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PIN GRID ARRAYS

D. R. Obenland

Published June 1993

Final Report
D. R. Obenland, Project Leader

MASTER

**Technical Communications
Kansas City Division**

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Abstract

The evolution of electronic assemblies towards smaller packaging requirements has led to the need to investigate the potential of incorporating higher density packaging in the form of pin grid arrays (PGAs) for weapons hardware. This study investigated the processes required to pretin, solder, and rework PGA solder terminations.

Summary

This endeavor demonstrates that pin grid arrays (PGAs) can successfully be soldered into printed wiring assemblies at AlliedSignal Inc., Kansas City Division (KCD).

Recommendations for processing are as follows.

- Pretinning. Pretinning shall be performed using a robotic actuator or similar fixed-automated, or semiautomated, tinning system. The system shall be capable of preheating the package to approximately 200°F prior to hot solder dipping into a static 500°F solder bath with insertion and withdraw rates of 1 to 5 inches per second and a dwell time of 2 seconds.
- Soldering. Soldering shall be performed by either drag or wave soldering. The soldering system shall be capable of preheating both the printed wiring board (PWB) and the PGA to approximately 200°F prior to contact with the solder.
- Rework. Defective solder joints may be reworked using typical reheat rework techniques. The subject printed wiring assembly (PWA) was successfully reflowed using a 600°F soldering iron with a 2 to 5-second application time.
- PGA Removal/Replacement. PGAs may be removed and replaced using a reflow solder system. A solder flow system is preferred over hot air because it offers the capability of replacing and resoldering a PGA with one additional heating cycle. The system shall be capable of preheating the assembly to 200°F prior to reflowing. The system shall reflow all the solder joints simultaneously, thus permitting the package to be removed.
- Inspection. With proper material and process controls, PGA solder joint quality can be ensured using visual inspection on the non-component side of the PWA only. Until alternate inspection techniques are developed, characterized, and accepted, visual criteria must be used.

Discussion

Scope and Purpose

This study was initiated for the purpose of incorporating soldered pin grid arrays (PGAs) and environmental stress screening into the B90 programmer. Upon cancellation of the B90 program the scope of this endeavor was narrowed to soldering of PGAs only. This continued interest in PGA soldering is due to anticipated future use of this technology.

Activity

Material

The material used in this evaluation was based on the B90 programmer printed wiring assembly (PWA). The PGA used was an 85-pin package manufactured by Kyrocera America Inc. The pins are gold on electroplated nickel over a Kovar base. Metallography samples verify that the gold is approximately 115 microinches and the nickel is approximately 250 microinches. The printed wiring boards (PWBs) used were 0.055-inch-thick six-layer polyimide glass boards with permanent solder mask on the outer circuitry. The boards were manufactured by Pioneer Circuits Inc.

Thermal Profiling

Thermal profiles of the processes were measured using a standard thermocoupled device. (See Figure 1.) Thermocouples #4 and #5 were welded to pins A2 and B8. Thermocouples #2 and #3 were bonded to the bottom of the die cavity and the bottom

surface of the package using thermal conductive cement. A fifth thermocouple, #1, was available for recording other process temperatures. The data was logged and plotted using a MOLE temperature profiler.

Pretinning

The gold thickness on the pins was verified to be approximately 115 microinches. While providing excellent solderability protection and minimal contact resistance, gold in excess of 4% can cause embrittlement and a "frosty" appearance.¹ Excess gold removal is easily accomplished by pretinning the leads in a static bath of molten solder.

Initial attempts to solder non-tinned PGAs resulted in frosty bulbous solder joints with abrupt wetting lines which are typical of non-tinned gold leads. Soldering was also attempted on a PGA that was tinned to only 50% of the pin length. The result was a component-side joint that was much shinier but still bulbous with questionable wetting angles to the leads. (See Figure 2.)

