International Rectifier

APPLICATION NOTE

Application Note AN-1011

Board Mounting Application Note for 0.800mm Pitch Devices

For part numbers IRF6100, IRF6100PBF, IR130CSP, IR130CSPPBF, IR140CSP, IR140CSPPBF, IR1H40CSP, IR1H40CSPPBF

By Hazel Schofield and Philip Adamson, International Rectifier

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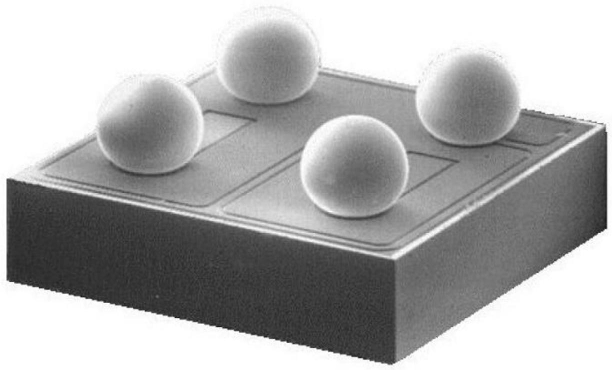

Board Mounting Application Note for 0.800mm Pitch Devices

Hazel Schofield and Philip Adamson, International Rectifier

For part numbers
IRF6100/PBF, IRF6156, IR120CSPTR/PBF, IR130CSPTR/PBF, IR140CSPTR/PBF, IR1H40CSPTR/PBF

Introduction

International Rectifiers Wafer Level Package (WLP) devices combine the latest die design with new packaging techniques to occupy the smallest possible footprints. International Rectifiers WLP technology now includes the FlipFET™ range of HEXFET® Power MOSFET devices (in which modified die design places source, drain and gate bumps on the front of the die), and also the 1A FlipKY range of Schottky Diode devices (where the anode and cathode are both placed on the front of the die). The 0.5A range of FlipKY product is covered in AN-1079.

To simplify board mounting and improve reliability, International Rectifier manufactures WLP devices to exacting standards. These high standards have evolved through evaluating many different materials and designs. Although such evaluations have yielded good results, the recommendations in this application note may need to be adjusted to suit specific production environments.

Device Construction

The modified die used in WLP devices have solder bumps on the front face for all contacts. To allow conventional surface mount processes to be used, the bumps are placed at a standard 0.800mm pitch. The manufacturing process used to create the bumps is well known and widely documented throughout the industry. Figure 1 shows a typical 4-bump WLP device.

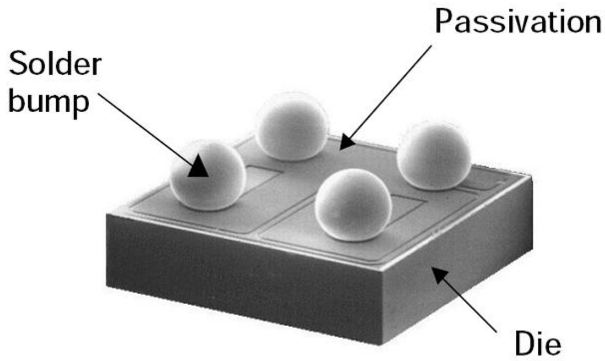

Figure 1 *Typical WLP device*

Figure 2 shows how WLP devices are constructed. The wafer is coated with silicon nitride passivation to protect it from the external environment. Only the areas that define the solder bump positions are left unpassivated. The under bump metallurgy (UBM) is deposited here to prevent the wafer metallization from interacting with the solder and to seal the passivation , which prevents the ingress of moisture around the contacts.

The UBM is approximately 5um electroless plated nickel, finished with a thin layer (0.1um) of immersion gold.

