Roadmapping the PCB Assembly Future

By Tom Davison and Bill Barthel

Recently published, the 1998 NEMI Roadmap outlines keys to assembly's future success.

The National Electronics Manufacturing Initiative (NEMI, Herndon, VA) recently published its 1998 roadmap. This document identifies the key technology and infrastructure developments required to ensure the competitiveness of North American electronics manufacturing companies over the next decade. The roadmap was designed to guide investment in research, development and deployment for electronics manufacturing.

The 1998 roadmap involved the input of more than 400 individuals from 175 original equipment manufacturers (OEMs), electronics manufacturing services (EMS) providers, suppliers, government agencies, universities and related consortia/trade associations. These individuals defined future manufacturing needs by determining "product emulators" for five product sectors—low cost, handheld, cost/performance, high performance and harsh environment—and used these needs to forecast trends for each of 17 technology areas, including board assembly.

The following article summarizes the NEMI Roadmap chapter on board assembly.

Board Assembly Processes

Board assembly processes are a critical part of overall electronics manufacturing. The product emulators used in the NEMI roadmap, although diverse in the functions and the markets they serve, all leverage board assembly process technologies. The priorities defined for these technologies are consistent across all product sectors: conversion costs; density and weight; and time management.

Conversion Costs

Minimization of conversion costs is the top priority across all of the NEMI product emulators. Conversion cost is defined as *the cost to take a group of parts and convert them to a functioning electronic assembly*. This cost is calculated by taking the price of the complete PCB assembly, including test and material procurement cost, and subtracting the material cost. With this calculation, all costs associated with manufacturing the assemblies are considered.

Table 1 summarizes the product sector conversion costs requirements by year. Based on cost projections developed for each of the product sectors, electronics manufacturers will need to reduce conversion costs—indicated by cost per I/O—anywhere from 42 to 62 percent over the next 10 years.

Several requirements and practices must be met to achieve further reductions:

Reduction of overhead through improved utilization.

Achieving high machine utilization is a key factor in reducing overhead. Development and implementation of technologies and practices that eliminate stoppages for model changeover, parts replenishment and time wasted for machine assists are critically important. Examples include continuous processing technologies such as reel-to-reel and bulk feeding of passive parts. By 2003, a significant technological breakthrough will be required to achieve machine utilization beyond 85 percent.

Improvement of process yield and convergence to asymptotic yield.

Advances in processes such as solder paste screening are moving in the right direction. Further, by leveraging recent advancements in automated noncontact testing, a real potential exists for self-correcting systems. These systems are moving toward providing parametric data (instead of pass/fail) that will enhance their capabilities as defect prevention tools.

Optimization of the factory via modeling and simulation.

By leveraging computer integrated manufacturing (CIM) technology such as modeling/simulation, systems monitoring, diagno-

Product Sector	Metric	1999	2001	2003	2009
Low cost	¢ per I/O	0.7	0.6	0.5	0.3
Cost/Performance	¢ per I/O	0.75	0.65	0.55	0.38
Handheld	¢ per I/O	0.8	0.7	0.5	0.3
Harsh environment/ Military	¢ per I/O	0.9	0.7	0.6	0.4
High performance	¢ per I/O	1.2	1	0.8	0.7

TABLE 1: Board assembly roadmap: Conversion costs by product sector.

sis and optimization, many technologies can be integrated and mutually optimized. In test, for example, the selection and integration of information from several areas can reduce overall test cost while maintaining coverage and efficiency. Further, by the development of high-speed, high-level modeling and simulation tools for cost analysis and virtual prototyping, CIM can also reduce time to asymptotic yield and market.

Development of standards for bulk-fed and odd form components.

Standards for parts dimensions and tolerances and parts packaging must be developed for both bulk-fed passives and odd form components. Developers of automation equipment and component parts will, then, be ready to support mass deployment of these emerging technologies. Bulk feeding will also require development for high product mix situations such as EMS.

Development of new pin-through-hole (PTH) parts.

The availability of PTH parts that are compatible with the temperatures required for mass reflow in surface-mount technology is a critical factor.

Density and Weight

The second priority is electrical circuit density of the printed circuit assembly (PCA). As products become smaller, functionality and degree of integration are constantly increasing. As a result, record-breaking packaging densities need to be achieved, and, if present trends continue, the boundaries between component and board assembly will begin to disappear.

