APPLICATION NOTE

RC BGA REWORK PROCEDURE

Purpose:

The purpose of this procedure is to describe the steps necessary to successfully remove and replace a ceramic ball-grid-array (CBGA) component on a modern printed circuit board (PCB) using hot-gas rework equipment. It is assumed that the circuit board to be reworked is not conformally coated and the device to be reworked does not include an integral heat sink. Removal of conformal coatings or integral heat sinks is beyond the scope of this document. This document is divided into three sections.

Overview describes the general steps involved in the rework process along with some optional methods that may be applied in each step of the process.

Section A is dedicated to describing the steps necessary to develop the parameters of the rework process. The parameters developed include the important process characteristics that must be controlled in order to produce repeatable results. The resulting combinations of parameters should; 1) ensure a reliable solder joint at each of the ball pads and, 2) minimize heating of adjacent components.

Section B describes the recommended rework process that was developed for the RC BGA package size and circuit board construction used.

Overview. The Rework Process

The rework of modern printed circuit assemblies can be accomplished using a variety of techniques and equipment. The most common method for simple device replacement is manual desoldering and reattachment using soldering iron, but this becomes impractical for devices with high I/O counts or fine lead spacing. For these devices, hot-gas rework stations appear to be the most common and practical tools because mechanical contact is not required to affect heat transfer to the device in order to reflow the solder. This minimizes the risk of mechanical and thermal damage to components or circuit board. There are also new systems that utilize lasers to generate the heat needed to elevate the component temperature above the point of reflow, though these systems can be somewhat expensive.

The rework process can be outlined using a few basic steps that are common to this process regardless of the type of equipment used or the component being reworked.

General Process Outline:

STEP 1: Device Removal – Reflow of solder joints and removal of device from PCB.

STEP 2: Site Cleaning – Removal of excess solder and leveling of ball pads.

STEP 3: Site/Device Preparation – Application of new solder for attachment of new device.

STEP 4: Device Replacement – Alignment of device with rework site physical placement.

STEP 5: Solder Reflow – Reflow of solder to complete device replacement.

STEP 6: Circuit Board Cleaning – Removal of residual flux and rework residues.

STEP 7: Inspection – Verification of rework process success.

STEP 1: Device Removal –

The objective of this step in the process is to remove the undesired component from the circuit without causing damage to the board surface or adjacent components, and consists of the following elements;

i) Circuit board preconditioning-

This involves prebaking the circuit board to drive off any moisture that may cause the components to "popcorn" when exposed to elevated temperatures. This concern applies primarily to plastic body components. Please refer to IPC-J-STD-020 "Moisture/Reflow Sensitivity Classification for Plastic Integrated Circuit Surface Mount Devices" for recommendations of prebaking temperatures and times for various sensitivity levels.

ii) Circuit board preheating-

The entire circuit board is preheated to a temperature of approximately 100°C to minimize the heat scavenged from the site during the removal process. Preheating is typically accomplished using a heater installed under the circuit board, as it is being held by the fixture in the rework station.

iii) Circuit board soak time-

This step is used primarily when the component to be removed is intended to be salvaged. After removal, the component itself is then reworked and new balls are attached to the ball pads. Component salvage is beyond the scope of this document and therefore will not be discussed further.

iv) Component temperature ramp-up rate-

This parameter defines the rate of the heating from the preheat temperature to the reflow temperature once the nozzle has been placed over the component to be removed. Heating rates greater than 3°C/sec are not recommended for circuit boards incorporating ceramic-bodied components.

v) Component reflow temperature and reflow time-

This is the time the component is held above the reflow temperature, and is Generally required to be at least 20 seconds to ensure that all joints are properly reflowed.

STEP 2: Site Cleaning –

The objective of this step in the process is to remove the undesired residue solder from the circuit board rework site without causing damage to the board surface. This consists of the following elements;

i) Circuit board preheating-

The entire circuit board is preheated to a temperature of approximately 100°C to minimize the heat scavenged from the site during the site cleaning process. Preheating is typically accomplished using a heater installed under the circuit Board, as it is being held by the fixture in the rework station.

ii) Reflow of residual solder on ball bonds.

iii) Removal of excess molten or solidified solder and solder balls from ball pads and the rework site. This may be accomplished by using any of the following methods;

-Soldering iron and solder wick
-Soldering iron and vacuum removal pen
-Combination hot-gas/vacuum site cleaning nozzle

iv) Surface leveling of solder remaining on the circuit board ball pads.

