Incorporating Planar Resistors in PCB Designs

Planar resistors can provide a means of improving space utilization in PCB design.

By Roy M. Signer, Engineering Dept. Manager, Ohmega Technologies, Inc., Culver City, Calif.

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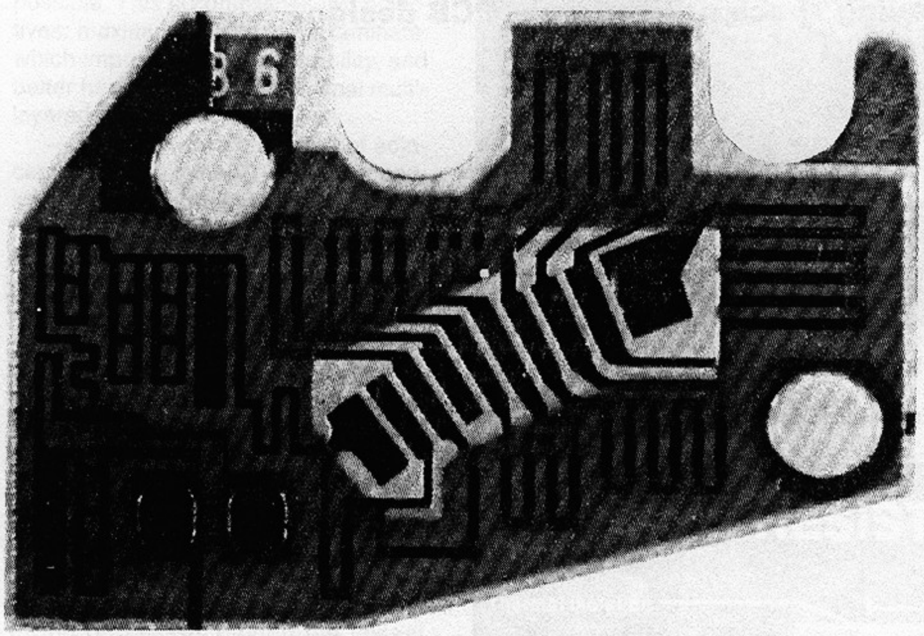

Special planar resistive circuit designed for a 35mm camera. Technique replaced use of thick film circuit and permitted custom, compact shape for fitting around a lens mount.

Since the technology to include resistor elements in printed circuit board (PCB) design was introduced in early 1972, designers have had the opportunity to fabricate either on the surface or inside PCB's to the exact requirements of the circuit. The methods used to design the resistor elements using this technology* are essentially the same as those used in the hybrid circuit industry.

Why Use Planar Resistors?

While that industry must deal with refractory substrates, screened and fired thick films, and vacuum-deposited thin film resistors, the newer technology consists of a copper-clad polymer substrate such as epoxy-glass with a resistive layer. Resistor elements are then formed by photolithographic and subtractive processing techniques which are already used in PCB manufacturing. A broader market can be served when such construction is compatible with existing printed board processing and the material system has fewer dimensional constraints.

The material system consists of a metal alloy film that is applied to copper foil and then laminated, alloy film side down, to a polymer substrate, such as epoxy-glass. Figure 1 shows cross-section views of the laminate construction possibilities. Available materials are categorized according to resistive material values, core types, thicknesses, and conductor types. Resistive layer sheet values, for example, come in 25, 100, and 1000 ohms-per-square, covering the range of values for a large number of applications from emitter-coupled logic (ECL) termination resistors to step potentiometers used in 35mm camera control circuits. Figure 2 shows the relationship of material sheet resistivity to element resistance value.

One advantage of using this material system is that after the circuit design is completed and the photomasks plotted, all manufactured units will be identical within the tolerance limits of the photolithographic and PCB production processes employed. With these advantages, however, the technique's limitations should be mentioned. If this technology is intended to replace thick film discretes or similar devices, they cannot operate at the same temperature as the ceramic-based elements. Reason: these resistors are part of a polymer system.

Another limitation is that initial resistivity tolerances are greater since this parameter depends on the material sheet resistance tolerance, which is ±5 percent, and the capability of the board fabricator to achieve specific element dimensions. These limitations may be addressed in design engineering, however, and resistors can be adjusted to required values.

