COVER STORY

# Sockets Meet Future Technology Challenges

## PART I

**BY GAIL FLOWER,** *Editor-in-Chief*

Though the basic requirement of sockets remains unchanged — making a stable electrical contact from the device to the PCB — the future holds even more demands on this important electrical/mechanical device. Production sockets are used for burn-in, functional test, and device programming. Other uses include development, and reliability work.

As products are designed with high-performance ICs, devices with finer pitch are used, I/O counts run higher, RoHS-required lead-free microprocessors are socket tested, time-to-market shortens, and cost control becomes more critical, the difficulty of designing sockets to meet future needs increases. As with any tool, socket design and eventual selection should be based on the right socket for a specific application. *Advanced Packaging* queried the users and suppliers of sockets listed at the end of this article to find out how sockets will meet future technology challenges.

**THE SHORT STORY**

As industry memory devices and new memory modules go through major changes, sockets to connect to them must also make adjustments. Part I in *Advanced Packaging*'s 2-part socket series talks about new package requirements, lead-free issues, standards, cost control, fine-pitch challenges and the BiTS workshop.

### New Package Requirements

*Does each new package style or type require a reciprocal socket?*

If the designer/builder re-spins a package, they usually try to keep the lands and associated connection pins in the same location to avoid the cost of a new socket and associated tooling. However, though a socket style might not require a new socket, a new package family or conversion to chip-scale or lead-free would require a new design (Figure 1). Generally, if the mechanical outline of a new package changes, then new production test contactors, burn-in sockets, programming sockets, and test requirements also change. In turn, that drives new specifications such as improved RF and high-speed digital bandwidth, more stable requirements, etc.

At times, the socket supplier can leverage an existing design with minor modifications to match the device alignment features and terminal patterns. But when a new package style comes out, such as when QFNs were first introduced, new designs need to be developed by the supplier base to accommodate these new package formats. This represents an investment for the supplier when molding and stamping tools must be purchased.

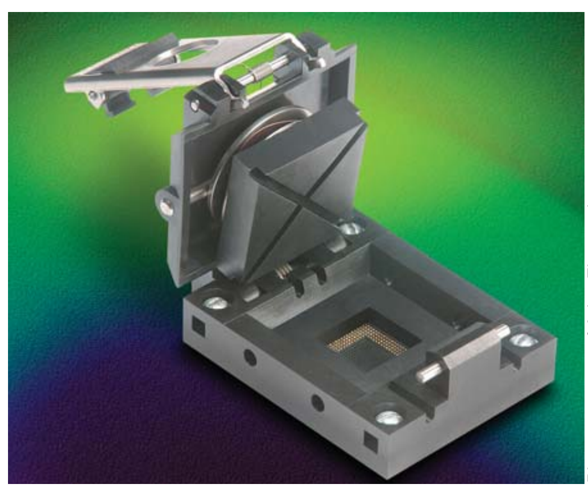

Photo courtesy of Aries Electronics.

**FIGURE 1.** Test and burn-in socket for CSP devices from 28–40 mm.

There are cases in certain markets, such as the memory area, where specific customers develop a common socket form factor with a group of suppliers. This allows customers to leverage suppliers and keep costs low.

Even existing package outlines often need new sockets because electrical parameters are tightened or production test or burn-in hardware changes by adding faster handlers or other variations.

### Lead-free Socket Results

*How have problems with lead-free electronics been resolved by socket manufacturers?*

Socket suppliers and users agree that lead-free makes connecting to the package more difficult. To make good contact, a crown tip on a spring pin will balance off the hardened stress of lead-free materials. As more force is required to make solid contact, wear issues become more critical (Figure 2).

One manufacturer designs and builds spring probes for lead-free testing using new alloys, hardening procedures, and surface finishes, as well as different test socket engineering design sets and mechanical properties (geometries, force, bias, internal pin capture). Next, they validated changes through testing using modified IC test handlers and pin cycling machines with test coupons plated with different lead-free finishes. They test with customer applications using lead-free devices.

