RJR QFN PACKAGE GENERAL ASSEMBLY AND MOUNTING RECOMMENDATIONS

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A	Initial Release	ECR 202007-02	October 28, 2020	G. van Straten
B	• Slight modification of document title FROM " RJR RQFN Package General Assembly and Mounting Recommendations" TO " **RJR QFN Package General Assembly and Mounting Recommendations** • Sec 2.2-Addition of information for Laminate-based QFN	ECR 202302-04	February 15, 2023	G. van Straten

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1.0 Introduction

This application note is intended to provide guidelines for assembly of products using RJR's QFN (RQFN) package substrates and lids, as well as general recommendations for mounting and soldering RQFN packages at the end-application. This document includes generic package and component information, and handling and storage guidelines.

2.0 RQFN Package Description

RQFN (Air-cavity Quad Flat No-leads) is an air-cavity package that comes in two formats: Leadframe-based RQFN and Laminate-based RQFN.

2.1. Leadframe-based RQFN

2.1.1. Package Description

The package consists of a substrate (250µm-thick Cu-leadframe molded with RJR proprietary epoxy molding compound) and an LCP lid, sealed together with RJR polymer glue.

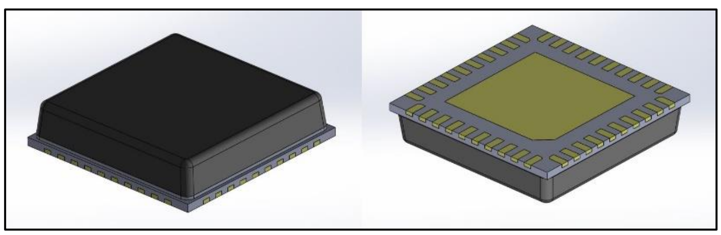


Figure 1: Example Leadframe-Based RQFN Package

Semiconductor chips are attached directly to the die pad for good grounding and thermal management. Connecting wires (Au or Al) are used for chip-to-chip and chip-to-terminal connection. The package is then sealed using the lid (or cap) with B-staged epoxy.

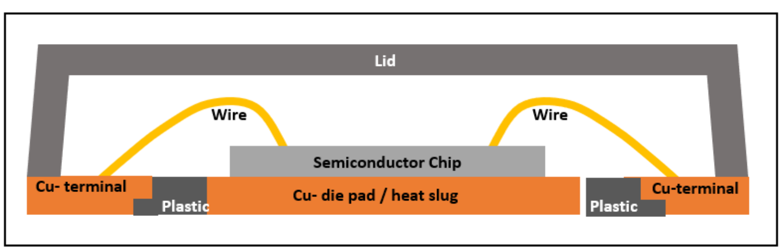


Figure 2: Cross-section Illustration of a Product Housed in Leadframe-based RQFN Package

2.1.2. Leadframe-based Substrates

The RQFN substrate is composed of a 250µm-thick NiPdAu-plated Cu-leadframe molded with RJR proprietary epoxy molding compound. It is supplied in single format for customer engineering and sampling purposes, and in coupon format for customer product mass-production. The substrate coupon contains individual substrates (sites) that can be separated by dicing.

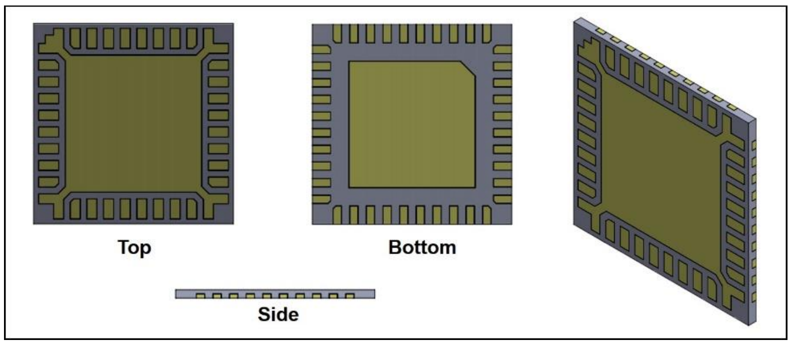


Figure 3: Sample Single Leadframe-based Substrate

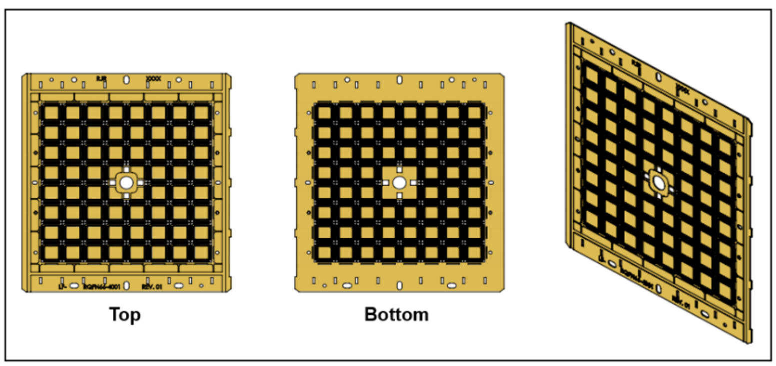


Figure 4: Sample Leadframe-based Substrate Coupon

2.1.3. RQFN Lids

The RQFN lid is an LCP-based cap with a pre-applied RJR polymer glue that is B-stage cured prior packing. It is supplied in single and matrix formats. The matrix format contains individual lids that can be separated by dicing.

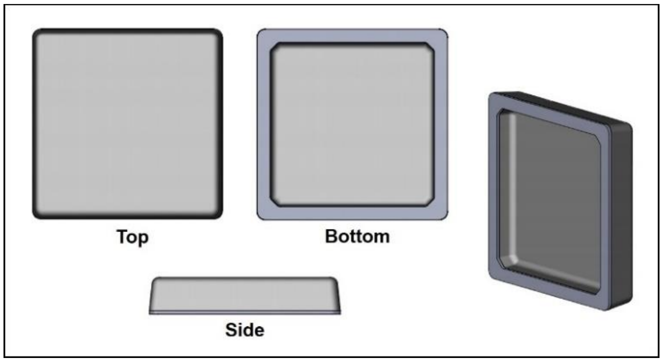


Figure 5: Sample Single RQFN Lid

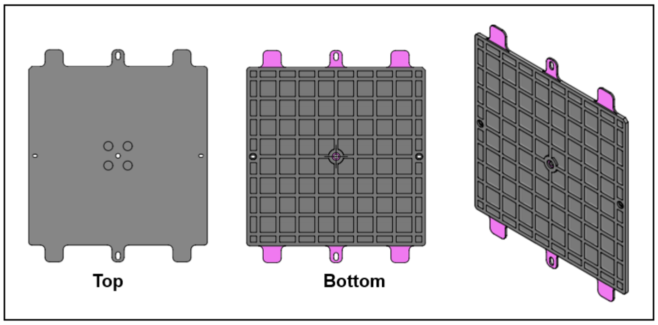


Figure 6: Sample RQFN Matrix

2.2. Laminate-based RQFN

2.2.1. Package Description

The package consists of a 500µm-thick laminate substrate and an LCP lid, sealed together with RJR polymer glue. The substrate's 500µm-thick Cu heatslug/diepad enables better thermal dissipation than the leadframe-based RQFN.