Existing Applications

The first major orders for planar resistive material came from Japanese

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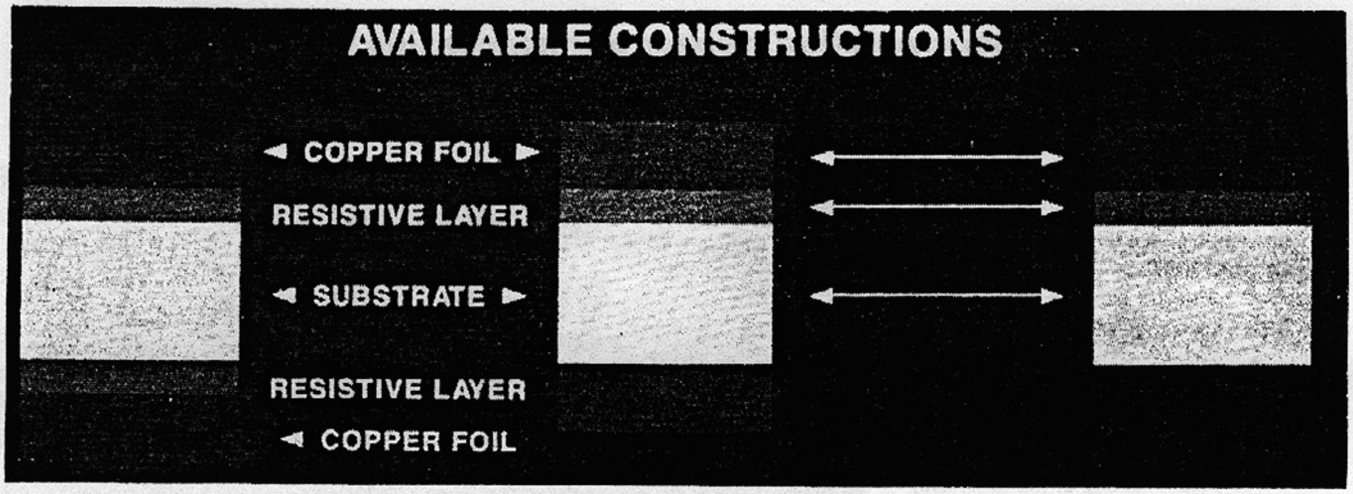
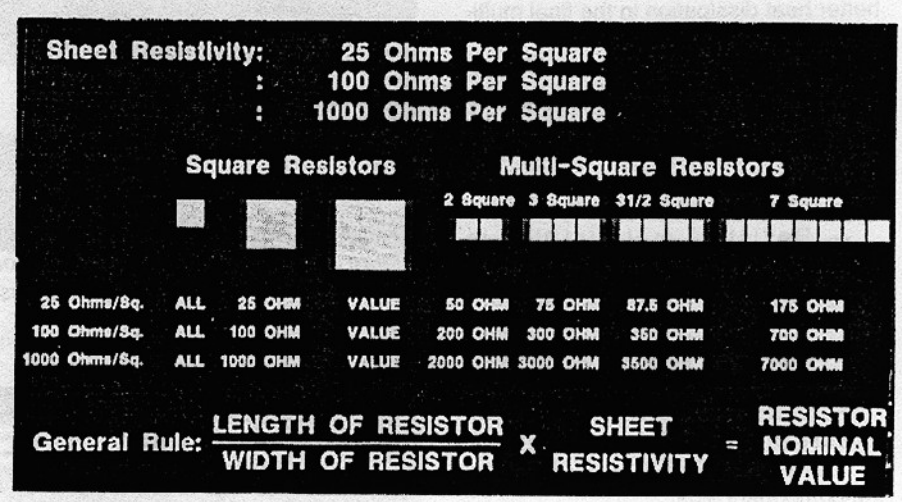


Figure 1, (above) a cross-section of the resistive laminate construction. Layer sheet resistivities include 25, 100, and 1000 ohms-per-square. These are a range of values for a large number of applications from ECL termination resistors to step potentiometers.

