New Manufacturing Methods Used for High Frequency Electronic Equipment

Not so long ago, there was a trend in the electronics industry called "design for manufacturing." This was part of the changing trends toward high-volume, low cost equipment. This report offers a look at some of the techniques that arose from those efforts, as well as some of the newest ways to turn an engineer's product design into a finished product.

Automation is King

For many years, few RF and microwave circuits took advantage of automated assembly. That started changing with the availability of most components in surface mount packages that could be handled by pick-and-place machinery. The combined factors of smaller geometries of SMT components and the ability of the assembly equipment to place them precisely opened the doors to lower costs for common products.

The first products to take advantage were such things as cordless phones, radio-controlled toys, and consumer entertainment equipment—radios, televisions and (at that time) VCRs. Today, SMT manufacturing has evolved to handle smaller components and higher component density, while the component industry has moved ahead to provide nearly all devices in packages compatible with automated assembly.

The ability to handle smaller size components and place them with greater precision has created a major shift in the way microwave products are made. Packaged devices have replaced the old chip-and-wire for almost everything below about 6 GHz. Carefully designed microstrip circuits on PTFE have been replaced by small lumped element components—or multi-function packaged modules—on thin FR4. The result of this manufacturing capability is cheap products operating in the 2 to 5 GHz range that was considered the exclusive realm of expensive ceramic and machined parts not too many years ago.

LTCC and Other 3-D Technologies

Packaging and manufacturing go hand-in-hand. Advanced component and module packaging make finished product assembly easier, but there are new challenges in the manufacture of the parts themselves. Among the recently-developed packaging enhancements are several that support multiple functions in a single package. Low temperature co-fired ceramic (LTCC) was probably the first of these techniques, allowing circuit lines and passive components to be encased in a single ceramic module. Couplers, filters and other networks are the largest group of components that use LTCC technology. LTCC is also used to reduce the overall circuit size when used in conjunction with external active and large-size passive components. For example, a MMIC amplifier may be mounted on an LTCC base that includes matching and coupling circuitry.

Similar in concept are multi-layer circuit board techniques that combine thin p.c. boards into a layered structure. While circuit board laminates may not have the same performance as a ceramic substrate, the assembly methods are simple and the adhesives used to bond the layers is cured at a much lower temperature than LTCC. This allows active devices to be included in the module, as well as a wider range of passive components. This method also is used to add additional functionality when used as the carrier for an RFIC/MMIC device.

Non-Solder Technologies

The heat, flux and physical handling required for soldering can be an impairment for some circuits. Instead, some components are designed for pressure mounting, using a conductive elastomer to provide a continuous electrical connection during mechanical stresses and thermal flexing. These elastomers may have limited performance at high frequencies, but can be used in some RF, microwave and high-speed digital products.

Another alternative to solder is conductive adhesives. These are usually organic adhesives (e.g., epoxy) with silver fragments embedded to provide the conductive path. These provide mechanical strength similar to soldering, but without the temperature rise. The primary difficulty is handling the liquid resin and hardeners. Maintenance and cleaning of the dispensing hardware can be significant, but in many cases, the advantages of the process outweigh the difficulties in its implementation.

Wire bonding is still a major part of semiconductor and high-performance microwave circuit assembly. It is used to carry the high currents in power transistors, connecting those devices to internal matching components and to the packages. Chip-and-wire is still used to place bare MMIC chips on ceramic or high-performance laminate substrates, reducing package parasitics by reducing the total interconnection path length, and reducing inductance with multiple wires. With the growth in wireless systems, the overall use of wire bonding has grown as well, which may be unusual for such an "old" technology.

Lead-Free Requirements

The European Union's RoHS Directive (Restriction of Hazardous Substances) was enacted to reduce the amount of hazardous substances found in electrical and electronic equipment. Although lead is the primary issue in electronic manufacturing, this Directive will ban the placing on the EU market of new electrical and electronic equipment containing more than the agreed levels of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) flame retardants, starting on July 1, 2006.

Component manufacturers have responded to the Directive's mandate by adapting their device manufacturing methods to comply with RoHS, mainly by replacing lead with alternative solders and plating. Many ads and product announcements in this magazine focus on the fact that the company's products are available in RoHS-compliant versions.

For some manufacturers, making the transition to lead-free assembly is a major headache. The traditional tin-lead (60/40 or 63/37 ratio) solders have a melting point in the range of 360º to 375ºF (182º to 190ºC), with lead-free replacements substantially higher—100% tin melts at 450ºF (232ºC), and 96% tin/4% silver melts between 430º and 440ºF (221º-227ºC).

This 70ºF increase in temperature requires re-engineering the thermal performance of many traditional materials. The issue is not absolute temperature—typical soldering iron tip temperatures are 500º to 700ºF—but rather the longer time required to raise the solder to a high temperature. Assembly facilities have been busy making the necessary upgrades to equipment and changes to their processes.

For other parts of RoHS, laminate manufacturers have already made changes to the type of flame retardant material used on board materials that require this treatment. Cadmium and mercury have been phased out of all uses but those that have no viable alternative.

Summary

Manufacturing is an integral part of engineering design, and at high frequencies, several valuable techniques—and a few challenging regulations—are affecting the way products are made. The usual design tradeoffs of cost, performance and time-to-market apply as much to these manufacturing methods as they do to the circuit and system design of the high frequency products themselves.

From December 2005 *High Frequency Electronics*