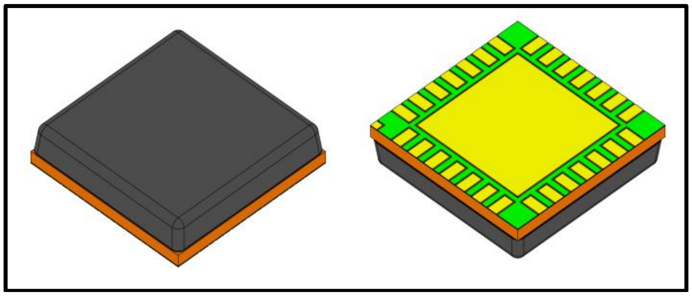


Figure 7: Example Laminate-based RQFN Package

Semiconductor chips are attached directly to the Cu-heatslug for good grounding and better thermal management. Connecting wires (Au or Al) are used for chip-to-chip and chip-to-terminal connection. Ag-filled via holes are used as terminals for connection to the application board. The package is then sealed using the lid (or cap) with B-staged epoxy.

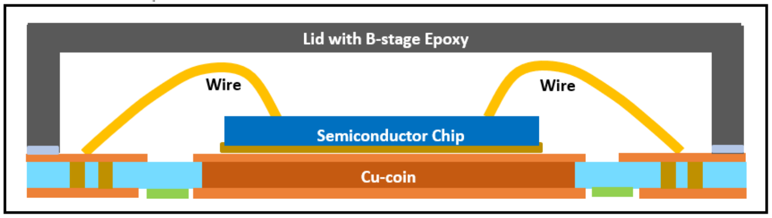


Figure 8: Cross-section Illustration of a Product Housed In Leadframe-based RQFN Package

2.2.2. Laminate Substrates

The laminate substrate uses EM526 material and has a 500µm-thick Cu heatslug/diepad that enables better thermal dissipation in comparison to the leadframe-based RQFN. Terminal connections to the outside world is done using Ag-filled vias connecting the metal traces on top and bottom of the substrate.

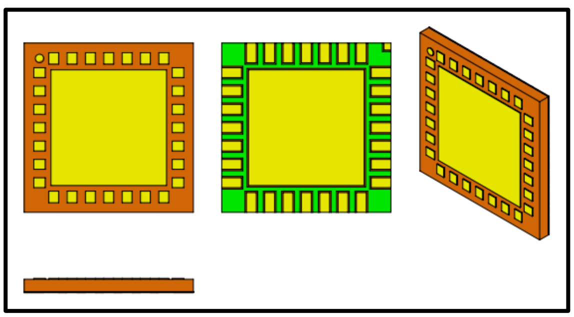


Figure 9: Sample Single Laminate Substrate

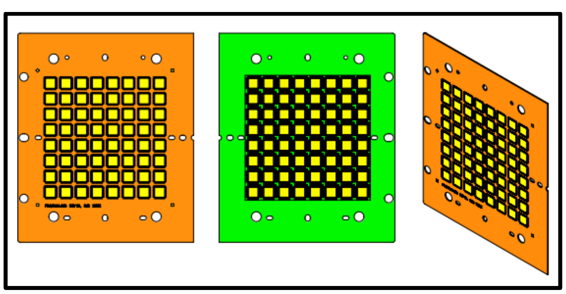


Figure 10: Sample Laminate Substrate Coupon

2.2.3. RQFN Lids

Refer to Section 2.1.3.

3.0 General Guidelines for Product Assembly Using RQFN Package

This section provides guidelines on handling and storage of substrate and lids for RQFN packages as well as the general recommendations for product assembly using the RQFN parts.

3.1. RQFN Substrate Packing, Storage and Handling

3.1.1. Packing

RQFN substrates are packed inside sealed anti-static moisture barrier bags (MBB) that are placed inside a foam-insulated shipping box.

3.1.2. Receiving

RQFN substrates should be put into storage between 15-25°C within 24 hours of receipt by the customer. RJR's 1-year warranty for RQFN substrates starts at the date of shipment.

3.1.3. Storage

Substrates should remain sealed in MBB and should be placed in a storage with temperature between 15 and 25°C and a relative humidity of ≤60% within 24 hours after receipt. Under these conditions, RJR's maximum shelf life warranty of one (1) year after the date of shipment will apply.

Substrates that are taken out of the MBB for inspection and will not be not used within one week should be re-sealed and put into original storage (temperature range between 15 and 25°C, ≤60% RH) within 24 hours after the bag has been opened. This step can be repeated as required.

3.1.4. Handling at Manufacturing Environment

Substrates removed from the prescribed storage conditions and taken to the manufacturing floor must be allowed to equilibrate to production room temperature before being used in the customer's manufacturing process. This is to avoid moisture condensation on parts that are colder than the ambient relative humidity when bags are opened.

Substrates that are not to be used in the manufacturing process on the same day as the MBB is opened should be stored in the production area using a nitrogen dry box with an ambient temperature of ≤25°C. Under this condition, the substrates have a one (1) year floor life.

3.2. RQFN Lid Packing, Storage and Handling

3.2.1. Packing

RQFN lids are packed inside sealed anti-static MBB that are placed inside a foam-insulated shipping box. A temperature indicator is to be applied to the insulating foam material facing the product.

3.2.2. Receiving

A joint agreement should be reached between RJR, its customer and the freight forwarder to ensure that the product's total transit time is minimized as much as possible and should not exceed one week from date of shipment.

RQFN lids should be put into cold storage within 24 hours of receipt by the customer. They should never be left on a loading dock where the boxes are subject to direct sun light. If that occurs, then the temperature indicators need to be checked before the boxes are put in cold storage.

RJR's 6-month warranty for RQFN lids starts at the date of shipment and the temperature exposure should not cause the 3rd bubble of the temp indicator to turn red.

Sample Temperature Indicator

3.2.3. Storage

RJR internal epoxy flow studies show that if parts are properly stored in prescribed environment, there may only be minor changes in flow characteristics of the epoxy over a six-month period. Studies also showed that if they are stored at ambient conditions and/or a mix of both conditions, a steady and gradual loss of flow characteristics over the same six-month period will occur. The change in the flow characteristics can have a negative effect on the adhesion of the lid to the substrate during the sealing process.

Within 24 hours of receiving the pre-applied epoxy products, lids in sealed MBB should be placed in refrigerated storage with temperature between 3 and 8 °C, and a relative humidity of ≤50%. Under these conditions, RJR warranty of a maximum shelf life of six months after the date of shipment will apply.

Lids should not be frozen as freezing pre-applied epoxy products will make the adhesive very brittle and will make the products subject to epoxy chipping.

Lids that are taken out of the MBB for inspection and will not be not used within one week should be re-sealed and put into refrigerated storage (temperature range between 3 and 8 °C, ≤50% RH) within 24 hours of after the bag has been opened. This step can only be done once to any bag of product.

3.2.4. Handling at Manufacturing Environment

Lids removed from the refrigerated storage and taken to the manufacturing floor must be allowed to equilibrate to production room temperature before being used in the customer's manufacturing process. This is to avoid moisture condensation on parts that are colder than the ambient relative humidity when bags are open.

Lids have to be left in the sealed bags and put in a safe place in the production floor for a minimum of four hours before opening and using them in the manufacturing process.

Lids that are not to be used in the manufacturing process on the same day as the MBB is opened should be stored in the production area using a nitrogen dry box. If the production room temperature exceeds 25°C, they should be stored in a refrigerator.

Once opened, lids are to be used within two weeks. RJR recommends that lids in an MBB that has been opened on the manufacturing floor and not used after the specified two weeks should not be used.

