A 20GHz pluggable 0.5mm pitch BGA connector simplifies test/verification

by Ila Pal [Ironwood Electronics, Inc. USA]

IC socket industry trends are impacted by a combination of technology and market-driven factors. Technology-driven factors include miniaturization, increased pin counts, faster operating speeds, higher operating temperatures, and higher current carrying capabilities. Market-driven factors include increased durability, shorter development cycles, and the need for more cost effective solutions. For many products designed with today's high-performance integrated circuits, ball grid array (BGA) socketing systems are an essential option during the design, testing, and/or production phases of the new product development process.

An IC socket is an electromechanical device that provides a pluggable interface between an IC package and a system circuit board or subassembly. This interface must be accomplished with maximum repeatability and minimal effect on signal integrity. Providing for a removable interface is a major reason for using a socket and may be required for ease of assembly, upgradeability, maintainability, and cost savings. A cost advantage may be possible by eliminating the need to directly attach the IC to the printed circuit board (PCB). The socket is permanently (soldered) attached to the PCB, while the IC device can be inserted into or removed from the socket without disturbing the connections to the PCB. This allows the IC to function as it is soldered into the PCB, but also to be replaced by another IC or multiple ICs. Sockets also aid in the ability to test, evaluate, and inspect the complete system. In the field, a socket provides enhanced capability for maintenance, testing, replacement or upgrades, which may become a critical factor in product life cycle because of technology evolution and IC availability.

In high performance end-use product applications, the requirement for directly attaching the device to the board is often critical. The consideration of a pluggable small footprint socket is made as an option to facilitate product replacement, upgrade, and repair in the field. The direct component replacement requirements result in the need to solder the socketing system directly to the target board. Solderability, in terms of meeting co-planarity requirements and in the prevention of solder wicking into the contact interface, is especially important. Key to success is the ability to withstand multiple reflow cycles without loss of reliable contact because of substrate warping and wicking of solder into the contacts. High-performance integrated circuits with pitches down to 0.5mm are becoming common. Because of the high density, a low insertion force (force per square area) is important criteria for usability. This paper will discuss mechanical and electrical characterization of pin and socket interconnects that are pluggable in a 0.5mm pitch array format.

Giga-snaP™ BGA socketing system

The system consists of two modules. The base module has socket pins arranged in a polyimide substrate with solder tails on the backside for attaching to the target PCB. The top module has terminal pins arranged in an FR4 substrate with a round head pressed flat against the substrate. This round head acts as a PCB pad to receive the actual BGA device. The BGA device soldered onto the top module and plugged into the base module, which is soldered onto the target PCB, completes the interconnect system. Figure 1 shows both the top and base module of the BGA socketing system. Removable interface requirements are generally stated in terms of the insertion/extraction force and number of insertion/extraction cycles a socket can support without degradation. Insertion/

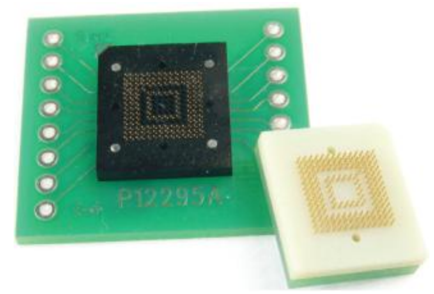

Figure 1: Giga-snaP™ BGA socketing system.

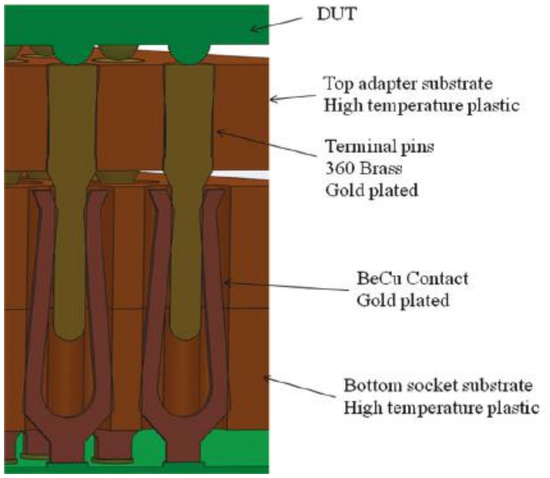

Figure 2: Socket and adapter pin cross section.

extraction forces become increasingly important as the pin count in the socket increases or the pitch decreases.

Figure 3: Insertion/extraction test setup.

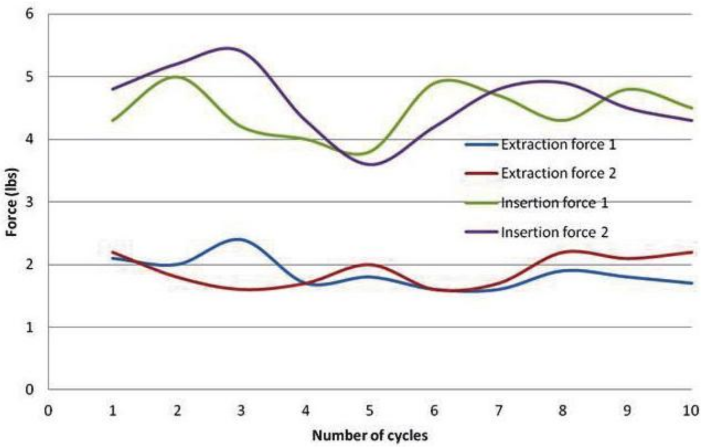

Figure 4: Insertion/extraction data.

