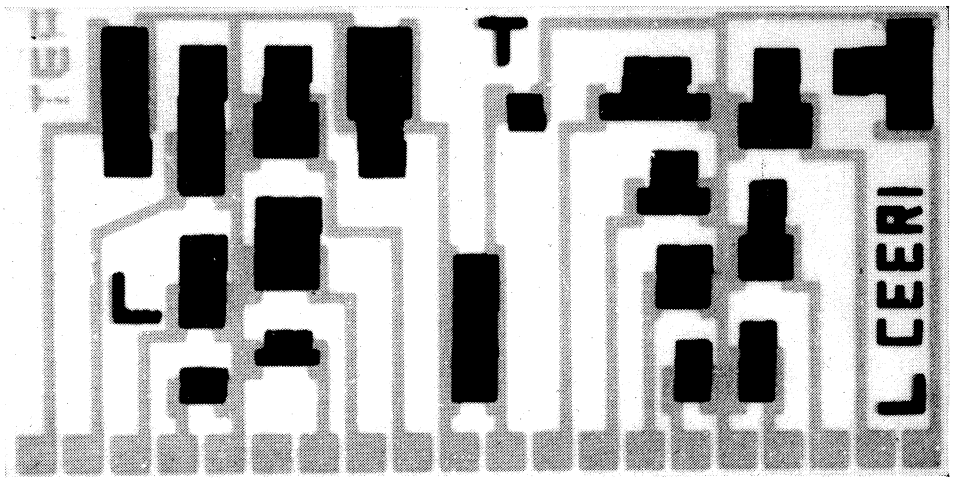

FIGURE 1 Resistor test pattern.

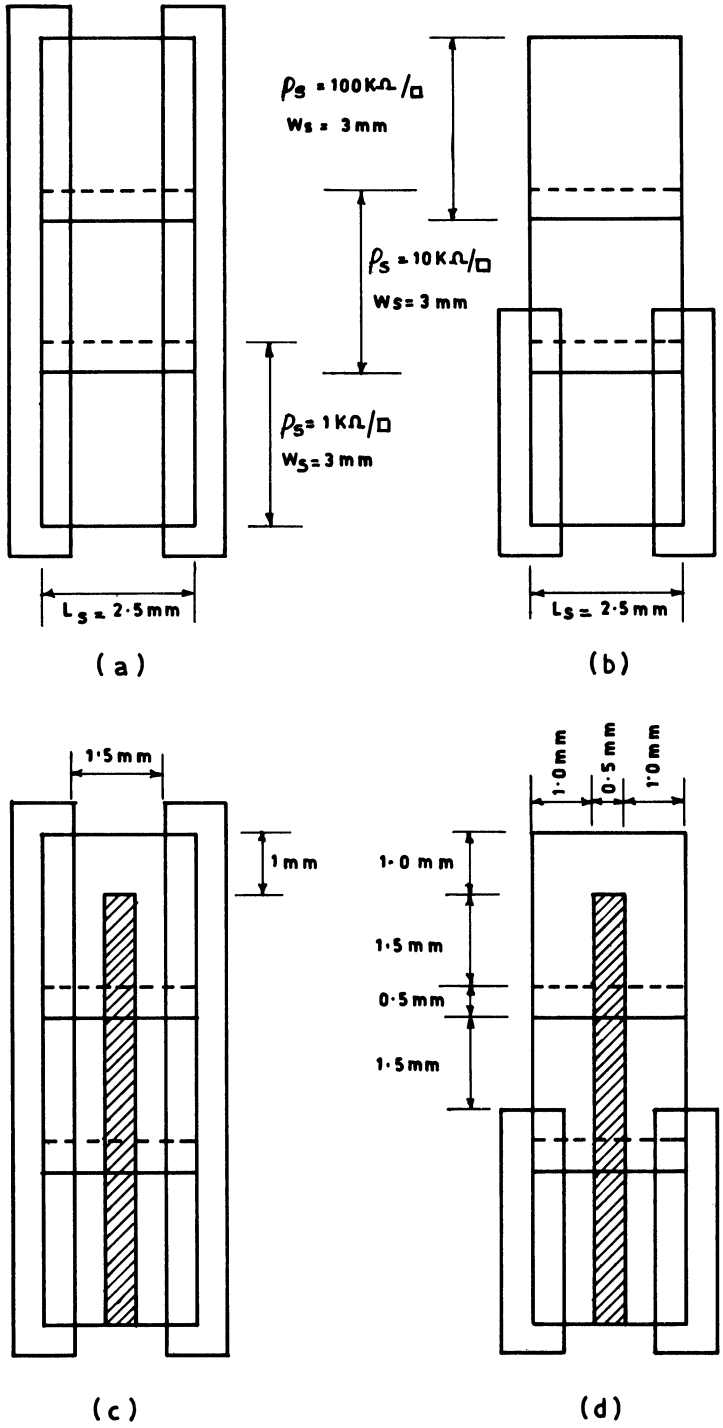

FIGURE 2 Layout of a RSR and a TSR structure. The hatched area indicates the resistor material removed by trimming.