3.3. ESD Handling

RQFN substrates and lids are non-ESD sensitive.

However, semiconductor chips and components are sensitive to electrostatic discharge (ESD). ESD is one of the significant factors that cause damage and/or failure of semiconductor devices during manufacture. Because of this, proper ESD precautions should be observed for handling, and ESD controls should be in place in the assembly environment.

Detailed requirements proper EAD controls are described in IEC-61340-5-1 and JEDEC JESD625. ESD specifications of devices should be indicated in product data sheets/information package.

3.4. Product Manufacturing and Testing Processes

3.4.1. Typical Manufacturing Flow for Products Housed in RQFN Package

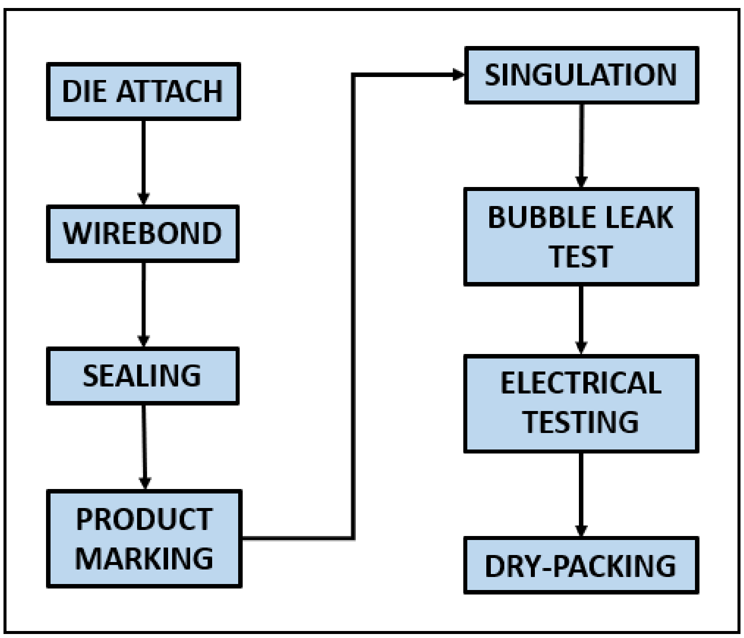


Figure 11: Typical Manufacturing Flow for Products Housed in an RQFN Package

3.4.2. Temperature Limitations for Die Attach and Wirebond Processes

RQFN substrates can withstand a maximum processing temperature of 230°C for 2 hours during diebond and wirebond. Exceeding this temperature limitation may result to deformation and weakening of adhesion between the Cu-leadframe and the LCP.

3.4.3. RQFN Package Sealing

3.4.3.1. Sealing Temperature and Duration

Sealing of the component is done by mounting the lid on the substrate. Adhesion is done via the B-stage cured epoxy on the lid.

After placing the lid on the substrate, the epoxy is pre-cured at a temperature of 125 ± 5°C for 30 minutes. An alignment mechanism or jig is needed to keep the lid and substrate in place during the pre-curing process. See section 3.4.3.3 for additional advice for the pre-curing process.

After the pre-cure sealing process, the units must be post-cured in a batch curing oven at a temperature of 180°C ± 5°C for 1 hour.

Batch Curing Oven

The specified conditions should be maintained in order to ensure the integrity and reliability of lid adhesion to substrate.

3.4.3.2. RQFN Single Unit Sealing

Upon request, RJR provides a manual for single-unit sealing process of packages using lids with RJR B-stage epoxy.

The document provides a standard procedure for attaching an RJR lid to a package body using a clip-bake process. It is advised not to use this procedure for large-scale manufacturing.

3.4.3.3. Sealing Pre-cure Using RJR's Isothermal Sealing (ITS) System

3.4.3.3.1. ITS Sealing System

In order to maintain the package dimensions and tolerances specified in the RQFN package outline drawings, it is recommended to use RJR's Isothermal Sealing (ITS) system for sealing and pre-cure process.

The ITS system is an affordable and durable semi-automated sealing system that guarantees package alignment accuracy and consistency (X, Y, Z location of lid to substrate), and minimal leaks caused by pinholes or blow-outs. By using this system, customers are guaranteed to have an efficient, faster and high yield sealing process.

This custom-designed system comes pre-programed with the appropriate sealing process parameters to ensure compliance to the customer's reliability and performance requirements. It features a Program Logic Controller (PLC) for overall sequencing and operational control, and process temperature controllers for plate temperature.

The ITS system can seal a wide variety of lid and substrate combinations. This is accomplished by changing the inserted plates. Different plates can be purchased and used with an existing system.

ITS systems exist in Model 400, 500 and 600.

Model 400 Isothermal Sealing System

The ITS M400 is the smallest sealing unit that is offered by RJR. This system has a manual open/close and load/unload function, and one sealing chamber. The sealing cycle is preloaded and is an automatic repeatable process.

The M400 unit comes with transfer tooling, to assist the operator in doing the manual load and unload functions. The transfer tooling is comprised of two parts – the vacuum pick-up head and the cold loading plate. While the unit is sealing parts, the operator can take the lids off the reels and load them into the cold plate. Then at the end of the sealing cycle, the operator first uses the transfer tool to unload the sealed packages and then uses it to load the lids into the unit. The parts are generally loaded one by one because the dies and wires on the substrate need to be protected.

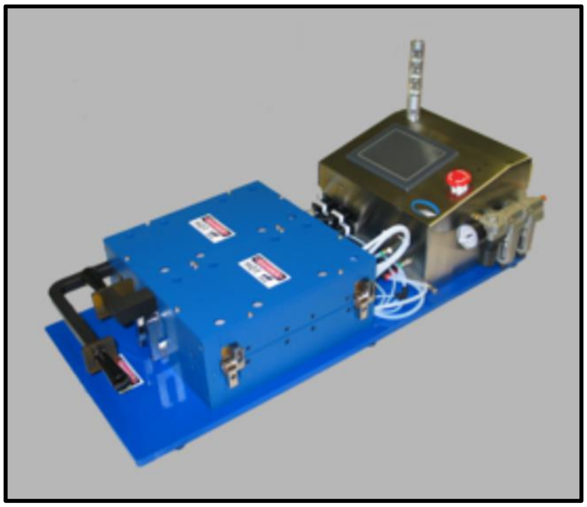
Because of its flexibility in accommodating different package sizes, the ITS M400 is ideal for engineering and prototype sample-making, as well as for small manufacturing lots. Single packages (individual substrates and individual lids) can be processed on the M400 using plates that can allow sealing of 4 packages at a time.

Model 400 Isothermal Sealing System

Model 500 Isothermal Sealing System

The ITS M500 is a mid-size unit that can be custom-designed for different sizes. For RQFN packages, it can accommodate 4 substrate coupons with matrix lids (no single lids).

Similar with the M400, this system has a manual open/close and load/unload function. The sealing cycle is preloaded and is an automatic repeatable process. The M500 unit comes with transfer tooling, to assist the operator in doing the manual load and unload functions. The transfer tooling is comprised of three parts – the vacuum pick- up head and two cold loading plates. While the unit is sealing parts, the operator can take the lids off the reels and load them into the cold plate. Then at the end of the sealing cycle, the operator first uses the transfer tool to unload the sealed packages and then uses it to load the lids into the unit. The parts are generally loaded one by one because the dies and wires need to be protected.