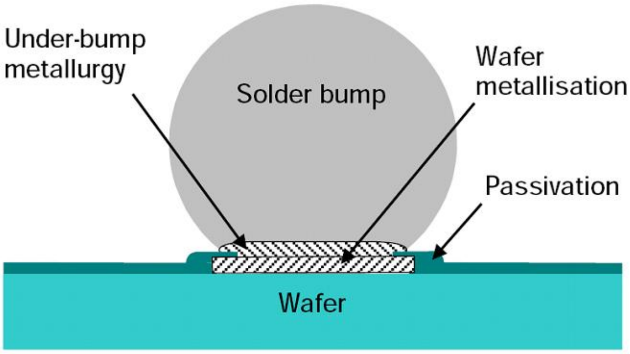

Figure 2 *Sectional view*

Device Outline
Bump configurations vary for different devices in the FlipFET and 1A FlipKY range, but all devices share some common features. They have a pitch of 0.800mm, with openings in the passivation coating of 0.200mm. Solder bumps have a nominal height of 0.260mm for part numbers with eutectic (63Sn 37Pb) solder bumps, and a nominal height of 0.230mm for part numbers with Pb-free (SnAgCu) bumps.

Figures 3 and 4 show views of a sample device, in this case an IRF6100. For full dimensions and tolerances of specific devices, refer to the relevant product data sheet and package outline drawing.

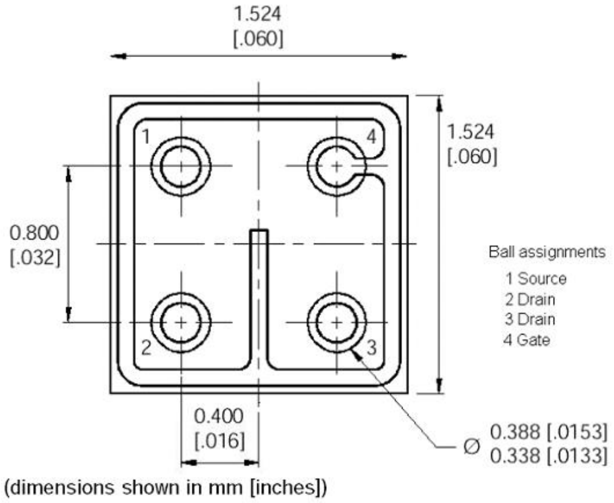

Figure 3 *Sample device (eutectic IRF6100), solder bumps uppermost*

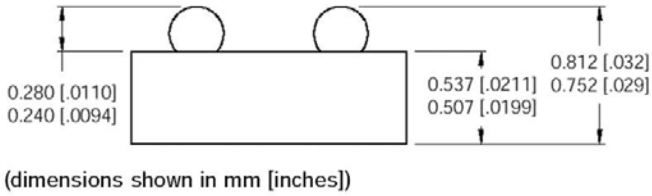

Figure 4
Sample device (IRF6100), viewed from side

International Rectifier WLP devices contain lasermarks on the back of the die. The first solder bump, ball 1, is identified by a small dot. Part number, batch number and date code are provided to support product traceability.

Packaging
WLP devices are supplied in tape and reel format. The position of the first solder bump, ball A1, is standard for all devices (Figure 5). For dimensions, refer to the relevant product data sheet and package outline drawing.

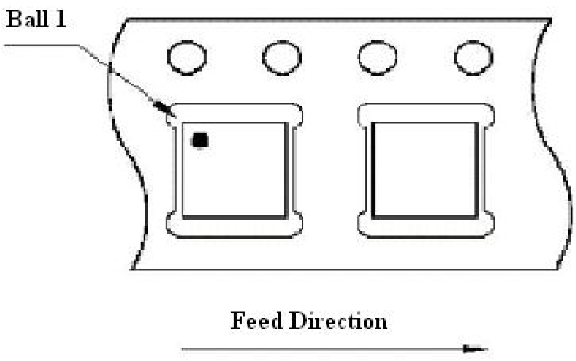

Figure 5
Diagram showing 0.800mm WLP in tape and reel

WLP devices can be used from the tape without intermediate operations. They are 100% inspected for solder defects and are tested at all rated values.

As no moisture-absorbing materials are used in WLP construction, no special storage conditions are required to prevent popcorning during reflow. This can be considered equivalent to JEDEC Moisture Sensitivity Level 1 (MSL1), although this specification and test method does not apply to this type of package.