Figure 2. (right) the relationship of material sheet resistivity to element resistance value. Applications range from logic devices to discrete components. Available materials are categorized according to resistive material values, core types, thicknesses, and conductor types.



camera manufacturers who were looking for a way to fit a control circuit into a 35mm camera body around a lens mount. By having planar resistors as part of the PCB, the flat profile and odd shape could be obtained, which also was an economical alternative to the thick film ceramic circuits used formerly. The title-page photo shows the camera circuit with potentiometer and laser-trimmed analog circuit resistor elements. Further, the low temperature coefficient of resistance (TCR) and current noise of the planar resistors improved the electrical performance of the potentiometer.

Incorporating the Procedure

Another significant application is termination resistors for high speed ECL multilayers. Figure 3 shows the inner layer of a typical five-layer multilayer used in one supercomputer model manufactured by Cray Research. Figure 4 shows the dual element resistor design that replaced a dual element thick film discrete resistor at a significant cost saving.

Other applications range from surface resistor elements used to mark thermal paper to resistance elements in microwave power dividers.

To use the resistive laminate technique, the designer first selects a circuit that is representative of the product. This tends to be a "worst case" example because design changes are inevitably a result of difficulties in routing and providing space for added components and signal lines. The incorporation of resistor elements inside the PCB actually frees up area to add such active devices while the elimination of vias permits routing of more signals without adding layers to the existing design.

Next, an engineering study is made to establish the functional and operational requirements for the resistors. This includes a re-examination of the thermal design to ensure that board temperatures are still within the operating limits of the materials.

The manufacturing processes are re-examined to determine that the materials will withstand them without imposing a degree of damage or degradation that would adversely affect performance.

Based on Hybrids

The resistance elements' design is actually based on hybrid circuit technology together with knowledge gained from years of experience in existing applications, which include:

— Using the largest resistor element size possible and practical depending on area available, reduction of mutual heating, and element width standardization.

— Providing thermal isolation between resistor element and terminations subject to heat-producing operations such as soldering.

— Standardizing resistor element width dimensions when possible, or keeping the number of different widths to a minimum within a board design.

— Orienting resistor elements in the same direction, or limiting the number of different orientations.

— Avoiding the location of plated-through holes and component-mounting holes in the length axis of resistor

Incorporating resistor elements inside the PCB permits the addition of devices and the elimination of vias.

elements (see Figure 4). Note that the resistor termination holes do not line up with the resistor element length axis, which is 45° from vertical.

Other Design Rules

— Try to keep the laminate containing the resistive layer and the cladding on the reverse side intact as much as possible. This accomplishes two objectives: maximum rigidity of the laminate, which improves manufacturability, and better heat dissipation in the final multilayered configuration.

— Keep the core thickness of adjacent planes less than 10-mils, depending on the requirements for impedance control. This will provide the best heat dissipation and result in reduction of resistor hot spot temperatures.

— Resistive material that is exposed is vulnerable to damage by abrasion and contaminants in the atmosphere. Care in handling and packaging is necessary until resistors are coated or relaminated.

— Keep the internal resistive layer nearest an external layer of a multilayer board (layer 2 or 3), preferably on the component side.

— Given the option, use manufacturing processes having the lowest temperatures and shortest dwell times.

— Incorporate test coupons in photomasks that will permit the checking of material sheet resistivities and actual values of a representative sample of resistor element designs within a board.

— When practical and possible, obtain comments on board and resistor element designs from other knowledgeable sources, designers, and manufacturers before plotting photomasks.

Proof of the Pudding

When the design is completed and solicited comments received and considered, prototypes must be produced on which two kinds of tests must be performed, manufacturability and in-system operational performance. The former tests will be a part of the fabrication process.

After evaluation of the board through the manufacturing operations, the real proof of the design is determined by installing a functional circuit assembly into an operating system, exercising it for a designated time, and measuring the system's performance.

