Evaluating the Integrity of LGA Package, 2nd Level Interconnect for µModule Family of Products

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Introduction

A good interconnect solution provides performance and cost benefits, ease of manufacturing, and meets or exceeds industry reliability requirements for any application. When the LGA component interconnect was introduced, board level manufacturers were given the task of incorporating the new component interconnect with their existing process. New interconnects often improve processing, but the acceptance for new interconnects can cause conflicts between the design engineers who need the new capability and manufacturing engineers who must accommodate the new package interconnect with their existing process and equipment. The LGA interconnect offers the designers better thermal and electrical performance and the manufacturing engineers the advantage of using existing equipment and processes, thus reducing both design and manufacturing development cycle times.

µModule™ History

Products evolve so they offer the latest technology or newest capabilities, and yet these new products must be able to do it all in smaller packages. This trend packs the proverbial 5 pound box with 10 pounds of performance. In other words, we have increased the density of the product; of course higher densities require solutions that need higher power. Both the PCB and the component are impacted; they must work in unison to allow for the higher performance. It is also necessary to meet industry environmental regulations. In selecting the LGA interface, Linear Technology considered several factors, but not limited to: Thermal performance, interface geometry or pad shape, environmental requirements and by far the toughest requirement to meet was to treat it like an integrated circuit.

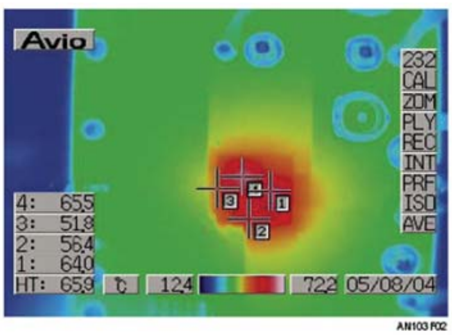
In lieu of the increasing need for board mount application support (2nd level interconnect) and the IPC 9701 requirements, Linear Technology performed extensive study of mounting these µModule devices to PCBs (solder paste type, stencil design, reflow profiles), solder joint characterization through X-rays, destructive testing like dye and pry, cross-section etc, and 2nd level reliability testing. Linear Technology has chosen to offer the µModule products with an LGA format instead of a BGA format. One of the requirements we considered was can the LGA package be a drop-in-solution with the current board manufacturing process. It is to be noted that the 2nd level testing that we are discussing in this paper does not cover all the applications, and it is recommended that each customer perform their characterization and process optimization to suit their application requirements.

Thermal

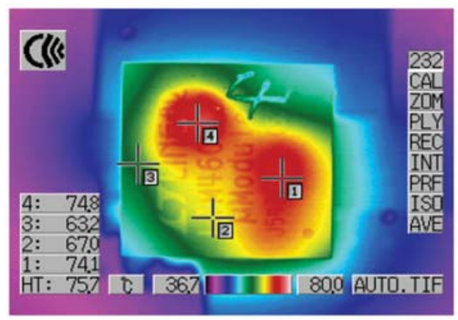
Linear Technology has chosen the LGA because of the thermal benefits offered by the closer proximity of the package to the PCB. The stand-off height of the LGA package is lower than that of a BGA package after board mount. The proximity of the component to the PCB has been shown to improve thermal transfer by as much as 3°C per watt over a BGA; for example, at full load the temperature difference is ~9°C for the LTM46XX DC/DC regulator µModule. The thermal delta between a BGA and an LGA is present throughout the operating parameters of the part. Also of particular interest is the thermal gradient across the part. The LGA component has a uniform thermal distribution when compared to the BGA. See Figure 1.