STEP 3: Site Repair –

The objective of this step is to repair any damage caused to the ball pads or solder mask during the part removal and site cleaning steps. If the previous steps are properly performed, no repair should be required. Site repair is beyond the scope of this document and as such will not be addressed.

STEP 4: Site/Device Preparation –

The objective of this step in the process is to replace the necessary amount of solder paste required to form reliable bonds. Component manufacturers and industry standards provide guidance for the volume of solder needed for formation of a reliable solder joint. The deposition of solder paste may be accomplished using any one of the following methods;

Direct Pen Deposition-	Use of a dispensing pen to directly deposit solder paste onto the ball pads.
Direct Application-	Application of solder paste by mechanical transfer of paste between the application device and the ball pads.
Preform Deposition-	Application of preformed solder to the circuit board ball pads.
PCB Micro Stenciling-	Application of solder directly to the balll pads using a small stencil designed to fit into the rework site.
Component Stenciling-	Application of solder directly to the ball surfaces on the BGA component using a micro-stencil and fixture designed for the component.

STEP 5: Device Replacement –

The objective of this step in the process is to properly align the component and the circuit board site, and consists of the following elements;

i) Device Alignment – Adjustment of X and Y location, and Theta orientation, of the component relative to the circuit board.

ii) Device Placement – Controlled seating depth of the component into the solder paste, either through using a reference height or a predetermined seating force.

STEP 6: Solder Reflow –

The objective of this step in the process is to bring the component joints to the proper temperature to uniformly reflow the solder paste and react any flux present (when no-clean flux is used), and consists of the following elements;

i) Circuit board preheating –
The entire circuit board is preheated to a temperature of approximately 100°C to minimize the heat scavenged from the site during the removal process. Preheating is typically accomplished using a heater installed under the circuit board, as it is being held by the fixture in the rework station.

ii) Circuit board soak time -
This is used primarily when the component to be removed is intended to be salvaged. After removal, the component itself is then reworked and new balls are attached to the ball pads. Component salvage is beyond the scope of this document and therefore will not be discussed further.

iii) Component temperature ramp-up rate -
This parameter defines the rate of the heating from the preheat temperature to the reflow temperature once the nozzle has been placed over the component to be removed. Heating rates greater than 3°C/sec are not recommended for circuit boards incorporating ceramic-bodied components.

iv) Component reflow temperature and reflow time -
This is the time the component is held above the reflow temperature, and is generally required to be at least 20 seconds to ensure that all joints are properly reflowed. Both time and temperature may need to be increased to comply with manufacturer's recommendations for the solder/flux system being used in the rework process.

STEP 7: Cleaning – (cleanable flux systems ONLY)

The objective of this step in the process is remove any cleanable flux residues from the surface in and around the rework site.

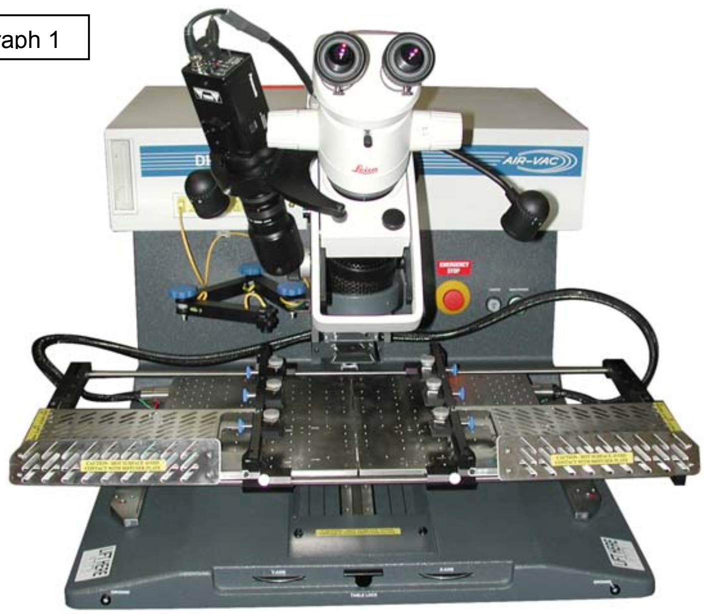
STEP 8: Inspection –

The objective of this step is to verify that the rework process has met expectations for device alignment, rework quality, and cleanliness.

