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## NXP Semiconductors

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**Title:** Solder mounting recommendations for Ldmos Power Amplifiers

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# General solder mounting recommendations for Ldmos Power Amplifiers

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## 1 Soldering mounting method: introduction

### 1.1 General

RF power semiconductors e.g. assembled in air cavity plastic packages like the SOT896B and ceramic packages like the SOT502B are mounted onto a PCB or heatsink by soldering.

The package is composed of several components. The flange is the lower part of the component used as a heat spreader. On the flange, the transistors and capabilities (dies) are plated. The flange is "put" (bolt down mounting or soldering mounting) in a recessed area onto a support in metal: the heatsink.

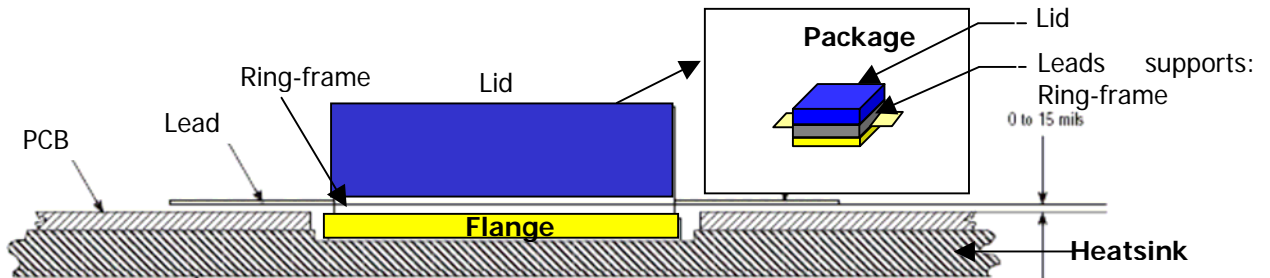


Figure 1 – Presentation of the device

Above is a drawing of the device. On the flange, a plastic package (or ceramic package) is "used". It is composed of a ring-frame glued on the flange (soldered for ceramic packages). The ring-frame supports the leads that are soldered on the PCB<sup>1</sup>. A lid is glued on the ring-frame to protect the capabilities and transistors.

Air Cavity Package has thus four main functions:

- Electrical interconnection between the silicon LDMOS chip and the external circuit;
- Protection from chemically aggressive agents, for long term reliability (protection of the Power Amplifier Module);
- Mechanical support to the LDMOS die to make handling easier;
- A thermally conductive path to transfer the heat generated in operation from the silicon LDMOS die to ambient or to the heatsink.

There are two different mounting family flanges shown in the figures below:

- On the first figure the flange is without screws (Flange mounted onto the heatsink by soldering: for example the SOT<sup>2</sup>896B) ;



- On the second figure the flange fixed by using two screws can be observed (Bolt down mounting: for example the SOT895A, SOT539A, SOT979A flanges).



**In this document only the soldering mounting method is discussed.**

<sup>1</sup> Printed Circuit Board

<sup>2</sup> Small Outline Transistor

Dies are connected to the leads by using bonded wires. It allows the PCB to be in contact with the component (Cf. Figure 1). Several problems can occur if several points are not taken into account. The soldering mounting method indeed requires knowing with which temperature profile packages must be soldered onto the heatsink and also what happens when different manners of soldering are used.

Other important problems are to take into account in mounting packages properly. Packages are unreliable if mounting conditions are not achieved. Damage, failure zero hour<sup>1</sup> or problems of reliability can be encountered.

## 1.2 Stakes

To preserve the efficiency of Air Cavity Package it is necessary to carefully follow the mounting recommendations. Recommendations are to be taken into account in order to have both a best thermal performance and a good electrical contact. It will allow guaranteeing a good functioning of the device in the package.

## 2 PCB/Heatsink design and tolerances

Because this document is applicable to packages with body dimensions the design rules of the mounting areas are general. The tolerance of each part of the device must be respected in order to ensure an optimal assembly.

If the package is mounted to a heatsink in a cavity the cavity dimensions must be at least:

- Cavity length= maximum package length+0.5 mm, allowed tolerance:  $\pm 0.1$  mm;
- Cavity width= maximum package width+0.5 mm, allowed tolerance:  $\pm 0.1$  mm;
- Cavity depth: depending on the thickness of flange and glue layer the depth can vary but depth dimension must be such that the maximum lead deflection is 0.3 mm. The lead deflection must always be toward the back of the component because it is important in controlling stresses on the component and the solder joint. The tolerance of the recessed cavity depth is  $\pm 0.08$  mm.