	Temp	Test 1			Test 2	Test 3					Test 4	Test 5
Unit#	°C	V_{IN}	I_{IN} (mA)	V_{OUT} (V)	I_{IN} (µA)	V_{IN}	I_{IN} (A)	V_{OUT} (V)	I_{OUT}	Eff	Output Ripple (mV)	Output Tran 0A-8A (mV)
BGA 4	75.7	12.011	41.56	1.5084	13	12.025	1.527	1.5109	10.042	82.63%	17	220

	Temp	Test 1			Test 2	Test 3					Test 4	Test 5
Unit#	°C	V_{IN}	I_{IN} (mA)	V_{OUT} (V)	I_{IN} (µA)	V_{IN}	I_{IN} (A)	V_{OUT} (V)	I_{OUT}	Eff	Output Ripple (mV)	Output Tran 0A-8A (mV)
LGA 1	65.9	12.06	43	1.5041	13	12.0276	1.541	1.5145	10.2	83.35%	17	220



LGA BOARD MOUNT THERMAL IMAGE

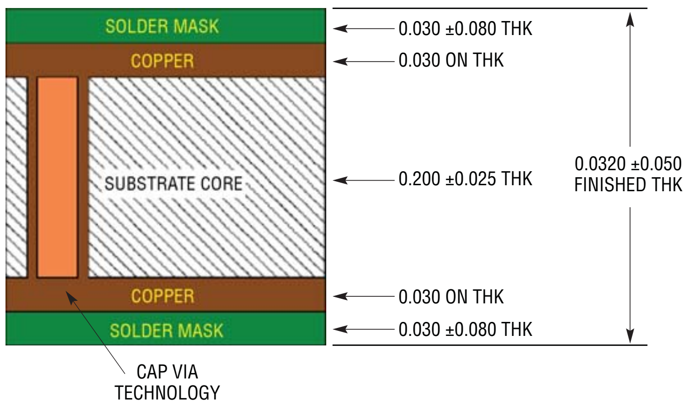


BGA BOARD MOUNT THERMAL IMAGE

TEST 1: 12V INPUT, 1.5V OUTPUT AT NO LOAD
TEST 2: SHUTDOWN CURRENT AT 12V INPUT
TEST 3: EFFICIENT AT 12V INPUT, 1.5V OUTPUT, 10A OUTPUT CURRENT
TEST 4: OUTPUT RIPPLE AT 12V INPUT, 10A OUTPUT CURRENT
TEST 5: OUTPUT TRANSIENT AT 12V INPUT, 0A TO 8A LOAD CURRENT STEP

Figure 1. LGA Package Has a Uniform Thermal Distribution and Lower Thermal Resistance When Compared to a BGA Package

Thermal operation of the component is improved using a high performance substrate which distributes the thermal power of the part using capped vias (see Figure 2). This allows for via placement anywhere they are needed for greater thermal distribution. Thermal dissipation is also affected by the cross sectional area through which the heat is passing into the PCB. This is critical for the component to get the heat away from the internal circuitry and into the PCB where it can be dissipated. Special interest should be taken with BGA vs LGA thermal scan in Figure 1. Not only is there a thermal gradient across the BGA part, but the PCB is also at a lower temperature on the BGA component, demonstrating the inability of the BGA to move the heat away from the critical power component. The BGA in these tests are LTM46XX DC/DC µModule which have had solder balls attached to the LGA grid.



LTM4600 HIGH PERFORMANCE SUBSTRATE

ELECTROLESS Ni/Au PLATING
SOLDER MASK = TAIYO INK PSR 4000 AUS 7
CORE = MITSUBISHI GAS CHEMICAL CCL-HL-832
Ni = 0.0030 MIN TO 0.020 MAX mm (197 µ INCHES NOMINAL)
Au = 0.0003 TO 0.0008 MAX mm(15.7 µ INCHES NOMINAL

NOTE: UPDATED VALUES USED FOR SPECIFICATIONS MUST BE
OBTAINED VIA THE APPROPRIATE LTC REPRESENTATIVE.