Though some problems with lead-free have been solved, questions still remain. For example, some customers are still experimenting with different lead-free BGA formulations — using varying ratios of tin, silver, and copper — and the quality of the interconnect is still in question. It is clear that there is not "one" solution to lead-free. For instance, an optimized contacting solution for a pure-tin IC device lead is not the same for a nickel-palladium-plated device. Some probe styles, as mentioned earlier, prove to be suited to hardened connections, depending on the device metallurgy and the way contact is applied in a test environment. Research continues as lead-free contacting solutions are still being developed and optimized.

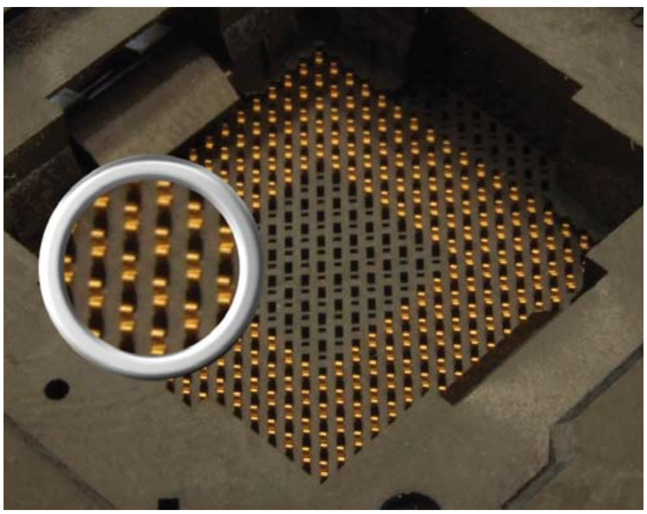
Photo courtesy of Yamaichi Electronics.

**FIGURE 2.** Burn-in sockets for 1.0-mm-pitch BGAs have zero insertion force, open-top structure, compact outline, low actuation force and improved contact reliability.

Each package type and terminal geometry (solder ball and pad size) introduces its own set of variables to be taken into account. The number of solutions matches the number of lead-free solders (NiPdAu, NiAgCu, matte Sn, etc.). Solution toolboxes must consider all variables: package type, test application, terminal type, terminal geometry, device type (digital, RF, high-speed digital, high-power).

## The Standards Issue

*What standards are needed for sockets?*

In a user's eyes, the industry has done a poor job establishing standards. Just look at automotive and military markets, they assert, and good standards abound. But in sockets, it just doesn't hold true. Measurement methods for electrical signal integrity and insertion loss should be standardized. Suppliers should know how customers will use their sockets. If a supplier says that one million cycles represent socket life, what does that mean exactly? Both supplier and user should use the same apples-to-apples approach to determine a number for socket life.

Pin-life specifications need to state resistance level at insertion count and test conditions. In many testing cases, once pins exceed 100 mΩ or so of internal resistance, they are worn out. In others, the test can tolerate even 1 Ω of pin resistance, so a specification that states a statistically reasonable resistance level at X number of insertions would be much more illustrative of the useable pin life.

A standard is needed for the amount of force applied per contact, and a method is needed to calibrate and verify this. Reportedly, some test houses increase force to "pass" components, but in doing so they create walking wounded. As more chip-scale packages (CSPs) become the norm, standards will be required to calibrate incoming inspection or verification.

In some other areas, most experts agree that standards are needed. For instance, there should be tighter tolerance on outside package size (Figure 3). Consolidation of the different semiconductor standards could be a plus. Limiting package variation might be helpful to achieve faster turnaround cycles and lower prices. However, this may be an unreasonable expectation as packages usually suit the needs of the end application (cell phone, PDA, digital camera, PC, etc.) resulting in package proliferation. Electrical specification, such as DC resistance, is another possible area; bandwidth, current capacity, and mechanical standardization require future work

Photo courtesy of Synergetix.