Design Considerations

The recommendations in this section are based on International Rectifier's investigations, combined with research into standard practices within the industry. However, they may need to be adjusted to suit specific production environments.

A key factor in the reliability of bumped components is the consistency of the solder joints. For maximum reliability, all joints must be of the same shape and size. This is primarily determined by the substrate design but is also influenced by the manufacturing and assembly processes used.

Substrates

International Rectifier developed WLP technology for use with organic substrates such as epoxy glass-woven and flexible laminates, but this does not preclude its use with ceramic substrates and other materials. Reliability testing and analysis is carried out on substrates finished with electroless nickel immersion gold because these are easy to store and solder, but many other surface finishes are available and most are suitable for use with WLP devices. The exception is hot-air-levelled solder, which is not recommended because it cannot coat pads of the required diameter with a consistent volume of solder.

Substrate Design

There are many factors that should be taken into account when designing a substrate for WLP devices. Key factors in most circuits are reliability and thermal performance. WLP devices have inherently short heat paths to the substrate so their thermal performance can be greatly enhanced by effective substrate design. Both reliability and thermal performance can be affected by the choice between solder-mask-defined and pad-defined (non-solder-mask-defined) layouts. Figure 6 shows the two styles.

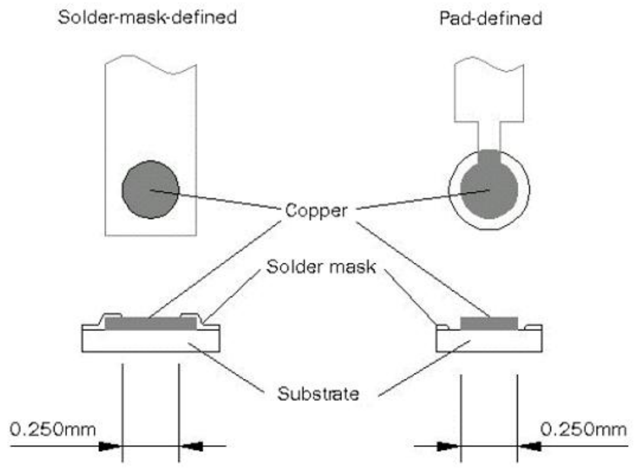

Figure 6 *Layout styles*

Some industry reports recommend pad-defined layouts for solder bumped packages because such designs can enhance thermal cycling capability. However, there is a trade-off in thermal performance compared with the larger areas of copper possible with solder-mask-defined layouts, which conduct heat away from the devices more efficiently. International Rectifier conducts all its reliability qualifications using solder mask defined layouts to ensure that its components perform reliably with them, and is therefore happy to recommend this style to its customers.

When using a solder –mask-defined layout, the recommended pad size is 0.250mm diameter. The minimum solder mask aperture is 0.200mm and the manufacturing tolerance must be added to this to determine and appropriate nominal measurement for the design. Particular care is required in manufacture to ensure that no solder mask residues are left on the edges of the pad, as this reduces the effective pad area and can impair reliability.

For pad-defined layouts, the recommended pad size is also 0.250mm. The minimum size is 0.200mm and, again, manufacturing tolerances must be considered in the design process. The solder mask should be 0.05-0.1mm from the edge of the pad to ensure that it does not affect the shape of the joint.

Assembly Considerations

International Rectifier's WLP devices are designed to be assembled using existing processes and standard reflow profiles. However, procedures and conditions can have a profound influence on assembly quality. This section outlines practices that have given good results during evaluations.

Solder Pastes

International Rectifier recommends low residue, no clean solder pastes but the best choice of paste depends on surface finish. For example, finishes such as organic solderability preservatives require a more active flux than gold. The solder alloy should be the same as the solder bumps (Sn63Pb37 for eutectic part numbers and SnAg3-4Cu0.5-0.7 for Pb-free part numbers) and of type 3 or finer. As with all fine pitch components, great care must be taken to avoid the formation of extraneous solder balls. These may become dislodged under the die or between contacts, causing short circuits.