Figure 2. Capped Vias Improve Thermal Performance

Construction of the LGA Pads

Typically, BGA style pads are round; the Linear Technology µModule products utilize square pads. Pad sizes are 25, 30 or 35 mils for the µModule family. LGA interconnects from some vendors resemble existing BGA style packages; imagine the BGA where the balls have been removed. Linear Technology has modified the geometry of the pad to offer a ~27% increase in area relative to the 25 mil diameter round pad (see Figure 3). This increase in area allows high thermal and electrical pathways. It also helps with testing of the device. Linear Technology currently tests the µModule family 100% at full load; due to this full load testing special contactors are required. These contactors would require a round pad equivalent to the size of a square pad if it were measured from corner to corner. If the pads were round the space between the pads would be reduced from 25 mils to ~15 mils, reducing the space between the pads on the PCB which would interfere with routing. Stress is also considered when using the square pads. It is well known that the round pad will have ~5% lower stress than the equivalent square pad. It was Linear Technology's intent to increase thermal and electrical pathways, lower the stress by increasing the pad area, and achieve 100% testing without reducing the routing area. The pads were also covered with electroless gold to ensure good solderability and to meet environmental issues.

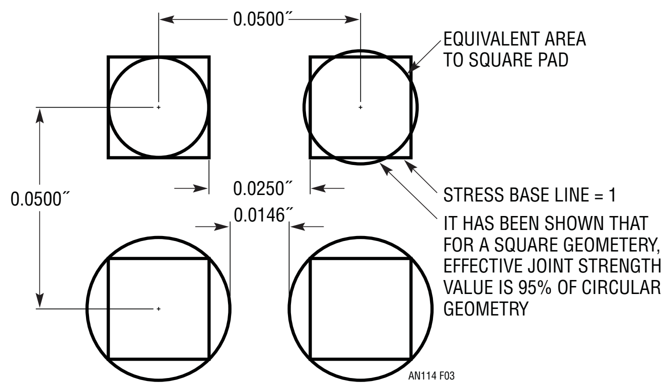


Figure 3. Square Pads Allow High Thermal and Electrical Pathways While Lowering Mechanical Stress

Environmental

Today's marketplace requires processes to be environmentally friendly; RoHS is a main focus for environmental requirements. The European Union has mandated that certain substances be restricted from electronics.

One of these substances is lead. Lead has typically been used as the major interconnect for most printed circuit boards. The current use of lead is restricted to a maximum ppm by RoHS. This number is generally below 1000ppm. Linear technology's LGA power modules are plated with gold over nickel over copper. The gold plating allows for RoHS compliance on the exterior of the part referred to as a precious metal interconnect designated by e^4 and provides a well known solderable interface. Both lead and lead free interfaces can be formed using the Linear Technology LGA interconnect. Moreover, Linear Technology's LTM46XX series µModule devices are fully RoHS compliant and are lead free on the external interconnect termination.

Reflow 2nd Level Interconnect

The µModule device reflow profile is shown in Figure 4. This profile was developed after several runs through the IR furnace. It should be noted that the profile is considered lead free or 260°C capable. What that means is the part can go through the oven which is using a lead free profile, but due to its mass, the µModule will not get up to 260°C. An industry standard for a part with a mass similar to the LTM46XX is 245°C maximum reflow temperature. Please see the Linear Technology web site for Application Note 100 "Recommended Land Pad Design, Assembly and Rework Guidelines for DC/DC µModule in LGA package (www.linear.com/micromodule)." The data taken in Figure 4 specifies the location of the thermocouple used to measure the temperature. X-rays of the 2nd level interconnects showed little voiding when the profile in Figure 4 was used to mount the µModule.