The maximum package length/width is defined as the nominal length/width added with the tolerance, as it is mention on the SOT outline drawing.

The achievable tolerance of the PCB thickness is to be kept to 0.18 mm.

## 3 Soldering the flange onto the heatsink

### 3.1 Introduction

The mounting method requires soldering the package to a heatsink with the leads soldered to a PCB. To solder the flange onto the heatsink there are many ways but the most commons are:

- Solder paste with pre-applied flux;
- Preform with pre-applied flux.

The flux is necessary in order to activate the contact area.

The method to solder the mounting surface is the reflow soldering method. A temperature profile is created to solder the package onto the heatsink. One reflow is when there is one pass of the device inside the oven. Two reflows are thus when the samples are twice inside the oven.

The following document will be focus on the Air Cavity Plastic Packages because they are far more sensible than the Ceramic Packages. First, for plastic packages the ring-frame is glued to the flange (not brazed) and secondly intrinsically using plastic for the reflow step is more delicate (device are **moisture sensitive**): like popcorn, the moisture in some plastic packages can vaporize and expand rapidly due to high temperatures causing cracks.

This study mainly looks after the soldering area between the flange and the heatsink. The affected packages are: all metal based flanged transistors, for example the SOT 896B. Furthermore, new high power packages will have flanges and so this document describes the recommended mounting requirements for these packages.

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<sup>1</sup> Before the operational use

## 3.2 Mounting recommendations prior to soldering

### 3.2.1 Requirement

- Due to the fact that many plastic packages and some ceramic packages are moisture sensitive the packages must be stored in a conditioned area. For further instructions see JEDEC spec.doc. No 020-C.
- For electrostatic sensitive devices NXP advises to handle the devices according to the JEDEC spec.doc no. 625-A, "Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices, (Revision of EIA-625) December 1999. The most common thing to do is to wear a wrist bracelet that is properly grounded to avoid electrostatic sensitive devices.

### 3.2.2 Cleanliness of soldering areas

The soldering areas (leads, lands of the PCB and the heatsink surface) must be free of contaminations like grease, (human) fats or other particles. It is advised to use gloves during handling.

### 3.2.3 Heatsink preparation

When mounting the package, observing the following recommendations will ensure good thermal and electrical contact between the package and the heatsink.

For packages dissipating up to 80 W, heatsink thickness should be:

- At least 3 mm for copper heatsink (>99.9% ETP-Cu);
- At least 5 mm for Aluminium heatsink (>99.9% Al).

These thicknesses should be increased proportionally for packages dissipating more power. Be advised that NXP recommends the following heatsink properties:

- 1) Flatness of the mounting area: better than 0.02 mm
- 2) Mounting area roughness:  $R_a < 0.5 \mu\text{m}$
- 3) Mounting area should be free of oxidation

### 3.2.4 Package preparation

The leads have a thin gold plating (about 0.8 -1 $\mu\text{m}$ ) and as seen in Appendix A the solder contained Tin in majority. To avoid brittle solder joints (due to too much gold in the joint), pre-tin the leads for example by dipping their full length into a solder bath at a temperature of about 230°C. Minimize the use of flux.

Otherwise, to avoid brittle solder joint due to the combination  $\text{Au}^1\text{-Sn}^2$  it is necessary to use enough thickness of solder. Since the flange is plated with 3  $\mu\text{m}$  of gold, sufficient solder materials ( $\cong 150 \mu\text{m}$  only based on NXP part) should be applied in order to take care that the level of gold within solder joint does not exceed 4% by volume.

## 3.3 Reflow soldering process

There are three basic process steps for single-sided PCB/Heatsink reflow soldering, these are:

- 1) Applying solder paste or preform to the PCB/heatsink
- 2) Component placement
- 3) Reflow soldering

### 3.3.1 Applying solder paste/preform to the PCB or the heatsink

#### • Preform

If preform is used NXP advises using a weight of about **300 mg**. No special difficulty can be encountered for the placement of the preform onto the support (PCB or heatsink).

#### • Solder paste

Using solder paste requires knowing the amount of solder paste and how to apply the solder paste onto the surface.