Model 500 Isothermal Sealing System

<u>Model 800 Isothermal Sealing System</u>

RJR is currently in the process of designing the Model 800, which will be an in-line fully automatic sealing solution for in-strip high volume assembly.

3.4.3.3.2. ITS System Installation and Operation

The system is easy to install because of the quick-connect fittings for the air pressure, vacuum and N2 supply (if applicable). To start the system, connect the power, air and vacuum from the source to the unit, and turn the system on. Select the RQFN sealing conditions and once the unit reaches its pre-programed operating temperature, the unit is ready for use.

Purchase of the unit comes with a free 2-day training session at the RJR facility in Oakland CA. Training can also take place at the customer's facility.

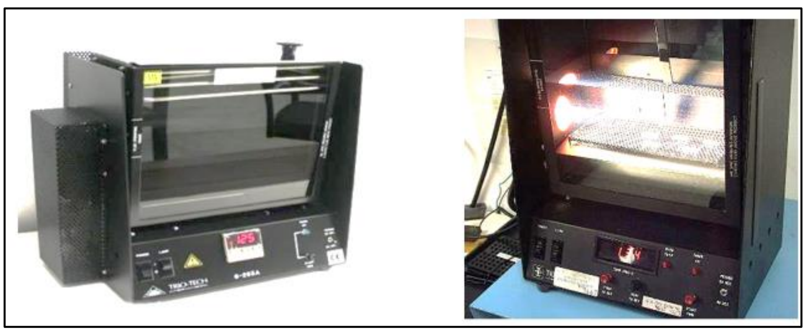
RJR provides a maintenance manual for the ITS system, as well as the sealing set-up and operation manual/instructions.

3.4.4. Singulation

Singulation of units should be done by dicing. RJR recommends using a dicing blade with a thickness of ≤0.036 mm.

3.4.5. Bubble Leak Test

To check package sealing integrity, units should be subjected to bubble leak test (also known as gross leak tests). RJR recommends following MIL-STD-202G. (see MIL-STD-202G document). In general, the assembled ACP package is submerged in an indicator fluid tank at temperature of 125°C for at least 30sec. The fluid typically used is Fluorinert® Liquid (FC-40).



Sample Bubble Leak Tank (Trio-Tech)

3.4.6. Maximum Load on Top of RQFN Package

For component electrical testing, pick-up, or any stress/reliability testing where clamping or pressure is applied on the lid of the component, the maximum load to be applied on top of the lid should not exceed 500 grams in order to preserve the mechanical integrity of the package.

The pressing mechanism should be designed in such a way that the load is uniformly distributed over the entire area of the lid.

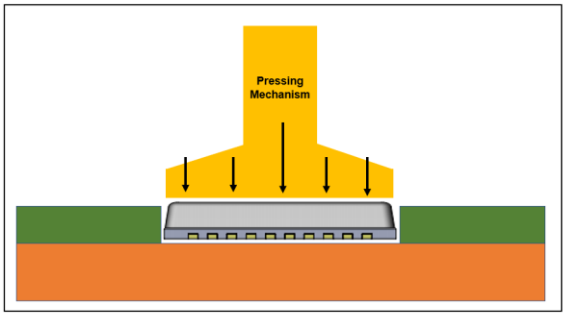


Figure 12: Uniform distribution of load over the entire lid area

Point-loading on the lid should be avoided at all times.

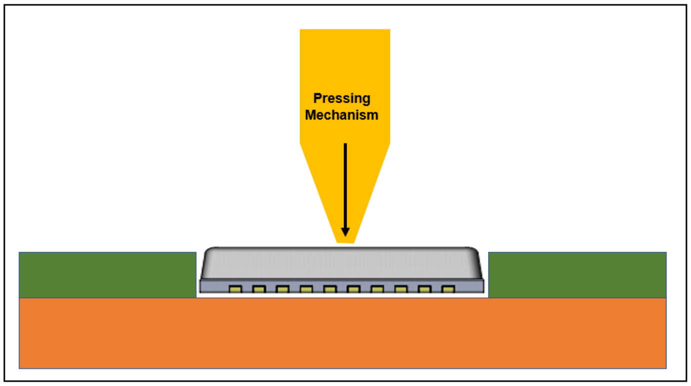


Figure 13: Point-loading on the entire lid should not be applied

3.5. Packing

In general, air-cavity plastic packages are sensitive to moisture. Therefore, products using this package shall be dried and packed according to IPC/JEDEC-STD-033 standards. Products should use anti-static dry-packing materials and should be vacuum-sealed in a moisture barrier bag (MBB). The products shall be stored in the MBB together with appropriate amount of desiccant and a humidity indicator card (HIC).

The moisture barrier bag (MBB) should have a moisture sensitivity identification (MSID) label that contains information on the product moisture sensitivity level (MSL), and the maximum allowed peak body temperature of the products. The same information labels should be attached to the outer packing boxes of the products.

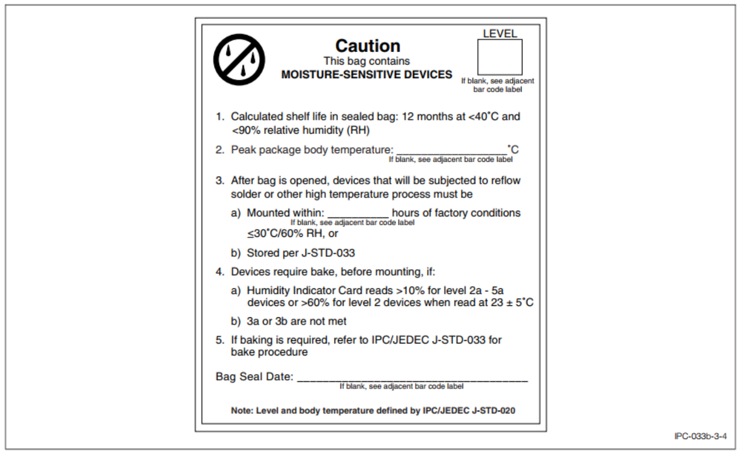


Figure 14: Example of Moisture-sensitive Caution Label

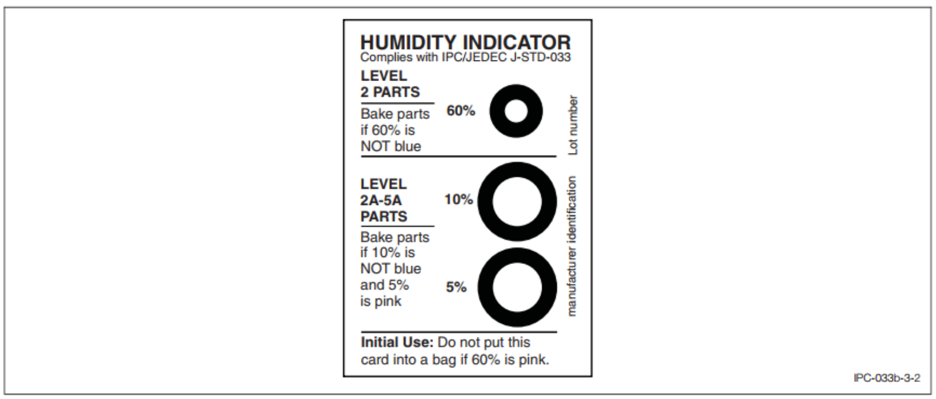


Figure 15: Example of Humidity Indicator Card

Table 1 shows the dry packing requirements and **Table 2** shows the conditions for baking prior dry pack for products housed in RQFN package based on IPC /JEDEC J-STD-033.