Socket pin anatomy

The socket pin is a single piece integrated clip design and is made of heat-treated beryllium copper alloy 172 with 30 micro inch of gold over 100 micro inch of nickel finish. The socket pin is press-fit into the polyimide substrate directly. The adapter pin is a machined round pin and is made of brass alloy 360 with 30 micro inch of gold over 100 micro inch of nickel finish. The adapter pin is press-fit into the FR4 substrate directly. **Figure 2** shows socket and adapter pin cross section details.

Contact force

The main function of the socket pin is to provide the required contact force for signal transmission with minimal loss. Material properties and contact geometry play a major role in determining the contact force. The contact clip has two fingers positioned in a diagonal fashion inside the drilled hole. Each finger is a cantilever beam; for a cantilever beam, the force versus deflection equation is shown below.

$$F = (D/4)\, E\, W\, (T/L)^3$$

Where, F = force due to deflection of the beam

D = deflection

E = elastic modulus

W = width of beam

T = thickness of beam, and

L = length of beam.

By optimizing the contact geometry and elastic modulus, appropriate contact force is provided over the full range of operation conditions. Another important material property relevant to contact force is stress relaxation. Stress relaxation causes reduction of stress in the beam under load as a function of time and temperature, thereby causing insufficient contact force over time, which results in system failure. Heat-treated beryllium copper possesses high stress relaxation resistance.

Mating mechanism

There are two phases to the mating process: initial deflection of the beam (phase 1) and sliding to the final position (phase 2) after the beams are fully deflected. Therefore, the total force per contact depends on contact force (described in the previous paragraph) and the coefficient of friction due to this sliding action. The total mating force between the two modules (top and bottom) depends on contact force, coefficient of friction, the additional force necessary to overcome misalignment of mating halves, and dimensional variances of the substrate. It is very important to consider total mating force of mating halves as opposed to individual contact force.

Experimental setup

Figure 3 shows the experimental setup. BGA socketing modules were developed for a 153-pin BGA device (0.5mm pitch). The base module was soldered onto a daisy-chained PCB. An alternate daisy-chained BGA device was soldered onto the top module. Both modules were attached to the fixture set inside the Imada DPS-110R force gauge, which measures force when the modules are inserted and extracted. A Metra HIT 30M four-lead ohmmeter was used for all resistance measurements. The resistance averaged 0.018ohms/contact.

Test results

A relationship between the insertion/extraction forces versus the number of cycles is shown in **Figure 4** for the BGA153 socketing system. From the graph, it can be seen that insertion force for the complete 153BGA system averages 4.5 lbs and it is repeatable over 10 cycles. The extraction force for the complete 153BGA system averages 2lbs and it is repeatable over 10 cycles.

Electrical requirements are generally stated in terms of the bandwidth. Bandwidth is typically specified in terms of insertion and return loss. A vector network analyzer is used for this experiment. A signal is sent from port 1 (top of the contact) and received at port 2 (bottom of the contact). Signal reflections are measured and reported as S21 curves shown in **Figure 5**.

An insertion loss of -1dB @ 20GHz is interpreted as 90% of signal pass through the interconnect medium and only 10% of signal is lost through the interconnect transition at 20GHz. Also, it can be noticed that both edge pins and field array pins show -1dB@20GHz, and the corner pins show -1dB@13.5GHz. This data shows that in addition to contact geometry, the location of the contact pin plays a significant role in RF performance. This is very critical for the test engineer because the specific pin functionality in the IC is being verified at a specific frequency.

Summary

A primary concern to anyone utilizing

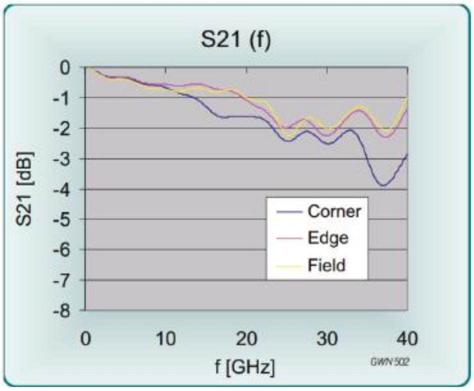

Figure 5: S-parameter data for corner, edge and field array pins.

high-density devices is that the socket must provide a high-performance, low and stable value of resistance while meeting mating requirements; in particular, it must meet requirements for the mating force and the number of mating cycles it must withstand without degradation. The test results presented for the Giga-snaP™ socket system share the electrical and mechanical characteristics of the contact interface. The simple design of the socket makes it cost efficient and allows assembly to the target board using a standard reflow process. The electrical path of the BGA socket adapters is a high priority performance issue; the physical length from the top connection point on the male adapter to the solder tail on the female socket is 3mm. This is the shortest connection length by far for interconnect pin sockets, therefore providing better transmission of high-frequency signals.

Acknowledgment

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Biography

Ila Pal holds an MS degree in Mechanical Engineering and an MBA degree; he is VP of Marketing at Ironwood Electronics Inc., USA; email ila@ironwoodelectronics.com