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<sup>1</sup> Gold

<sup>2</sup> Tin

The amount of solder paste to use depends on the thickness of solder required in order to respect some important parameters: the flux (necessary to activate the contact areas) could damage the glue layers situated between the ring-frame and the lid (a), and between the flange and the ring-frame (b). The solder paste must be **evenly spread** on the

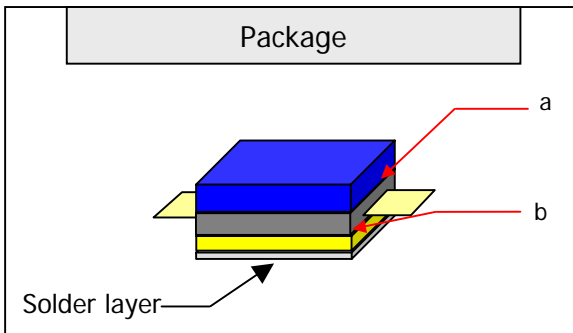


Figure 2 – Location of glue layers

contact areas between the flange and the heatsink (Cf. Figure 3). This action is made using a stainless metal stencil and a squeegee. The squeegee is passed across the stencil and onto the solder lands on the PCB. The size of the stencil (length and width) is similar to the flange.

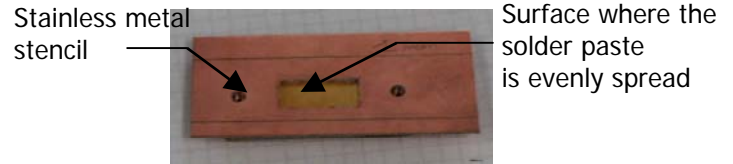


Figure 3 – Stainless metal stencil

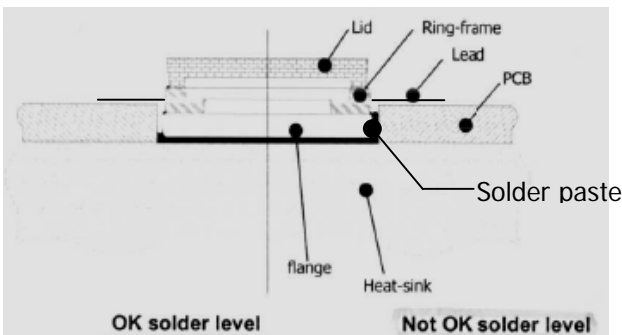


Figure 4 – Level of solder paste

According to tests performed using a lead free solder SAC 96.5Sn3.8Ag0.7%Cu (Cf. Appendix A) the reduction of the solder paste thickness after soldering is more than 50%. In the same time the reduction of the weight of the solder paste before and after soldering is about 15% (the reason is the evaporation of the flux).

To achieve the required thickness of solder NXP advises using a 0.5 mm thick stencil. It represents about **350 mg** of solder paste with pre-applied flux. After soldering the solder layer achieves about a 200 µm thickness.

• **Contact area after soldering**

The X-Ray machine allows an observation of the soldering area. It is observed that when no vacuum is used a lot of voids are visible between the flange and the heatsink. It means that the contact area between both the metallic pieces is not really optimal. The following pictures showed the surface before and after soldering using the oven without vacuum.



Figure 5 – The soldering surface before the soldering step (left) and after the soldering step (right) - No vacuum

When vacuum is used just some very small voids are viewed between the flange and the heatsink. It means that the contact area between both the metallic pieces is almost optimal. It is thus very important for the electrical and thermal conductivity. The following pictures showed the surface before and after soldering using the oven when vacuum is added.



Figure 6 – The soldering surface before the soldering step (left) and after the soldering step (right) – vacuum

• **Conclusion**

When an oven without vacuum is used in order to solder the package onto the heatsink with the solder paste voids appear on the soldering part. However, a vacuum oven is very small and thus does not allow soldering a wide range of products and a lot of devices at the same time. As seen in the introduction a convection oven is then used.

The amount of flux must be reduced to the absolute minimum. According to these tests NXP advises using preform with pre-applied flux. It reduces voids and ensures the required amount of solder ( $\approx 300$  mg).

3.3.2 *Component placement*

The position of the component with respect to the solder lands is of crucial importance to the end result of the assembly process. Misalignment can lead to unreliable joints or bridges between leads and/or open circuits. Placement accuracy is defined as the maximum permissible deviation of the component outline or component leads, with respect to the actual position of the solder land pattern on the PCB.

3.3.3 *Device moisture sensitivity*

As seen previously plastic packages are moisture sensitive. The standard JEDEC moisture/reflow sensitivity classification procedure (IPC/JEDEC J-STD-020-C) for lead free solder is used. The products are rated MSL3 preconditioning, thereby the material must be stored in a vacuum sealed bag with moisture gather inside, or when used in production, stored under nitrogen conditions for not more than 8 days, at max 30°C and max 60 RH (Relative Humidity) to limit possible moisture intrusion.