Table 1: Dry Packing Requirements Based on IPC / JEDEC J-STD-033

MSL	Dry before Bag	MBB with HIC	Dessicant	MSID	Caution Label
1	Optional	Optional	Optional	Not required	Not required if classified at 220 - 225°C Required if classified at other than 220 to 225°C
2	Optional	Required	Required	Required	Required
2a to 5a	Required	Required	Required	Required	Required
6	Optional	Optional	Optional	Required	Required

Table 2: Default Baking Times Used Prior to Dry-Pack that was Exposed to Conditions ≤60% RH

Package Body Thickness	MSL	Bake @ 125°C	Bake @ 125°C
≤1.4mm	2	7 hours	3 hours
	2a	8 hours	4 hours
	3	16 hours	8 hours
	4	21 hours	10 hours
	5	24 hours	12 hours
	5a	28 hours	14 hours

4.0 General Recommendations for Package Mounting on Application Board

This section provides general assembly recommendations for components housed in RQFN package. Information includes handling and storage, mounting board design, board assembly and rework procedure. The guidelines cannot cover every customer-specific assembly requirement as each customer has its own application and assembly requirements.

4.1. Package Handling and Storage

4.1.1. Moisture Sensitivity

Moisture from atmospheric humidity may penetrate the package materials by diffusion through the leadframe-to-plastic and substrate-to-lid interfaces. Exposure to high temperatures, especially during reflow soldering process, may cause the moisture to expand, resulting to interface cracks or delamination and package mechanical integrity degradation.

To prevent moisture penetration prior usage, products housed in RQFN packages should be dry-baked and sealed in moisture barrier bags (MBB) according to IPC/JEDEC-STD-033 standards. The products, together with the dessicant and a moisture indicator card should be stored in the vacuum-sealed bag. The “Moisture Sensitivity Caution Label” stickers attached to the MBB and the outer packing box should contain information on the product moisture sensitivity level (MSL) and the maximum allowed peak body temperature of the products.

The Moisture sensitivity level is a measure of the sensitivity of the component to ambient humidity. It is used to indicate the floor life of the component, the storage conditions, and the handling precautions after the original storage container has been opened. Floor life is the maximum period allowed for a component to be out of the bag, or from opening the MBB until the final solder reflow process. Components must be soldered within the allowable time period and must not exceed the maximum allowed peak body temperature during the reflow process. MSL and temperature requirements indicated on the packing labels must be followed at all times.

Table 3: Component floor life as function of MSL as defined in IPC/JEDEC J-STD-033

Moisture Sensitivity Level	Floor Life (Out of Bag) at Factory Ambient ≤30°C/60% RH, or as stated
1	Unlimited, ≤30°C at 85% RH
2	1 year
2a	4 weeks
3	168 hours
4	72 hours
5	48 hours
5a	24 hours
6	Mandatory bake before use. After bake, must be reflowed within the time limit specified on the label.

The floor life clock starts upon opening the MBB. Components should be removed from the sealed MBB just before mounting and soldering onto the PCB. In case not all components in the MBB are used, the remaining unused components must be resealed and placed in safe storage within one hour of bag opening. Components with a critical MSL may not exceed the allowed exposure time in ambient conditions during assembly runs. In case of two or more reflow steps, partially assembled boards should not be stored longer than indicated by the MSL in between steps.

If the moisture indicator card shows too much moisture upon opening the MBB, or if components are removed from the MBB and not soldered to the application board within the corresponding floor life, they must be dry-baked before reflow soldering in order to remove any moisture that may have entered the package.

Table 4 gives the conditions for re-baking of components after the floor life has expired or after other conditions have occurred that resulted to moisture exposure.

Table 4: Reference Conditions for Drying Mounted or Unmounted RQFN Packages based on IPC/JEDEC J-STD-033 (User Bake: Floor life beings counting at time = 0 after bake)

Package Body Thickness	MSL	Bake @ 125°C		Bake @ 90°C, ≤5% RH		Bake @ 40°C, ≤5% RH	
		Exceeding Floor Life by >72hrs	Exceeding Floor life by ≤72hrs	Exceeding Floor Life by >72hrs	Exceeding Floor life by ≤72hrs	Exceeding Floor Life by >72hrs	Exceeding Floor life by ≤72hrs
≤1.4 mm	2	5 hours	3 hours	17 hours	11 hours	8 hours	5 hours
	2a	7hours	5 hours	23 hours	13 hours	9 hours	7 hours
	3	9 hours	7 hours	33 hours	23 hours	13 hours	9 hours
	4	11 hours	7 hours	37 hours	23 hours	15 hours	9 hours
	5	12 hours	7 hours	41 hours	24 hours	17 hours	10 hours
	5a	16 hours	10 hours	54 hours	24 hours	22 hours	10 hours

4.1.2. Handling of ESD Sensitive Devices

Prevent product damage due to electrostatic discharge (ESD) by observing proper ESD precautions for handling and processing, and placing ESD controls in the environment.

Detailed requirements proper EAD controls are described in IEC-61340-5-1 and JEDEC JESD625. ESD specifications of devices should be indicated in product data sheets/information package.

4.2. Application Board Design Recommendations

4.2.1. Application Board

The design of application boards depends on the application itself and power management. The most common board configurations for RQFN are shown in **Figure 16 and Figure 17**.

Figure 16: PCB with Thermal/Ground Vias

Figure 17: PCB with Cu-coin

4.2.2. PCB Design

A proper PCB design is crucial for satisfying electrical, mechanical, thermal, reliability and board assembly requirements. The design should be based on the correct package outline drawing. **Appendix 2** shows a sample package outline drawing of RQFN6640. Contact your RJR representative for a copy of the package outline drawings.

4.2.3. PCB Solder Land Design

A solder land is the conductive pattern on the PCB where the connections of a component are soldered. Dimensions of PCB solder lands should be based on the nominal dimensions of the package die pad and terminals.

Guidelines for Solder Land Dimensions:

- The center solder land should have approximately the same size and shape as the component's exposed die pad for optimal thermal and electrical performance. However, the outer edges of the center solder land should have a minimum clearance of at least 0.25mm from the inner edges of the perimeter solder lands to avoid any shorts **(Figure 18)**.
- The length of the perimeter solder land should extend by ≤0.05 mm towards the center of the package and 0.01-0.04mm from the package edge **(Figure 18).**
- It is recommended to extend the width of the perimeter solder lands by 0.025mm at both sides **(Figure 19).**
- The pitch of the perimeter solder lands needs to be designed using the exact dimensions of the package terminal pitch.