Section A. Process Development:

After review of the available techniques for circuit board rework, the hot-gas method was chosen due to its popularity in industry and the availability of equipment with a high degree of process control capability. The equipment chosen for this work is the Air-Vac Engineering DRS24C Rework Station, shown in Photograph 1. This system incorporates computer control and monitoring of important process parameters and provides computer generated voice prompting to guide the operator through a scripted rework process.

Photograph 1



The specific process parameters required will vary depending upon the size of the component to be removed and the construction of the printed circuit board. The order of the required steps which are to be followed during the rework process and the method used to develop the necessary process parameters will remain essentially the same, regardless of component size or board construction. For the purposes of this document, the following PCB construction and component size was chosen;

Component size:	-	3x9 ball, 1.00mm pitch
Component spacing:	-	0.050 inches nominal on all four sides of a 4x16 1mm pitch pad array. This allows greater spaces on each side for the smaller 3x9 component.
PCB Construction:	-	8 layer, FR4, 0.090 inches overall thickness.
	-	Balanced board design using 2 oz. Copper on 4 simulated Ground (2) and Power (2) layers, and 4 Trace layers.
	-	HASL
	-	Solder mask dia. = .014 inches
	-	Ball pad diameter = 0.020 inches.

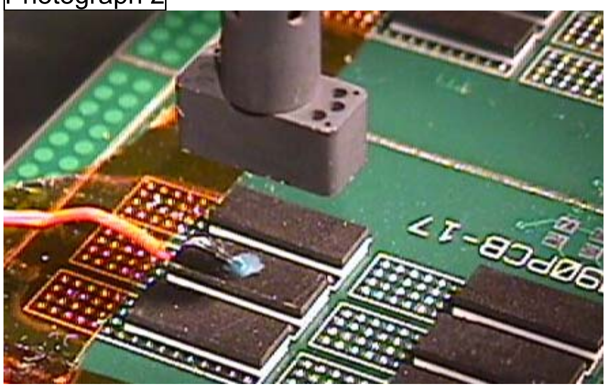
The profiling was accomplished using a closed-architecture nozzle that confines the area of heating to only the site to be reflowed/reworked, with minimum heating of adjacent components.

The profile process development involved the following sequence of steps;

i) One fine-wire Type-K thermocouple was installed from the backside of the PCB (opposite the component side) at a ball near the center of the component location to measure the temperature at the solder junctions and a second thermocouple near the component edge to assess the temperature of adjacent component pads.

ii) One Type-K thermocouple to monitor the component temperature during reflow was attached to the component surface using a small amount of epoxy, as shown in Photograph 2.

Photograph 2



iii) Application of eutectic solder paste to the ball pads using direct application.

iv) Alignment of the component using the DRS24C split-optics alignment system.

v) Seating of the component onto the profiling site with the component captured in the closed architecture rework nozzle.

vi) Set-up of the DRS24C reflow envelope to conform to the following target parameters;

Maximum temperature ramp rate :	3°C/second
Target Board Preheat Temperature :	95°C
Maximum Board Temperature :	130°C
Joint soak temperature range :	140°C to 170°C
Joint soak time :	60 seconds
Target Joint Temperature :	210°C
Reflow Temperature :	183°C (63/37 Sn/Pb eutectic solder)
Time solder joint is at reflow :	45 seconds
Time joint is over 200C :	30 seconds
Solder joint temperature :	210°C
Cool down phase trigger temperature :	170°C

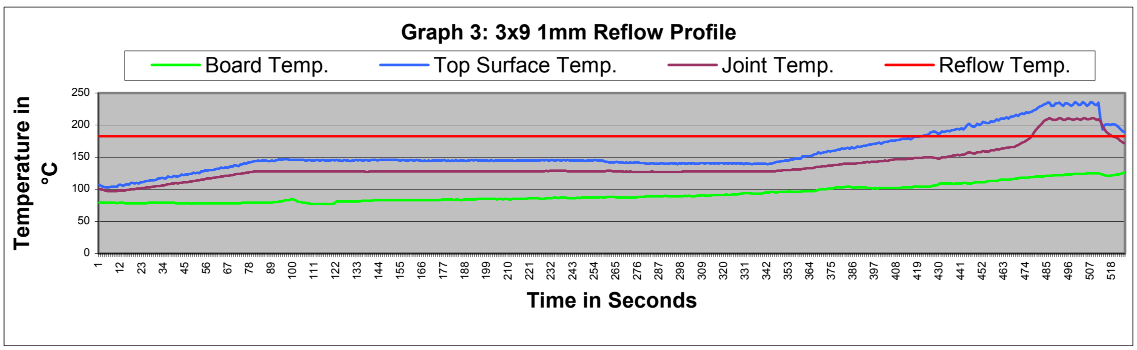
vii) The rework station was then initialized with the following starting limits;