3.3.4 *Reflow step*

Packages are submitted to **reflow profile** according JEDEC classification: Peak temperature 245 +0/-5°C. There are several methods of reflow soldering to provide the heat to reflow the solder paste like convection, conduction, and radiation. The conduction method is sensitive to tooling and the radiation method is colours depending. The preferred method is convection reflow.

• **Description**

The device is reflow soldered and cooled. NXP advises to use a convection oven rather than a conduction oven. It thus allows keeping a uniform heat and a very controlled temperature ( $\pm 2^\circ\text{C}$ ). Moreover, it allows soldering a wide range of products due to the temperature uniformity. During the reflow soldering process all parts of the board are subjected to an accurate temperature/time profile.

NXP uses SAC solders: e.g. 95.5Sn3.8Ag0.7Cu. Figure 7 shows a suitable profile framework for single sided reflow. The framework can be smaller due to other components that have other process requirements. It is important to know that this profile is for discrete packages only.

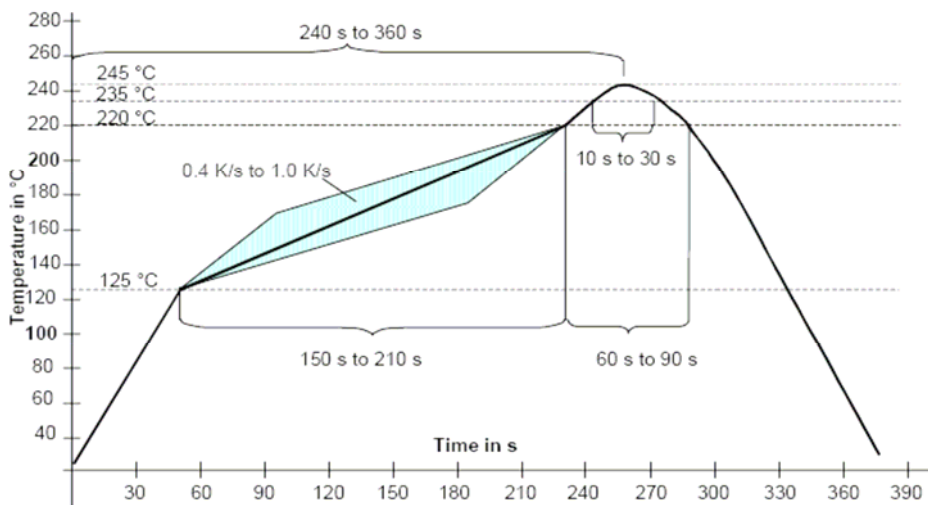


Figure 7 – Reflow profile

- **Remarks**

- The reflow soldering profile should be calibrated with thermocouple glued down on the cap of the ACP device to prevent a temperature offset (Cf. Appendix B).
- Create a reflow soldering profile with a good pre-heat period to allow flux to react completely and allow all volatile and liquid content to evaporate and perform optimal cleaning before the used solder reaches liquidus. Furthermore, it allows the heating rate of the board and the components to be the same.

#### **4 Cleaning step after reflow soldering**

NXP recommends cleaning the part as described below before doing electrical testing, after reflow solder cycles are completed:

- Allow the device to cool at ambient for 15 minutes minimal.
- Apply an activated water-soluble flux cleaner to the device leads by immersion of the entire part in liquid at room temperature for 10 seconds minimum.
- Clean the devices using multiple agitated de-ionized water rinses.
- Devices should be dried at room temperature prior to submission to reliability or electrical testing.
- Important: Check both flux-cleaning as well as de-ionized water baths regularly to prevent excess pollution of the baths.

## APPENDIX A: TESTS SOLDER PASTE

### Description

The solder paste used is with pre-applied flux. It's a lead free solder SAC 96.5Sn3.8Ag0.7%Cu. This solder paste contained 85% w/w<sup>1</sup> of powdered solder alloy (96 SC) and 15% w/w of flux.

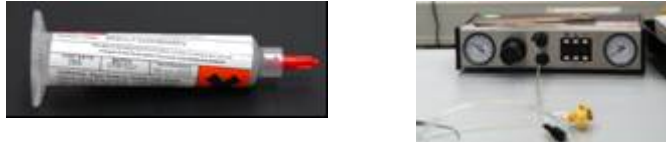


Figure 8 – Syringe of solder paste and dispenser

The paste is bought in syringe in order to spread it using a dispenser. This tool applies a pressure in the syringe during a chosen time. Different diameter of needles can be used. The following graph indicates the weight of solder paste spread versus the time.

