HIGH PIN COUNT
PGA SOCKETS RISE CHALLENGE

Ever since the automobile was introduced, the desire for speed has been entrenched in engineers' minds. Through the years of technological advancement, the quest for speed is still present today. A prime example is the deluge of high speed microprocessors that are, at times, obsolete as quickly as they are released to the buying public. For the pin grid array (PGA) socket manufacturer, the advent of high pin count PGA sockets is a sleeping giant.

Standards Develop

The Electronic Industries Association (EIA) committee on sockets, CE-3.0, has published a number of sectional and detail specifications dealing with both mechanically and non-mechanically actuated sockets. The sectional specifications comprise a family of sockets and define such items as test sequence, test severity, and preferred values for dimensions and performance characteristics. The detail specification provides all pertinent information necessary for a specific socket design or style. Conformance to these standards gives the user and manufacturer a valuable means to evaluate the potential performance characteristics of the sockets involved.

Contrasting Mechanically and Non-Mechanically Actuated Sockets

The offered PGA socket geometries are vast, ranging from a 10 x 10 grid pattern with 36 pins to a 24 x 24 grid pattern with more than 400 pins. The grid patterns have traditionally been offered on 0.100" centers. Interstitial PGA (IPGA) patterns up to and exceeding 500 positions also are available now.

The mechanically actuated socket is a zero insertion force (ZIF) application that employs a free-moving cam. In the open position, the cam allows the PGA device to be inserted and withdrawn without force. However, when the cam is actuated into the closed position via a lever, hex nut, etc., the normally closed contacts maintain a constant pressure on the PGA pins.

By contrast, the non-mechanically actuated socket is low insertion force (LIF) type where the PGA is mated to the socket with an applied force. These sockets are designed to accept an 0.018" nominal diameter PGA pin. Insertion and extraction tools normally are required to insert and remove the PGA device with high pin counts to eliminate the chance of physically damaging the device or socket.

It has been observed that the existing industry-available tools are not well designed, resulting in potential damage to the PGA devices. Although this topic is beyond the scope of this article, it is an important consideration that must be addressed. Significant improvement is required in this area.

Select sockets for Evaluation

For the past year, extensive evaluations have been performed on PGA sockets. This article will concentrate on the results of testing high pin grid count (20 x 20 or greater), 0.100” centerline, non-mechanically actuated, LIF PGA sockets.

Three manufacturers’ sockets were subjected to a series of mechanical/
environmental stress tests to establish base line performance data. The contact design, similar for all manufacturers, utilizes a two-piece construction whereby a spring clip is assembled to an outer contact shell (figure 1). The spring clips were a multiple-tine design plated with 30µin. min. gold over 50µin. min. nickel.

The mating devices were ceramic PGAs with the positions internally daisy-chained for purposes of monitoring electrical characteristics. The gold-plated PGA device pins were 0.018” dia. The pin tips of these devices are significant relative to their impact on the test results. The tips are flat with only a slight radius at the tip edge (figure 2). Other industry-standard PGA devices have been observed with blunt tips and burrs as well. These factors have been shown to directly affect mating/unmating force and socket contact performance.

Determine Attributes To Be Monitored

The mechanical attributes of mating/unmating forces and individual engagement/separation forces were monitored throughout the test program.

The key electrical attribute used for this evaluation is low level circuit resistance . This attribute is used to evaluate the electrical resistance characteristics of the contact systems under conditions where applied voltages and currents do not alter the physical contact interface and will detect oxides and films that degrade electrical stability. Electrical stability of the contact system is determined by analysis of the change in resistance occurring. This attribute is monitored throughout the test exposures. The test parameters use a 100 mA max. test current and an open circuit voltage of 20 mV (four-wire technique).

The actual observed initial resistance values varied from manufacturer to manufacturer due to the contact design differences such as material, beam lengths, and the bulk resistance of the daisy-chained positions within the ceramic PGA (mating device). However, the stability or change in low level circuit resistance was the pivotal factor. The failure criteria used in the performed evaluation was a maximum change in resistance of 25.0 mΩ across a pair of two daisy-chained contacts.

Observe Performance in Testing Environment

Three test groups were developed for this evaluation: vibration, durability/thermal shock/cyclic humidity, and heat aging. Low level circuit resistance was monitored periodically. A summary of the environmental severities used follows.