**FIGURE 3.** The pocket of the XACT socket can be adjusted to fit large devices.

Another issue comes from the equipment suppliers. Both test contactor and burn-in socket suppliers struggle to get adequate test-site and equipment specifications from test handler companies, loader/unloader companies, and oven/chamber manufacturers. Some handler companies publish

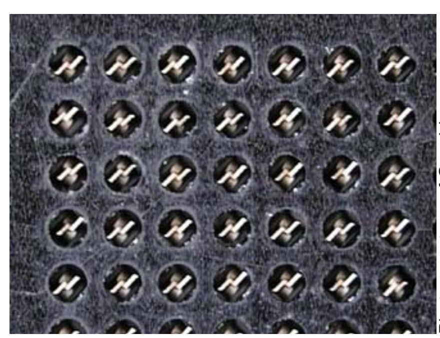
Photo courtesy of Gryphics.

**FIGURE 4.** A high-frequency compression-mount BGA burn-in socket built of materials that allow feature intricacy.

Photo courtesy of Gold Technologies.

**FIGURE 5.** A strip testing socket with thermal management.

standardized socket requirements on the internet, while others keep the detailed design of their test-site specifications under wraps to protect proprietary socket technology.

From the socket suppliers' perspective, socket standardization may not always be a good thing. Customization is their strength (Figure 4). The idea of standards for sockets has been discussed for years, but many large socket purchasers require features on their sockets that make them a bit unique. And if a need is expressed, socket suppliers are creatively capable and willing to protect proprietary strengths.

### Cost Control

*How have you kept the cost of socket design affordable?*

Here, socket suppliers have many ideas. The most difficult area to communicate to users is true cost-of-ownership. Socket buyers demand a lower price, yet technology grows increasingly complex. The most affordable production test contactor designs use standardized components where possible (possibly injection molded), and use contact technology that may be of lower performance. Ultimately, test sockets need to last hundreds of thousands of insertions without maintenance. Test cells can be more productive if the sockets provide a higher yield (less mistest or repeat test), provide the user with longer time between maintenance and cleaning, and if sockets are robust enough to operate in the severe test handler environment. Lower-cost probes or a lesser-grade plastic could be specified, but the overall cost-of-ownership over product lifecycle could be compromised by using this lower-grade material.

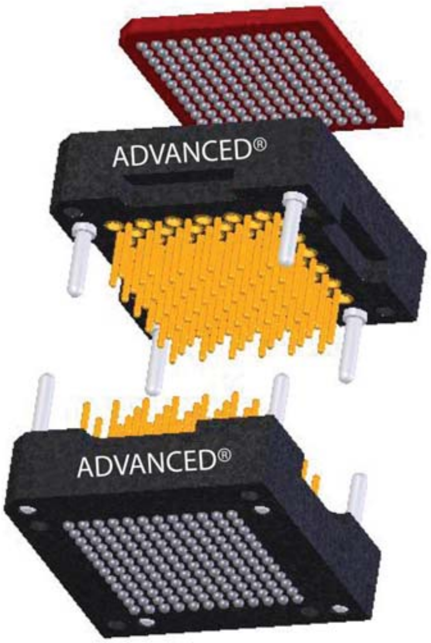


Photo courtesy of Advanced Interconnections Corp.

**FIGURE 6.** This 0.50-mm-pitch socket-adapter system provides a practical alternative to traditional test sockets at only 2.0 mm larger than a typical BGA or LGA package. Male and female terminals are arranged in an interstitial pattern.

Direct cost-cutting methods include: using universal designs; leveraging core technology on different products; using CAD software; optimizing the production process; molding instead of machining the entire socket housing; using full-grid molded insulators that are populated with terminals to match the device footprint; drilling in-house; incorporating customer-specific design standards, as well as generalized design guidelines; getting lead-free conversions "right" the first time; making pins in-house; mass production; and using socket cartridges.

On the user side, costs are kept low when sockets are benchmarked against each other. Price comparisons are critical. Also, if a user can forecast or predict socket requirements for their company ahead of time, then the cost of expediting an order can be avoided.