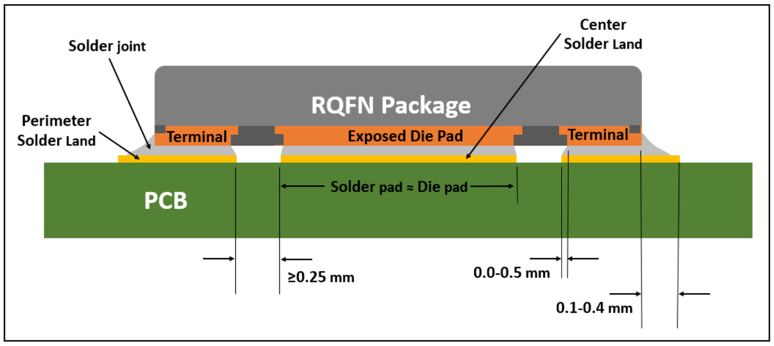


Figure 18: Solder Land Dimensions (Cross-section View)

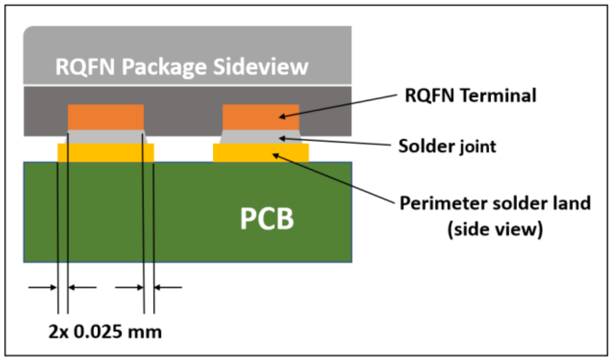


Figure 19: Perimeter Solder Land Width (Side View)

4.2.4. Solder Mask Design

Solder masks should be applied on the PCB to prevent solder shorts. However, due to the bigger solder mask placement and dimensional spread, the solder mask opening should be 0.12 to 0.15 mm larger than the solder land size, resulting in 0.060 to 0.075 mm clearance between the solder land and solder mask **(Figure 20)**.

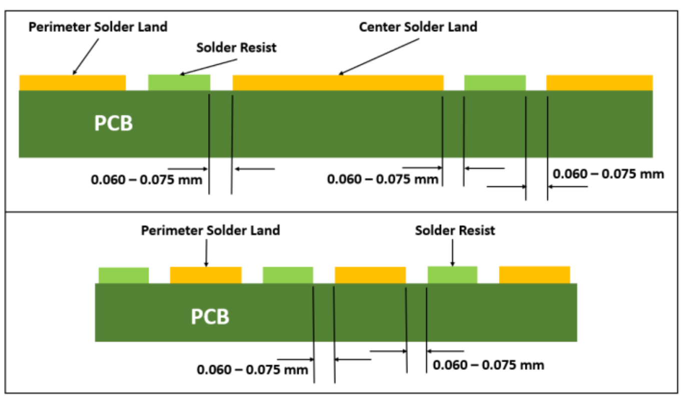


Figure 20: Solder Mask Design Guidelines

4.3. Board Assembly

4.3.1. Board Assembly Process Flow

A typical surface mount technology (SMT) assembly process flow is shown on **Figure 21**. It is recommended to use standard pick and place equipment and process. Manual soldering should be avoided.

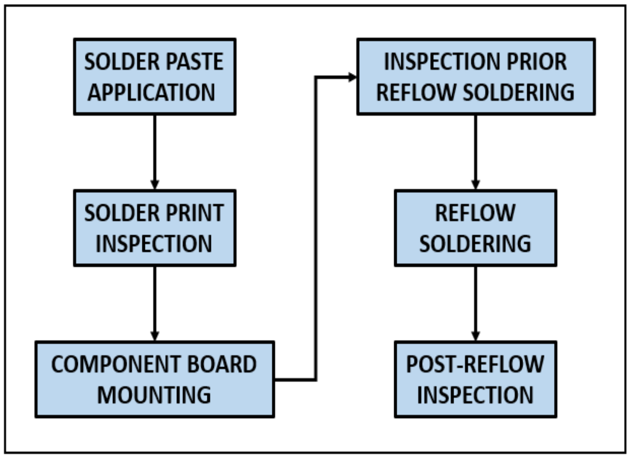


Figure 21: SMT Assembly Process Flow

4.3.2. Solder Paste Application

4.3.2.1. Solder Paste

Solder paste is a crucial component in SMT assembly process. It is a homogenous mixture of metal alloy particles, flux and viscosity modifiers. The combination is adjusted depending on the solder application and reflow process requirements.

<u>Solder Alloy</u>

In line with environmental legislations, RJR recommends the use of Pb-free solder paste although there are exceptions for certain applications. Typical solder alloys are combinations of tin (Sn), silver (Ag), copper (Cu), bismuth (Bi), antimony (Sb), indium (In) and other elements. The most common form of Pb-free solder is SAC (SnAgCu) such as SnAg3Cu0.5 (SAC305), SnAg4Cu0.5, (SAC405), or SnAg3.8Cu0.7 (SAC387). These solder alloys have different physical properties, and melting temperatures can range 215 to 220°C. Peak reflow temperatures should be above 235°C.

One of the most important component of solder paste is the spherical alloy powder or solder ball which is 83-92% of the weight of the paste. The spherical shape and size of the alloy powder is necessary for a uniformity and consistency of solder volume on the solder lands. Smaller spheres are required for high resolution solder paste printing and smaller pitch. As a rule of thumb, the minimum dimension of the smallest stencil opening shall be >4-6 sphere diameter.

Flux

Flux is the component of solder paste that ensures a good solder joint by removing surface oxidation and preventing metal oxide formation during reflow.

IPC standard J-STD-004 classifies flux into three types: rosin-based, water soluble and no-clean flux.

Rosin-based and water-soluble fluxes require cleaning of the board after reflow process due to the negative impact on product functionality and long-term reliability. Rosin-based flux are normally cleaned using solvents while water-soluble fluxes are cleaned using pure water.

No-clean flux doesn’t require cleaning since it is normally non-corrosive, non-conductive and leaves only a small amount of residue because majority is burned during reflow soldering. In general, it is recommended to use solder paste with no-clean flux since flux residues cannot be removed from underneath the RQFN package due to the low stand-off height.

4.3.2.2. Solder Stencil Design

A solder stencil is a board made of metal or a polymer that is used to apply solder paste patterns with a screenprinting technique on PCB. It contains holes representing the solder lands on the PCB. Solder stencil printing is preferred because of application precision and reproducibility, as well as good definition of size and shape.

As a general rule, the stencil aperture should be a minimum of 25 to 30µm smaller than the size of the corresponding solder lands to account for alignment and PCB tolerances. A fillet at the corners is needed to reduce the adhesion to the solder paste and improve the paste release upon application on the solder pad. The fillet radius should be larger than the diameter of the solder spheres. A minimum stencil aperture is needed to ensure the proper release of the solder paste during solder stencil printing.

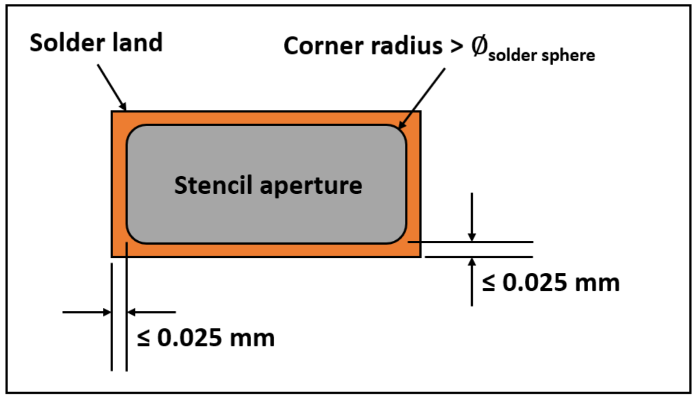


Figure 22: Solder Stencil Opening Dimensions

The required stencil thickness can be calculated using the area and aspect ratio **(Figure 23)**. Typical aspect ratio and area ratio used for leadless packages are >1.7 and >0.8, respectively.