Thermal Shock	5 cycles, -55 to 125°C, 30 min. dwell time
Cyclic Humidity	10 days, 25 to 65°C, 90 to 95% RH
Thermal Age	500 hrs., 105°C,

Table 1 summarizes the observed low level circuit resistance measurements of these environments. The data shown indicates that all three socket designs were stable throughout the sequences shown.

There were, however, three areas where significant and potential problems occurred during the test. These areas may affect long-term performance contingent on application and severity. The characteristics involve durability (wear), mating/unmating forces, and vibration.

Durability. Durability testing was performed as a preconditioning sequence prior to any thermal shock and humidity. It is performed to induce wear that might occur under normal service conditions on the contacting surfaces of the socket. The durability level performed on these sockets was 50 mating cycles.

The LIF PGA sockets, while maintaining electrical stability following durability, did cause a significant wear track on the PGA pin surface. Although there was no evidence of these wear tracks penetrating the plating surface, both the severity and consistency of the wear track indicated an aggressive plowing action that is counter to minimizing wear. This occurred in an area that requires attention for further design consideration.

Mating/Unmating Force Versus Individual Engagement/Separation Force. The total force required to mate and unmate the PGA to and from the socket and the individual engagement and separation forces as advertised in supplier product literature are clearly conflicting.

Depending on the manufacturer or contact geometries used, the individual engagement and separation forces measured are shown in table 2.

These forces were measured with an 0.018” ± 0.0002” dia. steel test pin with a spherical tip. The forces differ significantly from the total mating and unmating forces when equated over the entire socket.

Table 3 presents data comparing the “as advertised” to the “as tested” forces using the steel test pin calculated for a 400-position PGA. Table 4 presents data comparing the total mating/unmating forces observed in the test program equated to a 400-position PGA tested with actual PGA devices. The test was performed with a test rate of 1.0 in./min. and a self-centering fixture. This again strongly emphasizes the need for effective insertion/extraction tools.

The contributing factor for the discrepancy as shown in the different test vehicles used for each attribute. The test pin for individual engagement/separation forces is an 0.018” ± 0.0002” dia. polished steel gauge pin with a bullet-nose shaped tip. Conversely, the PGA device has gold-plated pins (0.018” ± 0.002”dia.) with either a blunt, slightly radiused tip or a blunt-end tip. The small radius on blunt-end tips significantly increases the mechanical forces required to mate a device to the socket.

Traditionally, published data only states the individual engagement and separation forces. While this parameter is effective in monitoring the stability and repeatability of the contact and assembly processes, it creates a difficult and frustrating situation for the user to determine how much force would be required to mate or unmate a PGA device. This is a significant problem for this type of socket that is still unresolved.

A second significant factor impacting the mating forces is the PGA device pin tip true position relative to the socket contact true position within the array. This factor interrelated to the pin tip configuration can result in the force magnitudes observed, further compounding the difficulty in projecting mating and unmating force from suppliers’ published engagement and separation data.

Vibration. Vibration testing evaluates the sockets to determine if the socket designs are susceptible to fretting wear and corrosion due to mechanical motion. It also will determine if the electrical stability of the system has degraded when exposed to a vibatory environment, or if electrical discontinuities exist at the specified level.

The test was performed with LIF PGA sockets mated to PGA devices with and without heat sinks. The heat sinks were bolted directly to the PGA heat dissipating “slug” by means of two nuts/washers. The test severity level was as specified in the EIA standard. The heat sink weighed 125 g.

Frequency	10-2000-10 Hz (sinusoidal)
Amplitude	0.06” da or 15 Gs
Duration	4 hrs./axis, 3 axis

The socket/devices without heat sinks remained electrically stable. Those with the heat sink exhibited excessively large changes in low level circuit resistance (table 5).

Visual examination and surface analysis indicated that fretting motion had occurred, (page 17). These test results indicate that an unstable condition exists when the sockets with heat sinks are subjected to this test severity. The observations present a question: Is vibration test condition too severe for PGA sockets when mated to devices with heat sinks attached-the normal technique used with this type of component? The standard vibration test condition of 10-2,000-10 at 15 Gs did not appear to cause electrical degradation when devices/sockets without heat sinks were tested.

At this point, it was decided to perform a more extensive vibration analysis in order to determine a proper test severity level. Random vibration was chosen because it is generally regarded as a test condition that closely resembles real life. The same number of manufacturers previously indicated were evaluated at the following conditions with attached heat sinks ranging from 70 to 250 g (table 6).