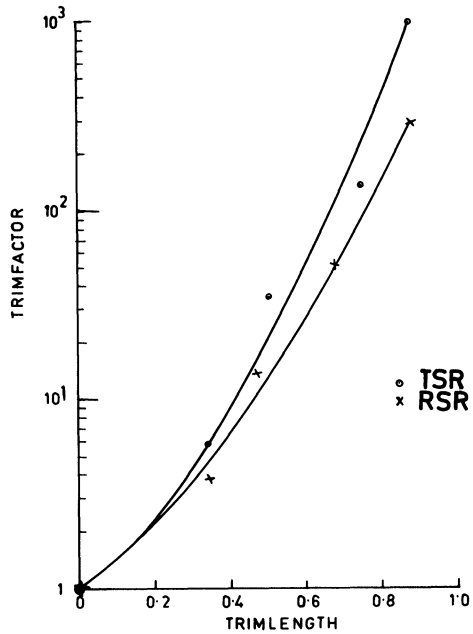

FIGURE 3 Plot of trimfactor versus trimlength for a RSR and a TSR structure.

resistor compositions of ρ_s 1 KΩ/□, 10 KΩ/□ and 100 KΩ/□ were used. First, the 1 KΩ/□ segment was printed with a 200-mesh screen and air dried at 150°C for 10 min. A similar procedure was followed for the remaining two segments. The pastes were then co-fired in a conveyor-belt furnace with a 70-min. cycle to a peak temperature of 850°C (12 min. soak). Finally, the resistors were overglazed with 9137 glass.

Both RSRs and TSRs were trimmed from the minimum ρ_s side five to six times using an air-abrasive trimmer (see Figures 2(c) and 2(d)). After each trimming, the resistance and the resistor width removed were measured. A constant segment width of 1 mm was left after final trimming in each case.

The rate of variation of trimfactor with trimlength (defined as the ratio of width removed to the total width of the resistor) for an RSR and TSR structure of similar geometry, is shown in Figure 3. The change in trimfactor becomes faster for the TSR after the first segment has been half trimmed. Initially, the variation is slow for both the RSR and the TSR because we are trimming the first segment of minimum ρ_s value. As we cross the interface between the first and second segments, the rate of variation increases due to the contribution from the next higher ρ_s ink. A smooth variation of resistance was obtained on transition from one segment to another and all intermediate values desired were achieved by this method.

Typical experimental trimfactors for the RSR- and the TSR-configurations are compared in Table I. The corresponding power ratings calculated from their effective area using 0.16 W/mm^2 dissipation for the pastes used, are also given. As the trimming reaches the final stage, the π-shaped resistance path length in the TSR is much longer, yielding a higher trimfactor. The same applies to the power because the current-carrying area in TSR is larger.

For TSRs, the trimfactor was studied as a function of resistor geometry, as shown in Figure 4. It is evident that the trimfactor increases with the segment width (W_s) and decreases with its length (L_s); this must be considered in designing TSRs.

TABLE I
Comparison of RSR and TSR Configurations†

Resistor type	Substrate area used (mm^2)	Trimfactor achieved	Power dissipation (Watts)
RSR	30	300	0.24
TSR	25	1000	1.52

†For comparison, the trimfactors possible with conventional rectangular and top-hat resistors of similar geometries and under the same power limits are ~10 and 20 respectively.

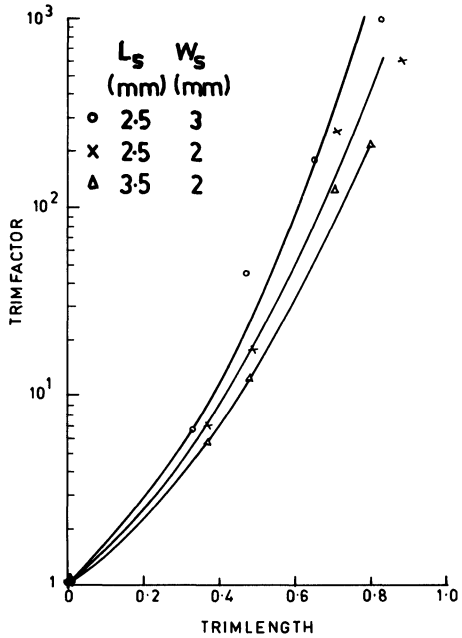

FIGURE 4 Variation of trimfactor with trimlength for TSRs of different geometries.

Thus trimfactors of the order of 1000 were readily obtained using TSRs with a small consumption of substrate area and higher power-dissipation capability. Depending on the specific circuit requirements, better area-saving designs of TSRs can be chosen.

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1. J.E. Karlskov Jensen, "Thick-film active RC-filter building blocks." *Proc. 4th European Hybrid Microelectronics Conf., Copenhagen, pp. 489–496 (1983).*