Screen Design

One of the most important factors in the soldering process is consistency in the volume of solder deposited on pads. During evaluations, International Rectifier considered various combinations of screen thickness and aperture size. Thin screens with large apertures are easiest for printing. A screen thickness of 0.075mm (0.003") and apertures with diameters of 0.250-0.300mm (0.010-0.012") gave good results. Apertures larger than this may lead to the formation of solder balls.

Screen thicknesses of more than 0.150mm (0.006") make paste release more difficult. Although this may not be a problem in itself, variable paste release leads to inconsistent solder volumes. Square apertures, particularly when offset to form diamonds, may improve paste release with thicker screens.

Screens can be etched, laser cut or electroformed. Electroforming gives a very smooth sidewall that can improve paste release; electropolishing laser-cut screens has a similar effect. Tapering apertures from the substrate to print sides by 2-5º can also improve solder release (Figure 7).

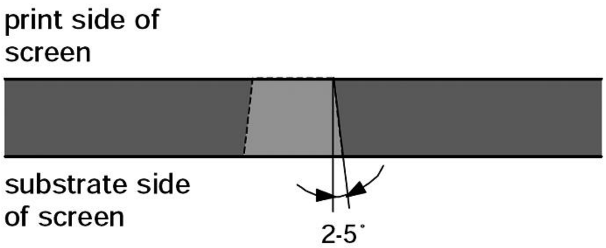

Figure 7 *Tapered Screen Apertures*

It is not always necessary for solder paste to cover the whole pad. The percentage of coverage required depends on the flux and surface finish used. With a moderately active flux on electroless nickel immersion gold, evaluations showed that the pads with only 50% coverage were completely wetted during reflow. However, with some other combinations, full coverage may be required.

Device Placement

When devices are place into the printed solder paste, the paste depth should be 20-50% of the bump height on all bumps. If the paste is too shallow, devices may move during transit to the reflow oven. If the paste is too deep, some may be transferred onto the face of the die. Bumps that are not in contact with the paste are unlikely to form good joints.

Devices must be placed to an accuracy of plus or minus the radius of the substrate pad. If the pad size recommendations have been followed, this equates to +/- 0.125mm. The surface tension of the solder causes all bumps that are in contact with the paste on the pads to self-center during reflow, giving symmetrical joints. The device markings can be used to verify correct orientation.

Automated vision systems can be programmed to detect either the edges of the die or the positions of individual solder bumps on it. In both cases, correct lighting is important. Standard lighting may be sufficient for edge detection but lighting from the side may be necessary for bump detection.

Reflow and Cleaning

WLP devices are suitable for assembly using surface mount technology reflow equipment. There are no special requirements for successful assembly but all reflow processes used in evaluation and qualification complied with the recommendations of solder paste suppliers. It is important to verify the profile on the substrate in use, since differences in thermal mass of substrates and components can make a large difference to temperatures reached.

All joints must reflow evenly and printed solder must fully coalesce with the solder on the die to form a uniform joint.

The recommended reflow profile is dependant on the type of WLP bump solder. 0.8mm pitch WLPs are available with Sn63Pb37 solder and SnAgCu solder. SnPb solder melts at ca. 183ºC. For this application, reflow profile guidelines are shown in Figure 8. This example consists of four zones:

Zone 1: Preheat zone, typically heating at 1-2ºC sec^{-1}

Zone 2: Soak zone, at 120-160ºC for 60-120sec

Zone 3: Reflow zone peaking at 210-230ºC and remaining above 183ºC for 30-60sec

Zone 4: Cooling zone, typically bringing the board back to room temperature at 2-4ºCsec-1

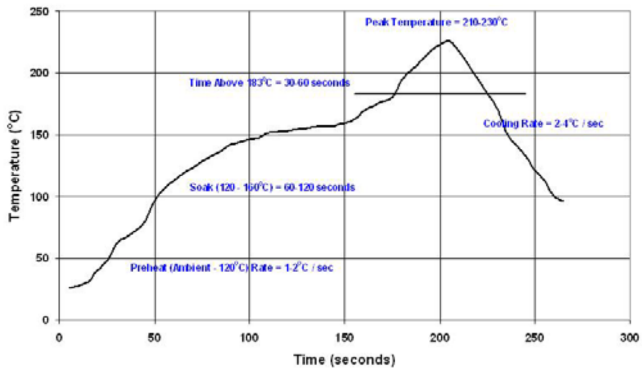

Figure 8 *Example of reflow profile for assembling Eutectic 0.8mm pitch WLP*

Recommended reflow profile guidelines for SnAgCu solder (which melts at ca. 217-221ºC) can be seen in Figure 9 and also consist of four zones:

