Optimizing Insertion Extraction Force in a Pin-Socket Interconnect

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 PCB (printed circuit board). 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 be replaced by another IC or multiple IC's. 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 due to 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 due to substrate warping and wicking of solder into the contacts. Large integrated circuits with pin counts over 1000 and approaching more than 2000 are becoming common. Because of high pin counts a low insertion force is important for usability. This paper will discuss optimizing insertion extraction force in pin & socket interconnects.

Giga-snaP™ BGA Socketing System

The system consists of two modules. The base module has socket pins arranged in FR4 substrate with solder balls on the backside for attaching to the target PCB. The top module has terminal pins arranged in FR4 substrate with round head pressed flat with substrate. This round head acts as a PCB pad to receive actual BGA device. BGA device soldered on to the top module and plugged in to the base module which is soldered on to the target PCB completes the interconnect system. Figure 1 shows both top and base module of 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/extraction forces become increasingly important as the number of pin count in the socket increases.

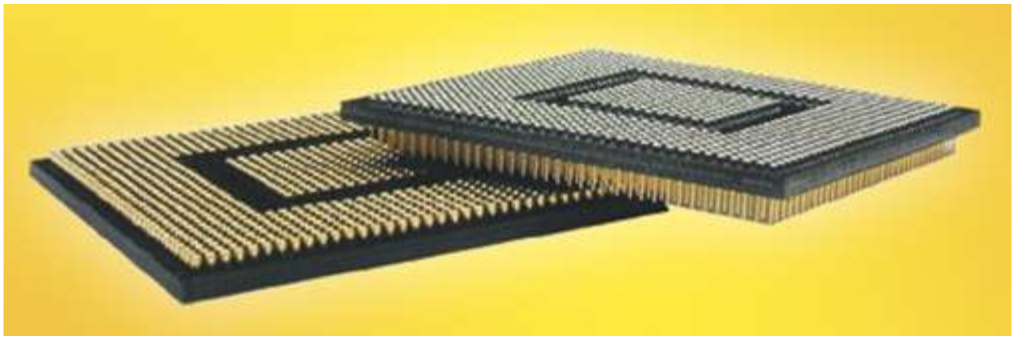

Figure 1: Giga-snaP™ BGA socketing system

Socket Pin Anatomy

The socket pin consists of socket shell, contact clip, and solder ball. The socket shell is made of Brass Alloy 360 with 10 micro inch of gold over 100 micro inch of Nickel finish. The contact clip (heat-treated Beryllium Copper Alloy 172 with 10 micro inch of gold over 50 micro inch of Nickel finish) is press-fit into the socket shell. The solder ball (63% Tin 37% Lead) is attached to the tail of socket shell. Figure 2 shows socket pin details.

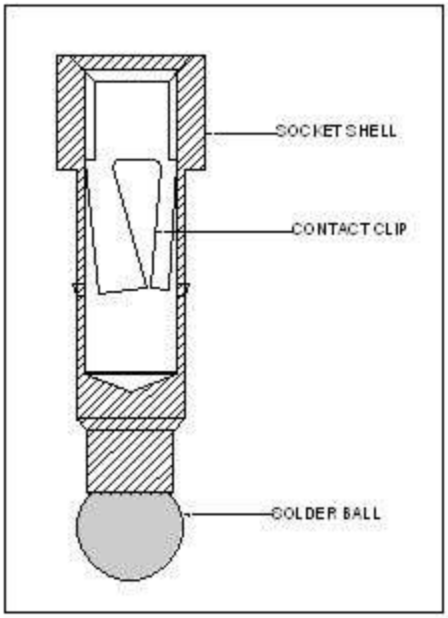

Figure 2: Socket pin cross-section

Contact Force

The main function of the contact clip 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. Contact clip has three fingers positioned in a circular fashion.

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
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. This causes insufficient contact force, 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. Thus 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, 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 388-pin BGA device. The base module was soldered on to a daisy chained PCB. An alternate daisy chained BGA device was soldered on to 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.

Figure 3: Insertion/Extraction test setup

Test Results
A relationship between the insertion / extraction forces versus the number of cycles is shown in Figure 4 for the BGA388 socketing system. From the graph, it can be seen that initial insertion force for the complete system starts at 14kg and increasing to 22kg at 200 cycles. The resistance averaged .010 ohms/contact. The extraction force for the complete system starts at 7kg and increasing to 18kg at 200 cycles. Increase in total force at higher cycles is attributed to the friction factor. After 200 cycles, the top module was lubricated which brought the insertion and extraction force back to the initial stage, 14kg and 7kg respectively.

Figure 4: Insertion / Extraction data

The next test shows relation between force and deflection between two different Giga-snaP™ pin diameters (0.2mm and 0.25mm). The same test setup was repeated, but every 10 cycles the top module with different pin diameter was used alternatively. A consistent pattern seen in Figure 5 reveals 0.25mm diameter pin module has more insertion force due to more deflection of the contact clip. Thus by controlling contact clip deflection and frictional force due to sliding action, insertion and extraction force can be kept to minimum.

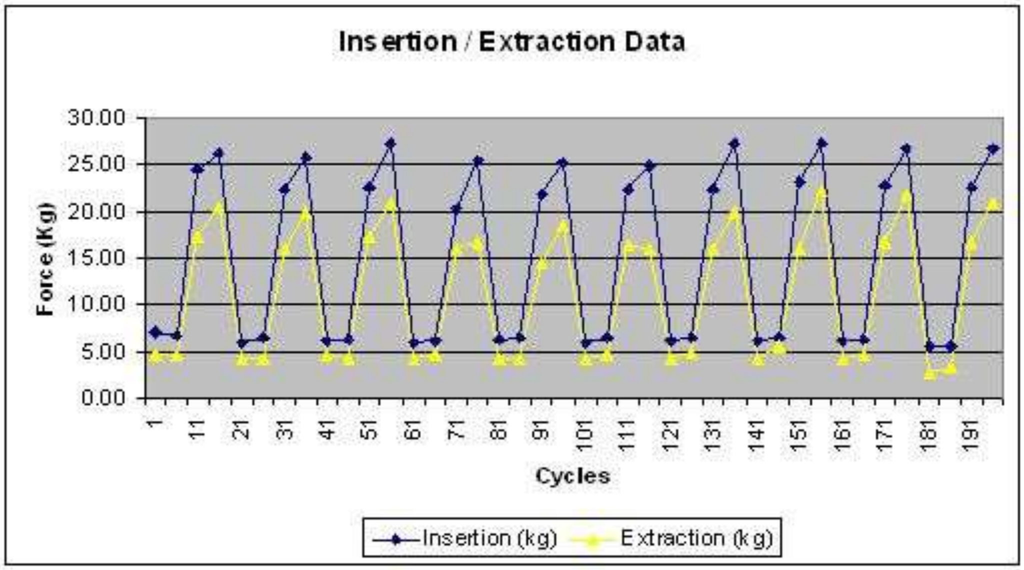

Figure 5: Effect of Deflection on Force

Conclusion

Optimizing insertion and extraction force in a pin/socket interface was driven by a combination of technology factors including miniaturization and increasing pin counts. Market factors included both the need for low cost and durability. When considering insertion/extraction force, total force has to be evaluated. Contact force is a function of deflection, elastic modulus, and contact geometry. Additional force due to friction, misalignment of mating halves and positional tolerances of pins in the substrate can impact total force considerably. Stress relaxation resistance influences the durability of socketing system. The test data shows how one parameter (deflection of contact clip) affects the force. Further studies are being conducted to vary other parameters and assess their impact on contact force and socket performance.

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