AN90013

Recommendations for Printed Circuit Board assembly of DFN0603-3 (SOT8013)

Rev. 2.0 — 29 April 2020 application note

Document information

Information	Content
Keywords	DFN0603-3, SOT8013, 0603 package size, reflow soldering, surface mount, solder paste, stencil aperture, PCB, SMD, footprint, landing pattern, pick and place, DFN Package
Abstract	This application note provides guidelines for board assembly of the ultra-small DFN0603-3 (0.63 x 0.33 mm2) leadless full encapsulated package. The main focus is on recommendations for reflow soldering. For general information about footprint design and reflow soldering see application note AN10365 (Surface mount reflow soldering description). If not otherwise stated, all measurement units given in this document are metric units. This means that also the package nomenclature, i.e. the term “0603”, refers to metric units.

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1. Introduction

Due to the trend towards reduced dimensions and increased density of functionality in smart phones and other mobile devices, there is an increasing demand of the industry for extremely small components. With the new DFN0603-3 (SOT8013) package which has a size of only 0.63 mm x 0.33 mm x 0.25 mm (0603 as metric, 0201 in inches), Nexperia offers an ultra-small surface-mount plastic package to support this trend.

Due to the very small size of the component, Nexperia investigated the board assembly process intensively in order to offer board mounting recommendations.

This includes Printed Circuit Board (PCB) mounting pads, stencil apertures, solder paste and board assembly process parameters.

Using the recommended dimensions for pads and stencil as described in this document will help to achieve:

- optimum stand up height
- minimum tilt
- minimum rotation
- good board assembly process performance
- optimum board level reliability:
  The reliability tests for qualification of the DFN0603-3 device have been executed on PCBs with the solder pads as recommended in this application note.

While this application note should help minimizing any unexpected failures, following the advice in this document is not a guarantee for a perfect SMT assembly result. The results may differ depending on the machine capability, ambient conditions, material, etc.

2. DFN0603-3 (SOT8013) package details

The DFN0603-3 (SOT8013) is a Discrete Flat No Lead package (DFN). It features NiAu metal contacts under the package (bottom terminations). This new DFN style package allows about 90% utilization of the package area for active silicon, offering a significant performance advantage per board area compared to products in leadframe-bases plastic-molded packages.

Key features:

- Ultra-small and flat package (0.63 x 0.33 x 0.25 mm^3)
- Full encapsulated CSP package
- Pad size 250 x 100 μm^2
- NiAu plated contacts for soldering on PCB
- No package internal interconnects like wire bond or flip chip
  This is beneficial to minimize electrical parasitics associated with the package.

While this application note should help minimizing any unexpected failures, following the advice in this document is not a guarantee for a perfect SMT assembly result. The results may differ depending on the machine capability, ambient conditions, material, etc.

The visual appearance of DFN0603-3 (SOT8013) is shown in Fig. 1. Fig. 2 shows the package dimensions.