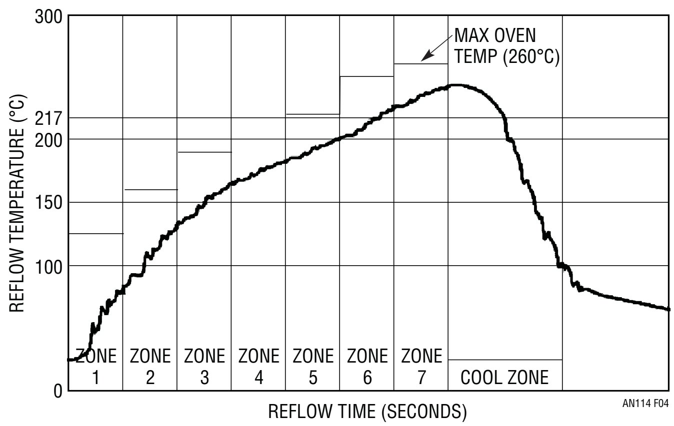


Figure 4. Temperature Reflow Profile for an LTM4600 µModule

LTM4600 µModule Reflow Profile Parameters

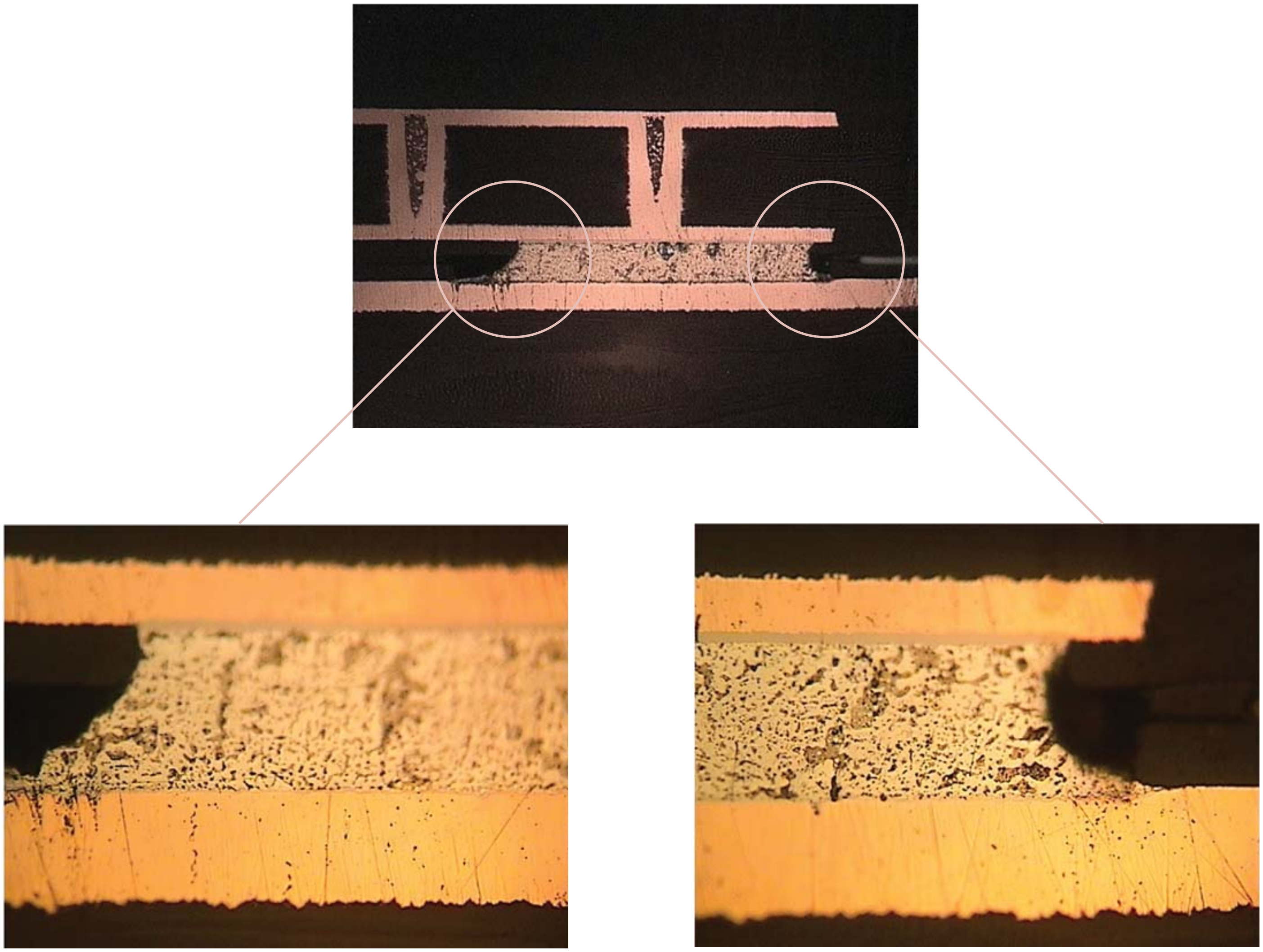
	TEMPERATURE (°C)		TIME (SECOND)		
	MIN	MAX	150°C TO 217°C	217°C TO 243°C	AT MAX TEMPERATURE (°C)
LGA (Under)	24	243	99	72	15
Board (Top)	26	249	105	74	15
Board (Under)	26	244	105	68	15