Closely related to density is product weight. As products miniaturize and many become handheld, minimal product weight becomes a key factor. Several events are key to projected density and weight:

Deployment of 0201 chip passives.

For discrete chips, 0402s have now been fully deployed. By 2001, 0201s will emerge as a mainstream technology and will eventually be displaced by deposited components or integral passives.

Development of CSP design standards.

Chip-scale packaging (CSP) is emerging as the technology choice for high-density, high-performance packaging. CSP will require the development of design standards for packages and parts packaging.

"Business pull" for FCA.

Flip-chip assembly (FCA) must migrate from a "technology push" to a "business pull" model for full deployment. The infrastructure must evolve to address reduction of the FCA conversion costs per I/O; interconnection material density to enable increases in packaging density; and integration into the standard surface-mount process.

Table 2 depicts some of the component attributes projected over time.

Time Management

The third ranked factor is time management, both in terms of managing time to market and process cycle time. By minimizing time to market, a manufacturer can react quickly to changes in technology, shifts in consumer demands, and changes in competitive environment. Continuous product change is critical for success in today's electronics business. Overall product cycle time must be minimized, which reduces the time required to implement model changes and limits inventory exposure. Process advancements will help improve time management in several areas:

Leverage leadership in board test.

North America is a leader in the area of board test equipment. By leveraging this technology, in conjunction with CIM, the feedback loop that test provides can allow faster convergence to asymptotic yield.

Leverage leadership in CIM.

North America is also a leader in the area of CIM. By the development of high-speed, high-level modeling and simulation tools for cost analysis and virtual prototyping, CIM can provide an advantage in time to market, responsiveness to shifting market conditions, and reduction in overall cycle time.

Further develop data driven processes.

Data driven processes allow for very rapid time to market and rapid response to engineering change orders (ECOs). These processes include circuit-writing materials (nano-particle materials), deposited passives and solder jetting.

Other Considerations

With the increased reliance on EMS providers, a new model in technology development versus that used in traditional vertically integrated companies is needed. OEMs must partner across their supply chain, including their EMS providers, to develop key technologies for products.

North America must actively engage in the development of environmentally friendly manufacturing technologies and lead-free soldering. In Japan, leading OEMs have announced their intent to eliminate all use of lead in interconnect, including solder and lead and board finishes, by April 2001. In Europe, a proposal is currently being debated that could ban the use of lead in electronics equipment effective January 1, 2004. This change in material may profoundly affect many of today's board assembly technologies and may require requalification of processes and materials due to changes in soldering temperatures.

Development of common standards for reliability testing of electronics devices and assemblies is also an area for focus. Currently, little commonality exists among North American electronics manufacturers in this area.

Conclusion

Board assembly processes are central to electronics manufacturing and can be lever-

Key Manufacturing Processes	1999	2001	2003	2009
Surface-Mount Discrete Chips	20 x 40 mils	10 x 20 mils	Deposited Rs and Cs	Deposited Rs and Cs
Surface-Mount IC Packaging, Minimum Component Pitch	BGA—1 mm CSP—0.6 mm FCA—0.18 mm	BGA—0.8 mm CSP—0.5 mm FCA—0.15 mm	BGA—0.8 mm CSP—0.4 mm FCA—0.13 mm	BGA—0.65 mm CSP—0.3 mm FCA—0.007 mm
Surface-Mount Special Component Thick-ness	2.5 mm	1.5 mm	1.5 mm	1.5 mm
Surface-Mount Component Attach	Solder	Solder	Low Temp	Low Temp
FCA Underfill (120 x 120 mm chip)	< 3 sec./chip	< 0.5 sec./chip	< 0.5 sec./chip	Standard Surface-Mount
FCA Underfill Cure	Convection oven, < 300 sec.	Convection oven, < 180 sec.	< 120 sec.	Standard Surface-Mount
FCA Attach	Solder	Low temperature connection		
Lead Alternates	Tin/lead solder	Tin/lead solder	No-lead solder	Organics

TABLE 2: Board assembly roadmap: components.

aged in the development of increasingly sophisticated products. For North American industry to capitalize on the numerous emerging electronics markets and remain competitive in electronics manufacturing, a number of technological advances will be required to improve conversion costs, time management, and density and weight.

For further details about the 1998 NEMI Roadmap, contact NEMI at http://www.nemi.org or (703) 834-0330.

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