Tinning was also attempted with an Air-Vac PCB RM-10 rework station. The PGA was lowered into a solder flow well corresponding to the package size. The convex curvature and turbulence of the well surface resulted in inconsistent tinning distances between adjacent pins. It was also difficult to control the dipping rate and the dwell time because the height is manually controlled.

Figure 2. Soldered PGA With Partial Tinning

An experiment was run on the robot using both Kester 197 (rosin, mildly activated) and Blackstone 2508 (organic acid, water soluble) flux with various dipping rates and dwell times. The response variables measured were visual surface inspection, wetting balance testing, and optical metallography. All the PGAs that were tinned looked excellent visually. (See Figure 7.) There was no significant correlation between the control variables and the quality of the solder surface as measured by these response variables. All 22 of the parts tinned in the experiment

were fine and gross leak tested with no failures.

The tinning process must also be capable of keeping the package bottom co-planar with the solder surface. Manual attempts at tinning PGAs to meet the above requirements resulted in leads of inconsistent tinning depth. This problem is exaggerated as the package size increases.

The tinning process must be capable of preheating the component body to approximately 200°F and dipping the leads to within 0.010 to 0.020 inch of the package

Figure 3. Tinning Range

bottom while keeping the package bottom co-planar to the solder surface. The solder temperature shall be $500 \pm 10^\circ\text{F}$ with a dwell time of 2 seconds and insertion and withdraw speeds of 1 to 5 inches per second.

A recommended small-scale robotic production cell could include a presentation tray or magazine, a cascade fluxer for consistent flux level, a hot air heat source for rapid preheating, and a rotating solder pot for consistent solder level control.

Soldering

An automated machine soldering process was the only practical method for soldering PGAs due to the need for a controlled process. With manual processes there is too much room for variability in heat and solder application. The machine soldering process used for this evaluation was drag soldering due to its availability at the Kansas City Division (KCD). However, the more common wave soldering process should produce equivalent results provided the preheating capabilities are compatible with the extreme thermal mass of the PGA.

The thermocoupled PGA was again used for the characterization of the assembly for this process with the additional thermocouple bonded to the top surface of the board at the approximate center. The flux used was Kester 185 (RMA) which was applied by the machine with a foam fluxer. The system incorporates two stages of preheaters. The first is a thermostatically controlled bottom-side resistive heater which provides preliminary heating. The second is a top and bottom quartz heater which utilizes an infrared camera for constant feedback of the board temperature. A major advantage of this drag system is the off-line solder elevator. When the board enters the solder station it is pulled off the conveyer and lowered into the solder pot. Because the solder application time is controlled by the elevator and not the conveyer speed, an assembly with large thermal mass can be

Figure 4. Properly Tinned Pins

slowly preheated to obtain uniform temperatures across the board.

The major challenge in controlling the drag solder process was to preheat the PGA to approximately 200°F without overheating the printed wiring board. The flux manufacturer's recommended preheat temperature is 180 to 220°F for maximum cleaning benefit. Typical solder parameters resulted in board temperatures as high as 294°F as shown in Figure 8. By lowering the preheater temperatures while increasing the cycle time, or time at each stage, the board and PGA temperature differential was minimized as shown in

Figure 9. The selected drag solder parameters are the following.

Drag Solder Settings

Preheat	375°F
Solder Temperature	490°F
Solder Point	1.9
Mode	0
High Speed	99
Low Speed	25
Swing Speed	5
Board Temperature	185°F

Figure 5. Solder Globules From Improper Tinning

Dip Time	0
Cycle Time	90
Flux Time	9.9

Fifteen PWAs with pretinned packages were soldered using these settings and produced excellent results. The solder joints displayed excellent uniformity in solder-side appearance. The wetting angles were small with no evidence of voids or pits. (See Figure 10.) One assembly had webbing between two pins on the solder side, which was not alarming

given the extreme lead protrusion on the solder side of the assembly.

