Will Passives Wind Up Inside the Board?

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The concept of embedding passive components in the layers of the printed wiring board goes back at least 30 years, to the days in the 1970s when Ohmega Technologies, Inc. introduced its Ohmega-Ply® thin film resistor material. The straightforward subtractive printed circuit processing (print-develop-etch-strip) of the Ohmega-Ply technology has a number of advantages, among them the removal of discrete resistors from the surface of the board. It also allows printing and etching of very small resistors with excellent tolerance, and thus eliminates the need for laser trimming of the elements.

In the 1970s, the embedding of passive components was limited to very specialized applications, such as aerospace systems where board space was at a premium. A few years ago, Ohmega teamed with Oak-Mitsui to bring out Ohmega-Ply/FaradFlex®, a resistor-capacitor laminate core that can replace even more surface-mounted passives. More recently, embedded passives began to shed their specialized aura and enter into more mainstream, higher-volume applications.

"This is not just a niche product any more—it's growing," says Ohmega Technologies vice president Bruce Mahler. "It's commanded the respect of the industry and of the supporting industries, which say, 'Hey, embedded passives are growing to a significance that we can't ignore.' Overall, with embedded passives, you're starting to see a lot of activity in cell phones, whether they're Nokia or Samsung or Motorola. So it's not just thin film Ohmega in things like VCO parts and in other devices within cell phones, but there's a growing usage and acceptance of both polymer thick film materials and thin film materials for embedded resistors. But I've also seen an increase in the use of both distributed and discrete capacitor materials in embedded applications as well, to eliminate a lot of those discretes."

Along with higher-volume applications has come the expansion of an infrastructure to support embedded passives, Mahler notes. The IPC is developing test standards for embedded resistors and capacitors. Design and reliability

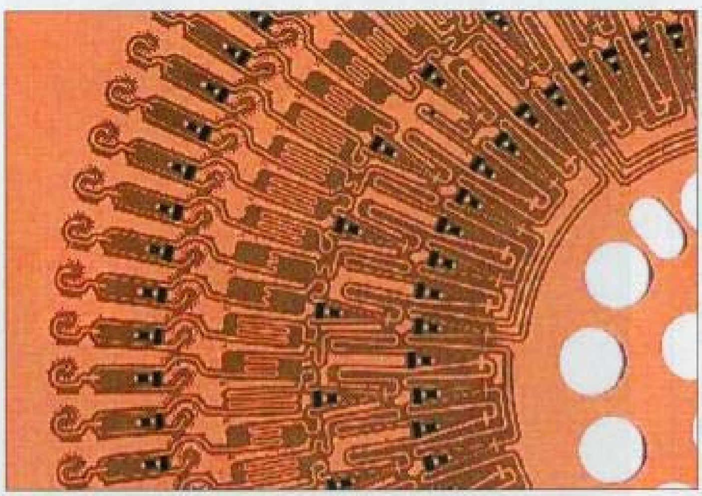

Figure 1: Ohmega-Ply embedded resistor layer, used in Globalstar earth-orbiting satellites. The dark areas are resistors that serve as power dividers in an active phased array antenna layer. By using embedded resistors, surface soldering of chip resistors is avoided. The embedded resistor material is not affected by cosmic radiation.

test standards are being worked out.

Perhaps the biggest indicator of future growth in embedded passives is the development and software released by both Cadence and Mentor that automates the design of embedded passives.

In the past, Mahler explains, "The designer would have to create resistor footprints. In other words, they would create a resistor library based on the resistor's value, power, and tolerance. Once they had the resistor footprint created, they had to decide where they wanted to put it inside the board. Then they would have to manually place the resistor footprint, that is, step and repeat the footprint in a whole bunch of locations, like a termination off of a BGA. It's fine if you have the time, and if you have the sophisticated people and software to go ahead and do that, but you really have to put some effort into it."

One of the areas in which Ohmega is seeing substantial growth is in flex circuits. Thin film resistors on flex (like Ohmega-Ply) have been done in specialized areas for 25 years or so. One largely unknown advantage is that the resistor is extremely durable and oblivious to flexing. Many of the applications are in consumer applications or are used as heater elements. This means non-flex and flex applications for embedded resistors are beginning to be processed and assembled in Asia.

"We see memory modules being built in Korea or Taiwan, we see components for cell phones that are being built in China and in Taiwan that are using our technology," Mahler says. "We see telecom boards being built in Singapore using our technology. What's happening is that we are starting to see a proliferation—it's a spreading of companies that are having to get into embedded passives."

On a far smaller scale, research is being carried out that involves the embedding of discrete, rather than printed, passive components. The applications, as you might expect, are very specialized. A project that is just getting underway at the Fraunhofer Institute in Berlin, Germany, will use embedded discrete capacitors to greatly increase the speed of a large BGA-type semiconductor.

Physicist Andreas Ostmann says, "It will be decoupling capacitors for the power lines. Also, some resistors are required." The semiconductor has hundreds of interconnects, and the capacitors and resistors will be embedded in the board beneath the bond pads.

Ostmann expects the incoming boards will be complete except for the top layer. His team will place the embedded passives onto the existing layer and then add the top layer. "We will put thin low-profile SMT capacitors on the inner core either by soldering or by adhesive joining, and then do the lamination. Of course, we have to work on how to embed them perfectly in the laminated layer because the [SMT passive] component is quite tall."

One absolute requirement is the completed board surface must be perfectly flat. And this places great emphasis on the materials and methods that are used to embed the passive components. No one knows the precise measurements yet, but (to use one example) an 0201 SMT capacitor is about 200 µm thick. Although 200 µm is only one-fifth of a millimeter, it still qualifies as "quite tall" by Ostmann's standards because the top layer his team will laminate onto the existing board, and onto the passives, will almost certainly be thinner than 200 µm. On an experimental basis, capacitors are available with thicknesses of 70

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and 20 μm.

Actually, the 200 μm 0201s might work. "We have already made some trials with thick chips, not with passives, but with chips up to 200 μm thick," Ostmann explains. "We achieved a quite nice planar embedding—the copper form over the component was flat."

The team will have two basic choices for the material of the top layer that it will laminate over the embedded passives. It might use a prepreg containing a woven fiberglass fabric, similar to FR4. The drawback of this type of material is that the woven fiberglass prevents it from flowing laterally when it is laminated over a component. You end up with a lump on the top surface unless you carefully cut holes in the layer before you laminate it. If Ostmann's team uses this approach, they will cut the holes with a laser, and will probably leave a 50 μm gap around the periphery of each passive component.

The alternative is a material like RCC (resin-coated copper) that contains no fabric. The material will not need to be perforated before lamination because the resin will simply flow sideways to accommodate the passive component, and the top surface will turn out perfectly flat.

Ostmann has strong experience in this area because his recent projects at Fraunhofer have included the embedding of active components. Typically, small silicon die are thinned to 50 μm and adhesively bonded to a board core material. The bond pads have previously been modified to be compatible with this method. A layer of RCC is laminated over the chip, and microvias are laser-drilled down to the bond pads and then copper-plated. The underlying purpose is not simply the saving of space (other components might later be surface-mounted on top), but to increase performance by shortening connection distances.

At least one consumer product using an embedded active component is already on the market, along with numerous products that contain embedded passives. Both trends will be worth watching in the coming months and years. ❑