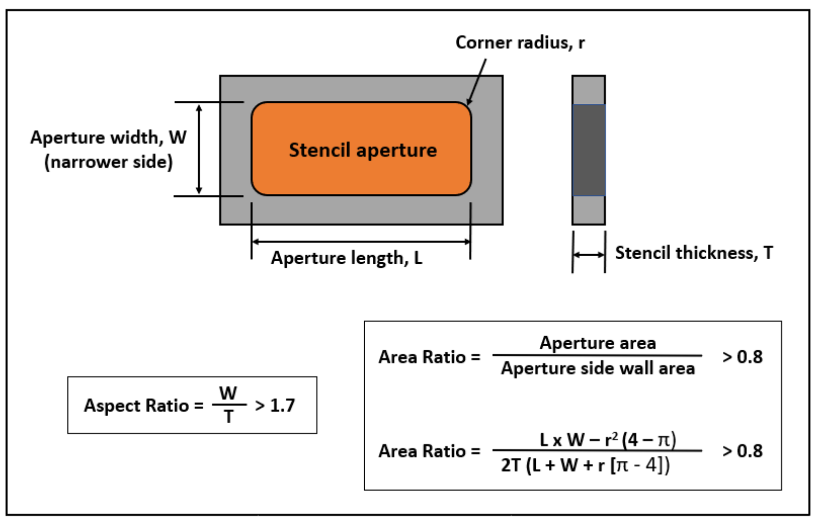


Figure 23: Determination of Solder Stencil Thickness

4.3.3. Component Placement

Due to the small size of the package and the high terminals density, component mounting process needs to be accurate and precise. In order to meet this requirement, a placement machine equipped with an optical recognition system for PCB and component centering during pick-and-place process is recommended.

4.3.4. Reflow Soldering

4.3.4.1. General Guidelines

The goal of reflow soldering is to bring the solder paste to the eutectic temperature so that the alloy will liquify or melt and exhibit cohesive and adhesive properties. With sufficient flux and while in liquidus state, the molten alloy will exhibit wetting, a necessary condition for solder joint formation.

The temperature profile must be fine-tuned to establish a robust process. The reflow profile parameters to be applied depend on the solder paste used, and recommendations given by the solder paste manufacturers should be followed. The use of nitrogen (N2) is recommended to improve solderability and to reduce defects.

Under reflow oven temperatures, certain areas of the board will heat up faster depending on the component's thermal mass. Large components and large Cu areas on the board will heat up faster than smaller components and smaller Cu-areas. Using thermocouples, the actual temperature has to be measured at various locations on the board in order to ensure that correct reflow temperature is reached everywhere on the board area. At the same time, the package top surface temperature has to be monitored to ensure that the peak package body temperature shall not exceed the MSL classification of the component. For RQFN packages, peak reflow temperature should be ≤260°C.

4.3.4.2. Reflow Soldering Stages

There are five phases in reflow soldering: Ramp-up to Soak, Pre-heat/Soak, Ramp-up to Peak, Reflow, and Cool-down. **Figure 24** shows an example of a SAC reflow profile.

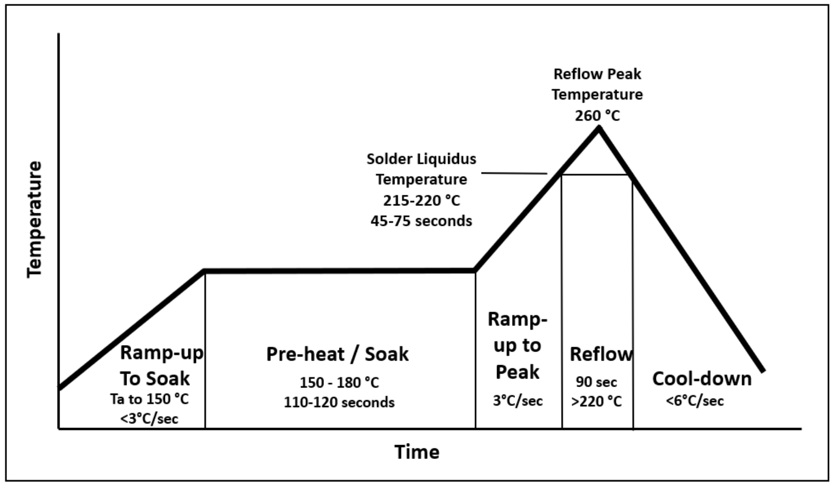


Figure 24: Example SAC reflow profile

Ramp-up to soak

During the ramp-up to soak phase, the entire board assembly is brought from ambient temperature towards a target soak temperature. The main goal is to get the entire assembly safely and consistently to a soak or pre-reflow temperature. During ramp-up, volatile solvents in the solder paste start to outgas. The maximum ramp-up rate shall not exceed 3 °C/second to avoid overstress to the package and prevent solder ball formation.

Pre-heat / Soak

The pre-heat or soak phase is intended to decrease any delta in temperatures across the entire board assembly. It is typically a 60 to 120 seconds exposure to a temperature 150 to 180°C. At this stage, solder paste volatiles are removed, and flux is activated to reduce the oxides on the interfaces to be soldered. A too high temperature can result to solder splatters or solder balls, as well as surface oxidation. At the end of the pre-heat zone, the entire board assembly should reach thermal equilibrium.

Ramp-up to Peak Temperature

At this phase, the PCB assembly is uniformly heated above the liquidous temperature of the solder alloy. The maximum ramp-up rate should not exceed 3°C/second to avoid package overstress.

Reflow

The reflow phase is the part of the process where the peak temperature is reached. The peak temperature is the maximum allowable temperature of the entire process and is determined by the component with the lowest tolerance for high temperature on the board. The recommended peak reflow temperature for SAC alloys is >235 °C. The maximum peak temperature allowed for RQFN packages is ≤260°C

The temperature and duration need to be monitored to keep them from exceeding the limit. The reflow time (period above the liquidus temperature) should be long enough to allow the liquid solder to uniformly wet the pad and land surfaces, and to form an intermetallic phase. Too long reflow time may lead to brittle solder joints and could cause damage to the board and components. Temperatures beyond 260 °C may cause damage to the smd components and foster intermetallic growth. The board will not reach the correct reflow temperature if the reflow time is too short. A too low temperature will prevent the solder paste from flowing adequately.

Cool-down

The cool-down phase serves to gradually cool the processed assembly board and solidify the solder joints. Proper cooling inhibits excess intermetallic formation or thermal shock to the components.

A fast cooling rate is recommended to create a robust fine grain of the alloy and to prevent excess intermetallic formation after the reflow phase. The ramp-down rate can be faster than the ramp-up rate but shall not exceed 6°C/second to avoid overstress.

4.3.5. Inspection

It is recommended to perform optical and X-ray inspection to verify if there are solder voids, as well as open and short circuits after reflow soldering. Micro-sectioning is a verification process that can be done during solder reflow process optimization but is not suitable for production inspection.

The solder joint on the exposed pads should form a fillet and the solder voids under the exposed die pad of the package should be keep to a minimum to safeguard electrical and thermal properties of the component.

4.4. Repair and Rework Procedure

4.4.1. Component Repair on Board

It is not recommended to repair single solder joints or the soldered die pad on the board as this cannot be done in a controlled way and can result to further damage on the assembly board. Proper rework procedures should be followed in repairing component solder joints.