Initial nozzle air flow rate :	30% (100% = 2.85CFM)
Component maximum temperature :	240°C

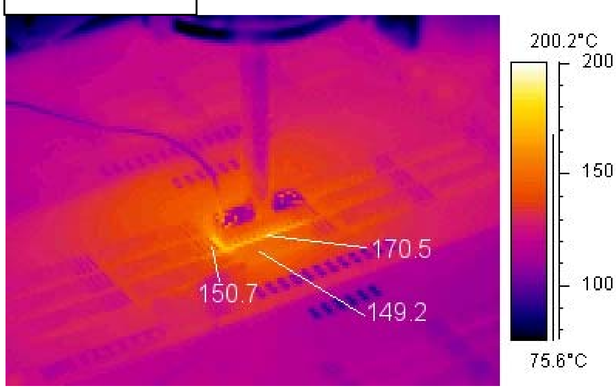
viii) Initiation of the profiling process using the “SMART Track” process development software. This software monitors the junction and device temperatures using up to seven installed thermocouples and can also incorporate an IR sensor, located above the board surface, as a non-contact method to monitor the PCB temperature. The IR sensor measures an area of about 2 square inches on the circuit board and is positioned to view an area within three to five inches of the rework site that is free of components or other obstructions that could cause errors in the temperature readings. As an alternative for this profile, only thermocouples were utilized.

ix) Automated computer adjustment of nozzle airflow rate, nozzle temperature, and maximum component temperature then proceeded under the control of the “SMART Track” software until target parameters were met.

The resulting profile for the 3x9 ball, 1.00mm pitch component can be seen in Graph 3.



Thermograph 1

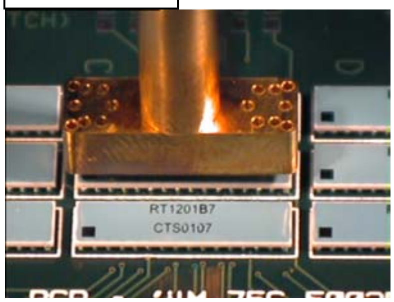


Section B. Rework Process:

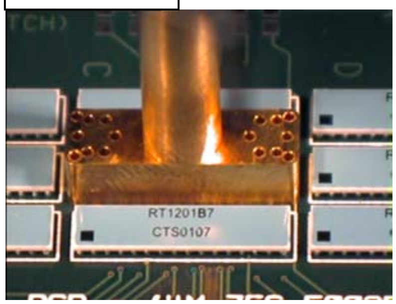
Device Removal:

After defining the necessary machine parameters, the center component in the test array on each board was removed using the closed architecture nozzle appropriate for that size of component. Photographs 3, 4, and 5 show the sequence of steps from nozzle alignment, part removal, and finally deposition of the removed part into the part tray for a similar device. Thermograph 2 shows the temperatures in the immediate vicinity of the device being reworked just prior to the point of part removal, when the temperatures are at the maximum point. Note that the solder joints of the immediately adjacent components do not reach reflow temperature. This illustrates the benefit of using the custom closed architecture nozzle to minimize any risk of disturbing the adjacent components during device removal.

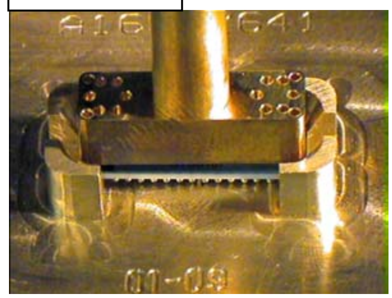
Photograph 3



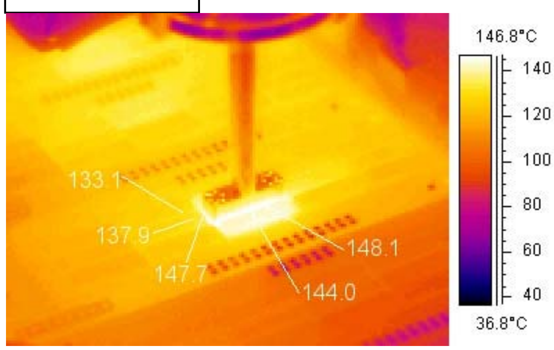
Photograph 4



Photograph 5



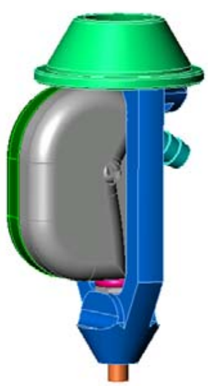
Thermograph 2



Site Cleaning:

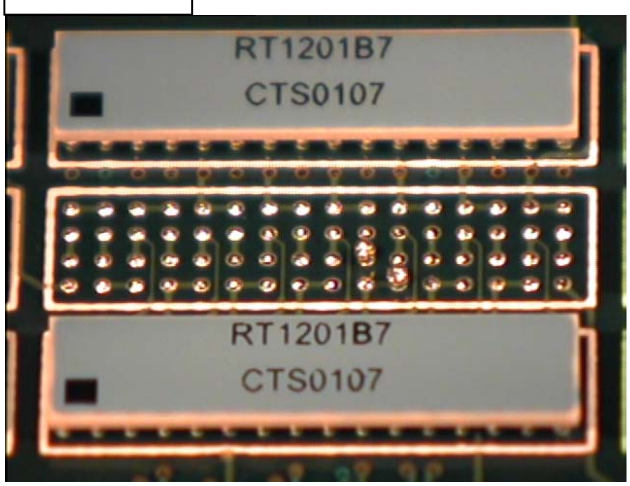
Once all components were removed from the test sites, the nozzle was changed to a standard site-cleaning nozzle. A drawing of this nozzle is shown in Drawing 1. Thermograph 3 shows the temperatures in the immediate vicinity of the nozzle during site cleaning. Note that due to the volume of hot-gas outflow, a large area is raised above reflow temperature, including the outer row of ball-pads on the immediately adjacent components. If the rework site is exposed to the nozzle for an excessive period, enough energy will be transferred to the board to cause all of the ball-pads on the adjacent component to exceed reflow temperatures. Under this condition, care must be taken to not contact and thus disturb the adjacent component. . This can easily be accomplished through operator skill and training. Photograph 6A shows the results prior to site-cleaning after removal of a 4x16 array component. Photograph 6B shows the same site after site-cleaning, demonstrating the simultaneous removal and leveling capability of the site-cleaning nozzle. A micro site-cleaning nozzle has recently been developed by Air-Vac Engineering which should further minimize adjacent component heating by reducing the size of the vacuum cleaning head and lowering the volume of hot gas expelled by the nozzle, but this was not available for evaluation during this study.

Drawing 1 : Site-Cleaning Nozzle

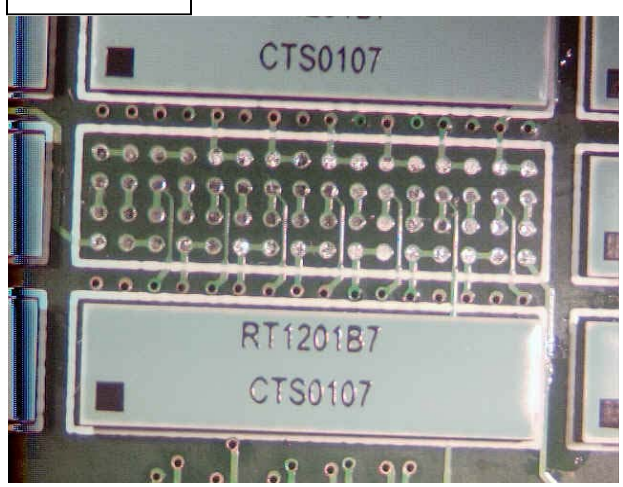


Thermograph 3

Photograph 6A



Photograph 6B



Site/Device Preparation:

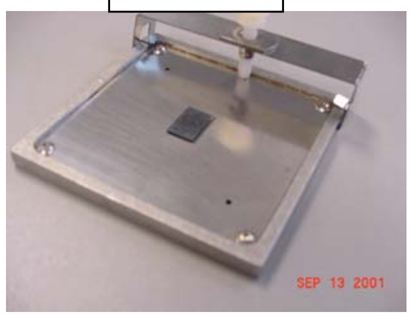
The initial step in device preparation is to deposit a sufficient volume of solder paste to replace the solder removed during the site-cleaning step. Due to the size of the components used in this study and the small component-to-component clearances in the circuit board layout, direct stenciling of paste onto the circuit board was not possible. In order to deposit reproducible volumes of solder, stenciling of solder paste directly onto the component balls was chosen.