LTM4600 µModule Reflow Profile Parameters

	ZONE SLOPES (°C/SEC)							
	1	2	3	4	5	6	7	COOL DOWN
LGA (Under)	2.0	1.3	0.8	0.6	0.6	0.8	0.3	–2.4
Board (Top)	2.3	1.6	0.7	0.5	0.6	0.8	0.4	–2.6
Board (Under)	2.1	1.6	0.7	0.5	0.6	0.8	0.4	–2.3

Cross sections of the LGA interconnect after reflow have a diconcave pattern that is the connections look similar to an hourglass. This is exactly the opposite of the diconvex pattern of a BGA. See Figure 5 LGA diconcave pattern.

The interface has been tested by using a technique called dye and pry. The dye and pry testing of the LTM46XX was done by an outside source. The following is an excerpt from the report "The pad area showed very strong solder



MAGNIFICATION: 400x, LEFT EDGE

MAGNIFICATION: 400x, RIGHT EDGE

Figure 5. Cross Sections of the LGA Interconnect After Reflow

joints that upon the pull process, the substrate (component side) was not pulled and remained on top of the solder joints". See Figure 6.

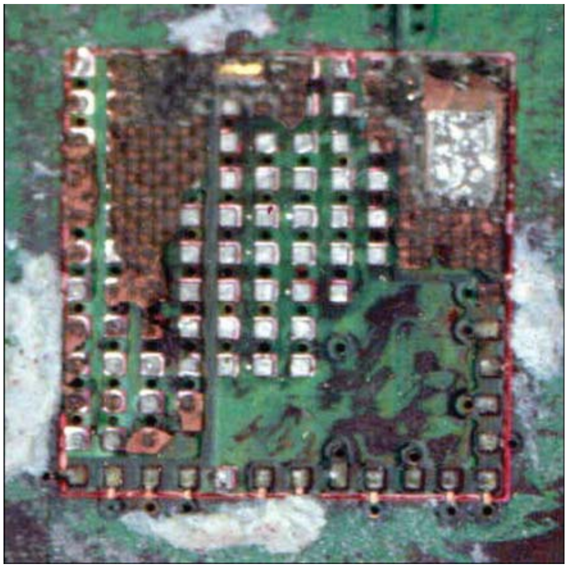


Figure 6. Dye and Pry Testing: Very Strong Solder Joints

This outside report was on µModules that were temperature cycled from –40°C to 125°C for 2000 cycles and 0°C to 100°C for 3500 cycles. All units passed full electrical verification at the end reliability testing. Additionally Linear Technology power cycled the board mounted µModule from 50°C to 100°C for 100,000 cycles with no failures (see Figure 7).

MSL level 4 reliability of the LTM46XX is documented on an on going basis the information is readily available at Linear Technology's website: www.linear.com.