4.4.2. General Rework Recommendations

RJR does not guarantee the quality of the package that has been removed from the board. Thus, component reuse should be avoided. In case of a defective package after board assembly, the device can be removed and replaced by a new one.

The PCB has to be heated during rework. As such, thermal limitations and moisture sensitivity of the board and components must be observed. This is due to the fact that during heating, the combination of moisture expansion, material thermal property mismatch and material interface degradation can damage the board and the components.

To prevent failures and defects associated with moisture ingress, it is strongly recommended to store the PCB assembly and components in controlled environment with nitrogen or dry air. If needed, a pre-bake step should be performed to remove moisture.

During rework, the influence of the heating on adjacent packages on the board must be minimized. Temperature must be set according to the different heat capacities of the board and the components mounted on it. Do not exceed the temperature rating of the adjacent packages.

As required by industry standards, RJR's RQFN packages are qualified for three (3) solder reflow passes which simulates two reflow soldering passes or a two-sided board assembly, and one rework step.

Components that are defective and have been removed from the board should be properly disposed to prevent accidental mixing with new components and being re-mounted on the board.

4.4.3. Rework Station/Set-up

There are various SMD rework systems in the market. In general, the rework station should have a light system, a platform that can be adjusted on X-Y-Z direction, and a hot air system with a top and bottom heater for component removal.

The hot air temperature and air flow must be properly controlled so that heating is concentrated at the component. The heating should be appropriate for the package size and thermal mass. The PCB should also be pre-heated from below. Nitrogen can be used instead of air.

A vision system is essential for the rework station so that the bottom side of the package and the site on the PCB can be visible during rework. A split light system could be used for proper package alignment. A microscope with the appropriate magnification for the device's pitch should be used.

Placement equipment should have a good accuracy. Appropriate vacuum tools may be needed for removal of solder residues from PCB pads.

4.4.4. SMD Rework Steps

SMD rework process can be broken down into the following steps: component removal, rework site preparation, solder paste application, component placement, reflow soldering and inspection.

4.4.4.1. Component Removal

Removal of a defective component should not result to additional damage to the component itself, to the board or other components on the board. The following steps should be followed to reduce the occurrence of damage during component removal:

- Before removal, dry bake components at 125 °C for 16 to 24 hours for boards with SMT components, or at 95 °C for 16 to 24 hours for boards with temperature-sensitive components.

- When de-soldering the component from the board, ensure that the package peak temperature is not higher than standard assembly reflow temperatures and that the temperature ramps are not steeper than the standard assembly reflow process.

- Do not to apply too high mechanical forces during component removal as this can damage the component and/or the PCB and may limit failure analysis of the defective package.

- Heating should be applied on top of component and under the PCB **(Figure 18)**. The temperature setting for the top heater and the bottom heater depends on the component rating. Use an air nozzle of correct size to conduct the heat above the component, so that a vacuum pick-up tool or a pair of tweezers can properly remove the component. It is recommended to use a temperature of 150°C under the PCB.

- It is recommended to place a bending prevention mechanism under the PCB to prevent the PCB from bending or deformation during heating.

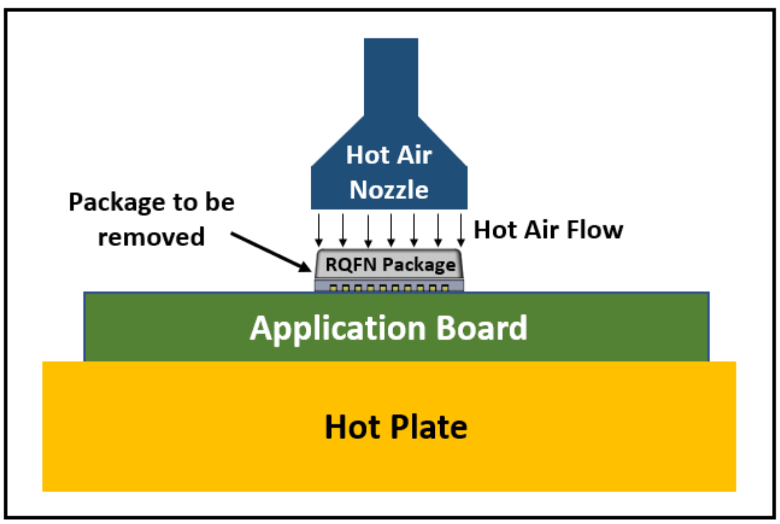


Figure 21: Schematic Set-up for Package Removal from Board

4.4.4.2. Site Preparation

After component removal from board, the solder lands on the PCB must be cleaned to remove solder residues and to prepare for placement of new component. Flux should be applied on the site first, then solder removal is done by vacuum de-soldering or by using a solder sucker, solder wick braid, etc.

Unremoved solder residue can cause uneven surface that will result to improper solder paste printing and non-uniform solder layer, eventually causing improper connection of the mounted component. Moreover, re-melted solder residue may flow and cause circuit shorts.

After removing the component and removing the solder residue, the site may need to be cleaned using a solvent to remove flux. Use non-abrasive brushes in cleaning the surface.

A de-soldering station can be used for solder dressing. The applied temperature should not exceed the rating of PCB material to prevent solder land peeling from the PCB.

4.4.4.3. Solder Paste Application

A new layer of solder paste should be applied to the PCB solder lands by printing or dispensing before placing a new component. It is recommended to use a no-clean solder paste.

Solder paste printing during rework has to be done using specialized tools and stencil. The specialized mini-stencil should have the same thickness, aperture opening, and pattern as the normal stencil used during board assembly. A small squeegee blade is used to apply the solder paste in the specific area. The printed pad should be inspected, to ensure even and sufficient amount of solder paste before placing the component.

In case the neighboring parts are very close to the component for rework and the mini-stencil will not be an option, then solder paste can be carefully applied by solder dispensing. The volume of solder paste must be controlled using appropriate dispensing needle size in order to prevent shorting on the component and/or neighboring components. It is preferred to use the same type of solder paste that was originally applied on the board.

4.4.4.4. Component Mounting

The component should be placed precisely on the corresponding location on the PCB. The rework set-up must have a good optical or video vision capacity for a more accurate component placement on the board.

4.4.4.5. Reflow Soldering

The same temperature profile as the normal reflow soldering process should be used for soldering the new component to the PCB. During soldering, the package peak temperature and temperature ramps must not exceed those of the normal assembly reflow process. Refer to section 4.3.4.

It may be necessary to dry bake the board before it is exposed to reflow temperatures for the second time.

4.4.4.6. Inspection

Perform optical and x-ray inspection after soldering to verify for open and short circuits after soldering.

Appendix 1. References

1) IPC/JEDEC J-STD-020D (Joint Industry Standard Moisture/Reflow, Sensitivity Classification for Non-hermetic Solid-state Surface Mount Devices)

2) IPC-7351 (Generic requirements for Surface Mount Design and Land Pattern Standard, IPC)

3) IEC-61340-5-1 (Protection of Electronic Devices from Electrostatic Phenomena – General Requirements)

4) JEDEC JESD625 (Requirements for Handling Electrostatic-Discharge-Sensitive [ESDS] Devices)

5) MIL-STD-202G (Test Methods Standard Electronic and Electrical Component Parts)

6) RJR Document ENP-052-004 (RJR Clip-Bake Lid Attach Using RJR B-Stage Epoxy)

7) RJR Document ENP-052-007 (RQFN Prototyping Process Using M400 Isothermal System [ITS])

8) RJR ITS M400 User's Manual