A custom component micro-stencil for each size of device was obtained from Mini Micro Stencil, Incorporated of San Marcos, California. The process of stenciling solder paste onto the component balls involves the following steps;

i) Location of the component in the proper micro stencil.
ii) Assembly of the component clamp. (Photograph 7)
iii) Inversion of the assembly and application of the solder paste.
iv) Return the assembly to the upright (component on top) orientation.
v) Removal of the component clamp. (Photograph 8)
vi) Placement of the micro stencil and component into the pick-up tray.

Photograph 7

Photograph 8



Photograph 9

The pick-up tray holding the micro stencil and component (Photograph 9) is then placed in the pick-up position on the DRS24C rework station so that the vacuum head in the rework nozzle will pick up the device. Stenciling and placement of the component must be performed one component at a time to minimize variations in the deposited thickness of solder paste due to paste drying. It is advisable to complete the placement of each component within 5 minutes after stenciling the solder paste onto the device balls.

Device Replacement:

After the replacement component is captured in the rework nozzle, the component must be brought into proper alignment with the circuit board to ensure proper placement. This is accomplished using the LTP beam-splitter vision alignment system of the DRS24C. This system uses white LED's to illuminate the ball pads on the circuit board and green LED's to illuminate the spheres of the replacement BGA device. This allows quick adjustment of x-location, y-location, and theta-orientation to bring the device into precise alignment with the printed circuit board. Once proper alignment is achieved, the component is lowered into contact with the circuit board using the motorized transport controlled by either the force sensor or z-position, depending upon how the system was programmed.

Solder Reflow:

The same sequence of previously programmed heating steps used to remove the original device from the board are now executed to bring the board to the proper temperature and attach the replacement component.

Circuit Board Cleaning:

The component replacement process is now complete and, depending upon the flux system used, the circuit board may require washing to remove any flux residues left behind after the reflow process. Please refer to the flux/solder paste manufacturer's recommendations for this process.

It should be noted that it is NOT ADVISABLE to used aqueous-wash solder flux systems for rework on boards that were manufactured with no-clean flux systems. The converse of using no-clean solder systems on boards that were originally produced with aqueous-wash flux systems is acceptable.

Inspection:

After washing, the circuit board is inspected to ensure adequate cleaning, proper device alignment, and correct solder fillet formation.

Equipment:

Rework Station:

The equipment required to successfully remove and replace a ClearONE device can be obtained from a variety of suppliers. For the purposes of our process development work, the DRS24C system manufactured by Air-Vac Engineering Company of Seymour, Connecticut was used. This system employs computer control of the hot-gas temperature and flow rate for repeatable rework of components.

Air-Vac Engineering Company, Incorporated
30 Progress Avenue
Seymour, Connecticut
(203) 888-9900

Solder Stencil:

The solder stencil employed to apply solder directly to the balls of the replacement component can be obtained from;

Mini Micro Stencil, Incorporated.
San Marcos, California
(760) 591-3804

Rework Nozzles:

The nozzles required to successfully remove and replace an RCBGA or a ClearONE device are custom-designed to fit the rework station being used and are specific to each size of device. Please refer to the table below for rework nozzles available at the time of this report to fit the Air-Vac equipment. Nozzles may be ordered by contacting Air-Vac Engineering at;

Air-Vac Engineering Company, Incorporated
30 Progress Avenue
Seymour, Connecticut
(203) 888-9900

Available Closed Architecture Nozzles

	ClearONE		RCBGA
Ball Array Size	**1.00mm Pitch**	**1.27mm Pitch**	**1.00mm Pitch**
3x3	0	**N163MZ163**	0
3x4	0	0	0
3x5	0	0	0
3x6	0	0	0
3x8	**N130MZ327**	0	0
3x9	0	0	**N158MZ395**
3x12	0	**N161MZ612**	0
3x15	0	0	0
4x4	0	0	0
4x6	0	0	0
4x8	0	0	0
4x9	**N169MZ365**	0	0
4x10	0	0	0
4x12	0	0	0
4x16	**N169MZ641**	0	0