The ongoing reliability testing is part of Linear's overall quality program called Quick Reaction Reliability or QR2 program. This continuously running quality and reliability program monitors the manufacturing facilities at Linear Technology. The monitor is designed to catch infant mortalities or process deviations. This self imposed process monitor drives and maintains Linear Technology's high reliability standards providing customers the highest performance and quality available.

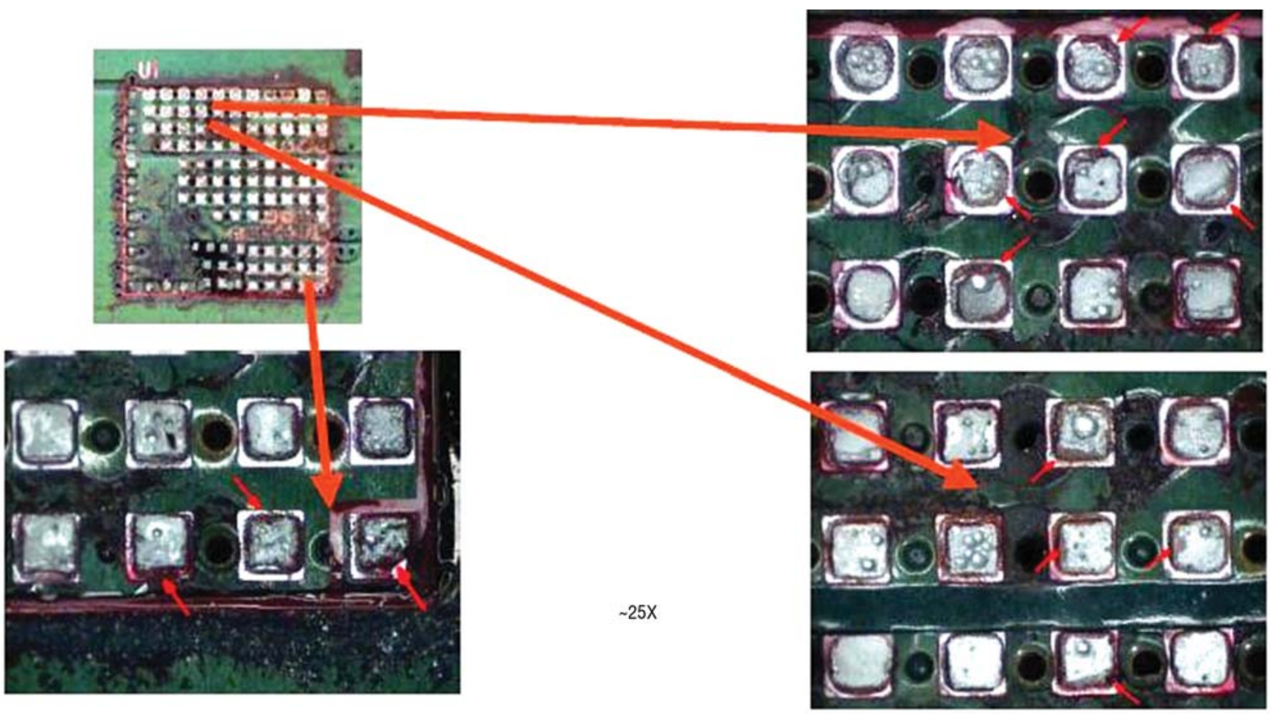


Figure 7. No Failure After 100,000 Cycles (50°C to 100°C)

Conclusion

Obtaining information about a new interconnect becomes key to its implementation and access to support can drive a project ahead with very little impact to existing infrastructure. Solutions are often generated over time, but the ability to prepare for new interconnects will provide a seamless transition to the new interconnect style. It is Linear Technology's goal to provide a high performance product with the necessary background information to facilitate the use of the µModule LGA interconnect. Extensive testing done on the LGA interconnect proves superior performance in many areas: Thermal, mechanical, environmental and reliability of this product line.

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