**Fine Pitch**

*What challenges have fine-pitch brought to the forefront?*

Fine pitch is perhaps the most challenging aspect of next-generation socket design. Device pitches at 0.4 mm and below dictate that interconnects get extremely delicate. At the same time, the test handler may be the same one used for parts at 1-mm pitch or above — thus device placement precision is a problem. From a test socket point of view, 0.4-mm pitch and below require qualification of new socket materials, and push machining technology to build parts with holes and slots to the micron level. Fine-pitch socket assembly requires a near-clean-room level of cleanliness, since contamination can severely influence contactor performance.

Even when designing a socket adapter system for 0.5- and 0.65-mm pitch devices, companies still face obstacles to overcome, such as tight tolerances, space requirements for each component, and machine capabilities to manufacture these components (Figure 6). One com-

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Carole Booth, President


Photo courtesy of Everett Charles Technologies.

**FIGURE 7.** The Gemini 0.4mm dual-spring probe is designed to deliver the desired force in a small format.

pany's solution to create more space on a set fine-pitch assembly was to invert every-other socket (female) with an adapter (male) terminal. This allowed the use of components that were actually larger than the pitch would allow with inversion. Another challenge that had to be overcome was the reliability of these much smaller components, which was resolved by adding large-diameter alignment terminals in the outermost corners of the socket adapter assembly. Alignment pins facilitate insertion while protecting the delicate pin field.

Other creative examples of fine pitch include fanning out the socket terminal leads to a pitch pattern larger than the device itself, to match board fabrication requirements. If a customer's packaging assembly process or supplier has a dimensional shift, it may generate repercussions in socket functionality. In the case of BGAs, fine pitch generated smaller solder balls. Smaller balls may require concessions on issues related to interface locations, contact force, resulting solder ball markings, and a host of other critical variables. Finer pitch is driving the industry to rethink what is considered standard and acceptable.

It is almost an inverse rule: the smaller the pitch; the larger the problem. Accuracy, consistent device alignment, and guaranteed target contact become more difficult. Fine pitch not only affects spacing, but creates electro-thermo-mechanical issues as well. For example, fine pitch means smaller-diameter wire. This leads to higher current density in the wire. The cross-sectional area contacting the pad or bump leads to higher temperatures in the probes (Figure 7). Higher temperatures result in weakened mechanical strength. Modeling only goes so far.

Some companies are pioneers in shrinking structures. They use stamping, etching, and MEMS technologies to produce contact elements. To improve housing, they use the latest injection molding techniques as well as high-flow-rate materials. To meet the demands of fine pitch, there will be many adjustments in sockets.

## BiTS, Where User Meets Supplier

*What did you learn at last year's BiTS workshop?*

Both supplier and user of sockets had plenty of good things to say about the Burn-in & Test Sockets Workshop (BiTS). At last year's BiTS meeting in Tempe, AZ, people learned about new material options, how to deal with very fine CSP devices, new test ideas, and thermal issues. Everyone felt that, along with excellent technical presentations, the networking opportunities to talk to buyers and supplier professionals, even competitors, provided invaluable information. During the networking they discussed sticky issues, such as the lack of standards and how to interpret what suppliers mean when they determine socket life. One supplier admired how each year he learned more about what various companies know and how they approach different problems. This yearly conference has become the meeting place that is focused on the issues surrounding sockets. BiTS 2007 takes place March 11–14 in Mesa, AZ (www.bitsworkshop.org).

## Conclusion

Innovations abound in the world of sockets. This article examines just a few challenges. Some of the most perplexing issues are not directly related to sockets, but rather reflective of issues in devices and packaging that are being brought to market by socket customers. Higher frequencies, higher data rates, higher power, smaller feature sizes, finer pitch, variability in device terminal configurations, and solder types are among the issues that socket suppliers must contend with while fulfilling the customer's expectations in areas of cost, performance, and delivery. Discussions of these related issues will appear in Part II in the May/June 2007 issue of *Advanced Packaging*: thermal management, contract testing, failure analysis, and socket life measurement. **AP**

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