Inspection

The assemblies were submitted to a certified visual inspector for inspection. The inspector felt that the joints could adequately be inspected in the sample because the PGA solder joints on the component side were visible when viewing under the package. However, the likelihood of viewing all PGA joints on an actual assembly is minimal due to adjacent components being soldered simultaneously with the PGA. For this situation, the KCD

Figure 6. Robotic Dipping Demonstration

soldering specification states, "Joints that are only partially visible (e.g., one side only) at the time of soldering shall be judged on the basis of the visible portion."

The package body was removed from three of the assemblies using a diamond saw, confirming no evidence for concern of either shorting or solder joint quality. (See Figure 11.) Cross sectioning of solder joints showed excellent hole fill and wetting with no evidence of voids. (See Figure 12.) In a PGA application, visual inspection of all solder-side components is acceptable, provided there are sufficient controls on

board quality, surface solderability, and cleaning process assurance.

The four corner pins of the PGA have a 0.075-inch diameter seating ring which spaces the package 0.050 inch off the component-side circuitry of the board. While there has been no evidence of solder flow restriction (tenting), wetting stops at the top edge of the ring. (See Figure 13.) Tinning the surfaces above this point would allow the solder to flow over this corner but would potentially allow solder to contact the brazed area. Although these pins have corresponding bonding pads inside the cavity, they should

Figure 7. Properly Tinned PGA

not be utilized unless absolutely necessary, to avoid questions of integrity of these abnormal looking joints.

The general soldering specification specifies a maximum lead protrusion of 0.062 inch from the board. The board used in this evaluation is of typical thickness, measuring approximately 0.055 inch, which results in a lead

protrusion of approximately 0.075 inch. (See Figure 14.) In this situation, if taking exception to the protrusion requirement is not possible, the leads should be cut before soldering if possible to avoid cracked solder joints.

Figure 8. Profile of Drag Soldering With Typical Settings

Figure 9. Profile of Selected Drag Solder Settings

Figure 10. Solder Joints After Drag Soldering

Touch-up

Soldering experience shows that there will always be a need for both rework and touch-up techniques. While the solder joint yield of 0.16% is considered excellent, the two leads that were bridged must be reworked. The solder web was removed using prefluxed copper braid and a 600°F Metcal soldering iron. The total solder application time was less than seven seconds even with the added heatsinks of the bridged leads and the package body. Normal reflow of other defect conditions such as voids, poor wetting, insufficient solder, etc. can be accomplished with iron

application times as low as 3 seconds. While hand soldering seems relatively easy, the process lacks the control and consistency of the preferred machine soldering process.

PGA Removal

With the potentially high cost of the PGA packages, there is an obvious need for the capability of removing these devices in order to salvage the device or the assembly. Like any multi-leaded through-hole device, all leads would have to be desoldered to allow removal. The preferred alternative is to use a reflow

Figure 11. Component-Side Joints With Package Removed

Figure 12. Cross Section of Solder Joints

Figure 13. Solder Coverage of Corner Pins

process where all the solder joints are simultaneously reflowed while the PGA is removed.

This was successfully demonstrated using an Air-Vac PCBRM-10 flow solder station. The is mounted on a fixturing frame. The

Figure 14. Lead Protrusion

PWB is positioned with the leads over a flow well corresponding to the lead pattern. Solder is then pumped through the well, contacting the PGA solder joints and providing the simultaneous reflow. Once the PGA is removed, a low-pressure air

hood can be lowered over the joint area to blow the excess solder from the holes, allowing PGA replacement into the board. Preheating and solder contact times can be controlled to match the thermal profile of the machine soldering operation in Figure 9.

Accomplishments

It has been demonstrated through this project that pin grid arrays can successfully be soldered into the programmer printed wiring assembly. The processes utilized to accomplish this can be adapted for the incorporation of PGAs into future weapons applications.

Reference

¹*IPC Assembly-Joining Handbook*, No. 2.4.2.2.1 Intermetallics.

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