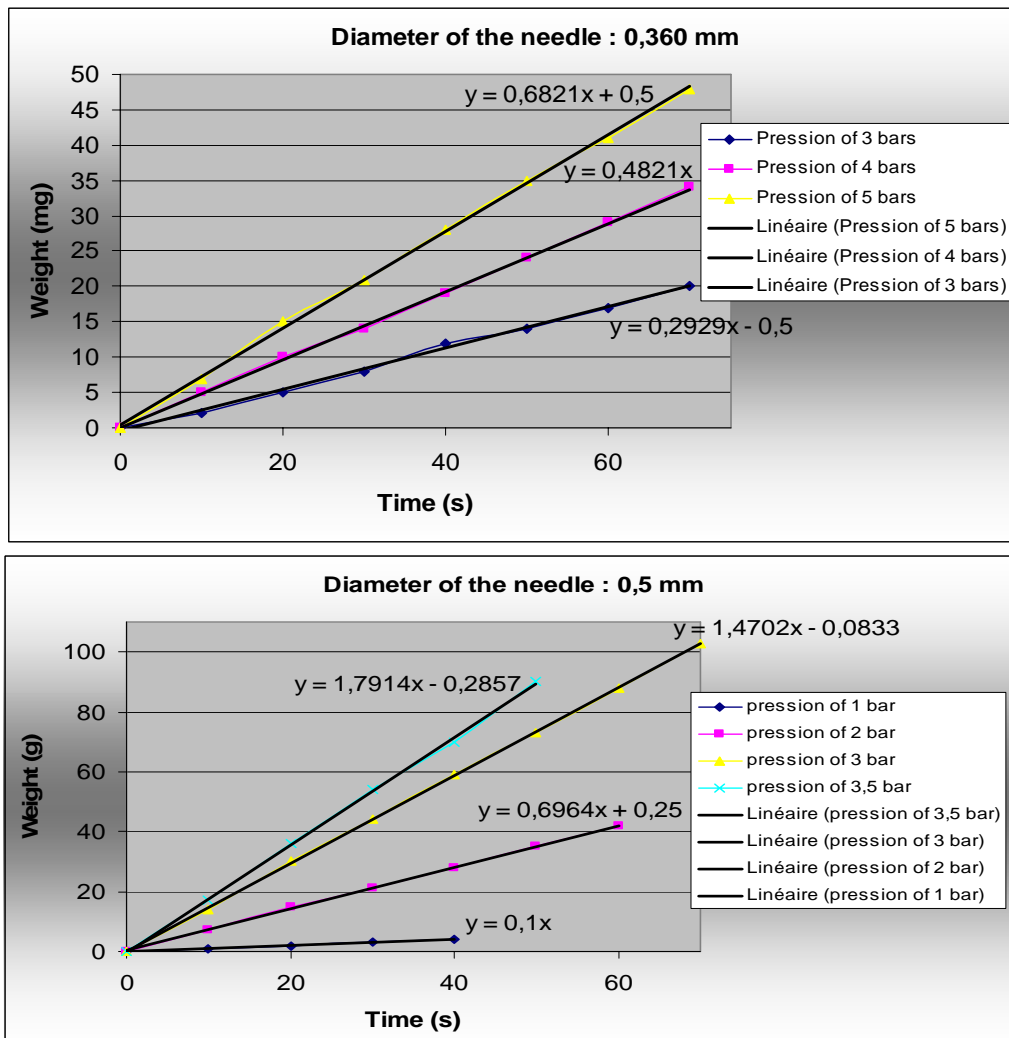


Figure 9 – Weight of solder paste spread versus the time

<sup>1</sup> w/w : In relation to the weight and not to the volume

It will give an indication of how long the solder paste must be applied to achieve a required weight of solder paste.

- **Solder step**



A vacuum oven is used to solder the contact areas between the flange and the heatsink. It thus allows knowing the influence of using vacuum versus no vacuum (with the same oven). A vacuum oven is small. It is impossible to solder a lot of samples at the same time.

Figure 10 – Vacuum oven open

## APPENDIX B: CONVECTION OVEN

The convection oven is about 3 m long. It is composed of 6 parts in each the temperature is adjusted in order to achieve a good temperature profile.



Figure 11 – Entry of the convection oven (left) and exit of the convection oven (right)

The graph below shows three very slow temperature profiles. These temperature profiles have been obtained (built) by using three captors situated on three devices representing exactly the devices used for the reflow tests: it is thus important to know the total mass of the package/heatsink/PCB to be soldered in order to create the temperature profile.



Figure 12 – The three devices with captors on the top of the packages to create the temperature profile

The following draw indicates the belt speed (10 cm/min) and the temperature inside each part of the oven for a very slow profile.