Zone 1: Preheat zone, typically heating at 1-2ºC sec^{-1}

Zone 2: Soak zone, at 150-200ºC for 60-120sec

Zone 3: Reflow zone peaking at 250-265ºC and remaining above 217ºC for 40-80sec

Zone 4: Cooling zone, typically bringing the board back to room temperature at 2-4ºCsec-1

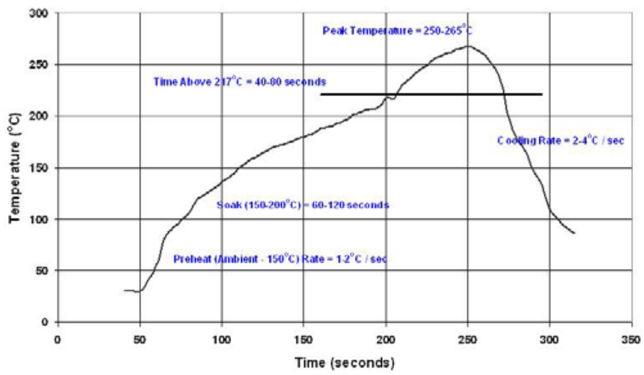

Figure 9 *Example of reflow profile for assembling Pb-free 0.8mm pitch WLP*

If a cleaning process is used, it must be carefully developed and monitored to ensure removal of all contaminants from underneath the device.

Underfill

Underfill is not required for WLP with fewer than 16 bumps, but it is recommended to enhance temperature cycling performance for devices with 16 bumps or more. Environmental conditions, including exposure to shock or vibration, may require the use of underfill for specific applications. The materials used in qualifications for such applications are listed in the relevant qualification reports.

Underfill materials should be carefully selected to give good adhesion to the silicon nitride passivation, solder mask and any flux residue. Materials acting as both flux and underfill are available from several suppliers and may be suitable for use.

Rework Guidelines

Modern rework stations for ball grid array and leadless packages often use two heating stages. The first heats the substrate, either with a conventional hot plate or a hot-air system. The second stage uses a hot-air system for localized heating, often with the option of unheated air for faster cooling of the solder interconnections on the replaced device; this improves the solder grain structure.

The device placement mechanism or arm usually has a hot-air de-soldering gun as part of the pick head equipped with a vacuum cup and thermocouple. Once the solder reflow temperature has been reached, the vacuum is automatically engaged to allow the device to be removed from the substrate. This reduces the risk of causing damage by premature removal.

To replace a WLP device:

Note: If you usually bake to remove residual moisture before rework, insert your normal procedure here.

1: Heat the substrate to approximately 100ºC using substrate heating stage. This reduces the amount of heating required from the hot-air de-soldering tool, which in turn reduces the risk of damaging either the substrate or surrounding components.

2: Lower the placement arm to bring the de-soldering tool into contact with the device. When the device and solder interconnects reach reflow temperature, lift the placement arm to remove the device from the substrate.

3: Clear the residual solder and flux from the site with a blade-type de-soldering tool and de-soldering braid. Take care in cleaning the site: damage to the solder-resist may produce undesirable results. When the site is ready, apply new solder paste with a micro screen and squeegee.

4: Heat the site to approximately 100ºC using the substrate heating stage. Position the new device with the placement arm and then use the de-soldering tool to heat both device and solder interconnects to reflow temperature. Retract the arm, leaving the device in Place. Cool as quickly as possible to achieve good grain structure in the new joint.

Handling After Board Mount

There should be no mechanical contact with the WLP die after assembly onto the PCB. Mechanical contact from handling and tooling/equipment can cause damage to WLP components.