The development and evaluation time for the resistive laminate designed for the 35mm camera is estimated at about 18 months. As the number of users and PCB manufacturers increased, however, this time decreased significantly. Also, for the case described, the initial design successfully passed both the manufacturability and system performance tests. A product improvement change in the resistor element was made to increase yields in the manufacture of bare boards, but in neither design has there been to date a field failure of a resistor element in the millions of accumulated resistor operating hours. **EM**

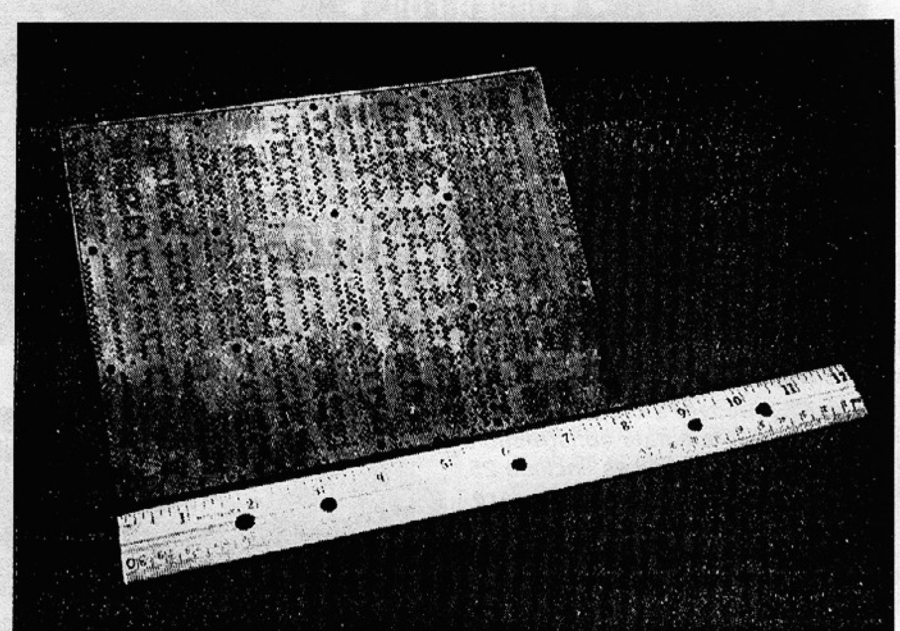


Figure 3, the inner layer of a five-section multilayer, used in a supercomputer. Planar resistive design is appropriately used for termination resistors for high speed circuits.

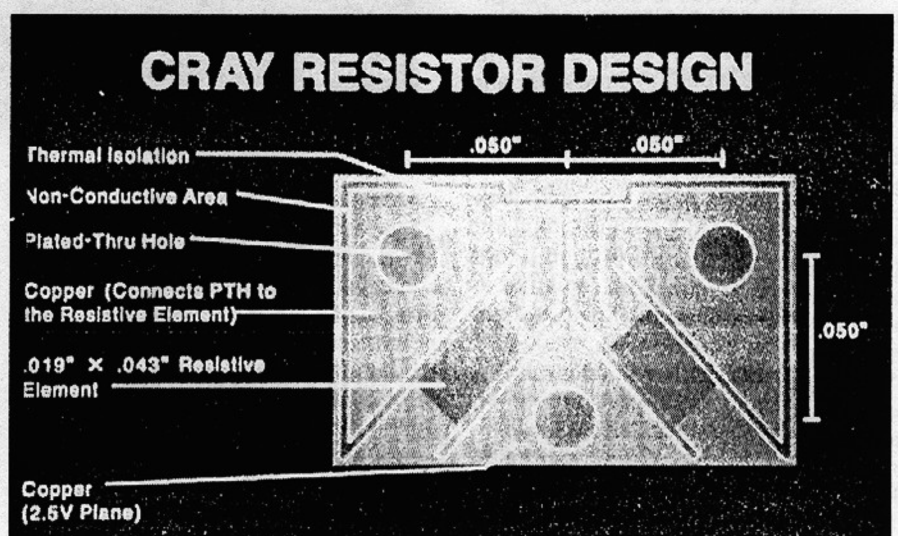


Figure 4, shows the dual element resistor design that replaced a dual element thick film discrete resistor at a significant cost saving. Other applications range from surface resistor elements used to mark thermal paper to resistance elements in microwave power dividers.

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