The test results from the matrix were inconsistent, and no direct correlation could be determined relating the vibration conditions, heat sink designs, and failure levels. It is felt that the heat sink design attributes (mass, size, vibration response, and attachment mechanisms) synergistically affect the performance of the PGA socket/device interface. A significantly expanded test matrix of vibration conditions, PGA pin count, heat sinks, attachment mechanisms, etc., needs to be performed to determine conclusively finite limits for these parameters.

It must be emphasized that heat sinks are an integral part of a high pin count PGA/socket system. The heat sink and its attachment technique cannot be ignored. Due to the wide variations in existing heat sinks, attachment techniques, and new evolving designs, a significant problem exists for both user and socket manufacturer relative to the applications where vibration (including amplification) is a concern.

In essence, due to the heat sink/attachment technique variables that must be considered, the standard sine vibration test is not considered a viable evaluation technique for PGA sockets with or without heat sinks. At this stage of product evolution, vibration has to be approached as an application-specific situation. This is due to the fact that heat sink designs are evolving with large form factors – masses of 250 g or more – and the possibility of integrally mounted fans on the heat sinks. Also, the systems' micropackaging options of spring clips or other mechanical attachment mechanisms attaching the heat sink to the PGA/socket need to be addressed by both the socket industry and end user.

Conclusion

Relative to the non-actuated socket design, the results of this study indicate significant potential problems may exist with the contact styles evaluated. Although other contact designs exist and new designs are evolving, the areas of concern should be revisited when choosing this type of socket.

- Contingent on contact geometry, significant and severe wear could result.

- Mating/unmating forces are of a magnitude where potential damage to the PGA can occur. There also may be a physical pin count limitation for the traditional LIF PGA sockets to be practical. Additionally, special tools may be required to prevent damage to the devices. Mating/unmating data should also be added to the vendors' product literature so unexpected surprises can be avoided by the user.

- A careful study of the vibration levels expected along with amplification factors should be performed in conjunction with the heat sink design and configuration for proper assessment of the socket system.

The situation is not totally bleak. Some manufacturers are addressing these issues, and new designs, including attached heat sinks and mechanically actuated sockets, are evolving, which addresses some of the discussed concerns.

TABLE 1

Low Level Circuit Resistance Measurements

	Maximum Change in Resistance					
	Thermal Shock		Cyclic Humidity		Thermal Age	
	ΔR	Category	ΔR	Category	**ΔR**	**Category**
Manufacturer 1	<+16.0 mΩ	Stable	+12.0 mΩ	Stable	+8.0 mΩ	Stable
Manufacturer 2	<+10.0 mΩ	Stable	+10.0 mΩ	Stable	+4.0 mΩ	Stable

Manufacturer 3	<+24.0 mΩ	Stable	+19.5 mΩ	Stable	+6.0 mΩ	Stable

Note: ΔR = Change in resistance

TABLE 2

Engagement and Separation Forces

	Engagement Force	Separation Force
As Advertised	2.0/6.0 oz./contact	0.5 oz. min./contact
As Tested	1.5/5.0 oz./contact	0.5/4.0 oz./contact

TABLE 3

Mating and Unmating Forces Using Steel Test Pin

	Mating Force	**Unmating Force**
As Advertised (calculated)	50 to 150 lbs.	12.5 lbs. min.
As Tested (calculated)	37.5 to 125 lbs.	12.5 to 100 lbs.

Note: The values do not take into account potential misalignment conditions.

TABLE 4

Mating and Unmating Forces with PGA Device

	Mating Force	**Unmating Force**
Force/contact	13.4 to 18.4 oz.	12.7 to 15.0 oz.
Total Force (400-position PGA)	335 to 460 lbs.	317.5 to 375 lbs.

TABLE 5

Change in Low Level Circuit Resistance for Devices/Sockets with Heat Sinks

	ΔR	**Category**
Manufacturer 1	<+200.0 mΩ	Unstable
Manufacturer 2	<+50.0 mΩ	Unstable
Manufacturer 3	<+400.0 mΩ	Unstable

TABLE 6

Vibration Analysis Testing Levels

	A	**B**
Frequency	50-2,000 Hz	50-2,000 Hz
Average Grms	11.6	7.3
Power Spectral Density	0.1 G^2/Hz	0.04 G^2/Hz
Duration	45 min./Axis	45 min./Axis