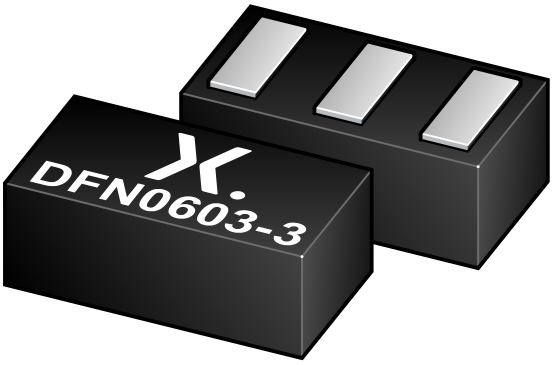
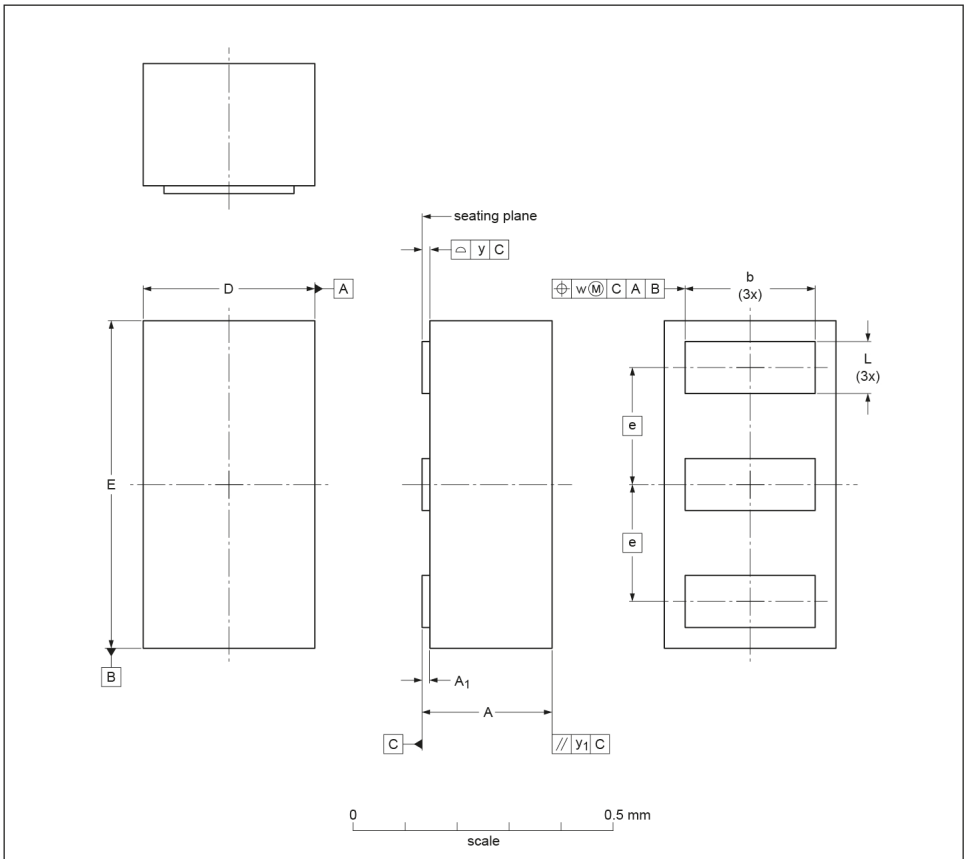


Fig. 1. DFN0603-3 (SOT8013) visual appearance



Dimensions (mm are the original dimensions)

Unit[1]		A	A_1	b	D	E	e	L	w	y	y_1
mm	max	0.275	0.03	0.27	0.350	0.650		0.12			
	nom						0.225		0.04	0.03	0.05
	min	0.225		0.23	0.305	0.605		0.08			

Note
1. Device is electrically symmetrical

Fig. 2. Package dimensions DFN0603-3: Leadless ultra-small full encapsulated package; 3 terminals (SOT8013)

3. PCB solder pattern

3.1. Solder pad design general options

There are two types of solder pad / solder resist designs:

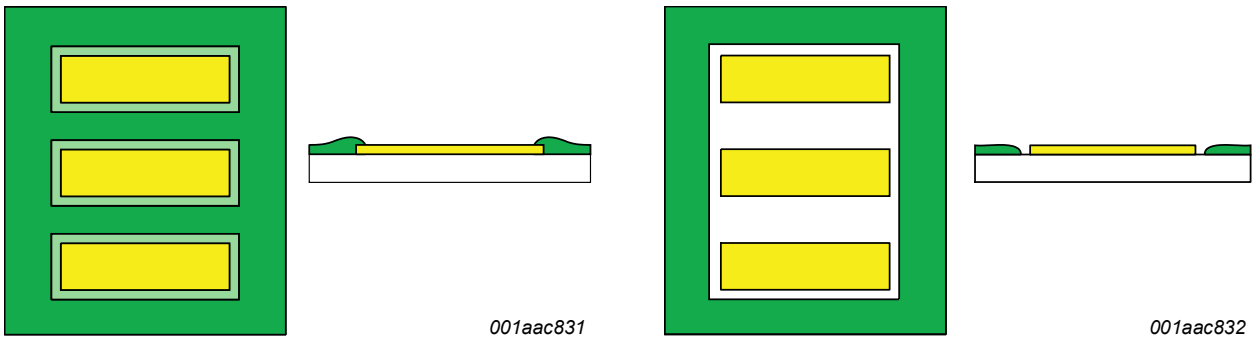
- Solder Mask Defined (SMD)
- Non-Solder Mask Defined (NSMD)

SMD is a method of designing the solder resist to partially overlap the Cu landing pattern on the PCB, whereas NSMD designs have a gap between the solder resist and the Cu landing pattern on the PCB. These two types are described in more detail in the next chapter.

3.1.1. Solder Mask Defined (SMD) pad versus Non-Solder Mask Defined (NSMD) pad

If the solder mask extends onto the solder lands, the remaining solderable area is solder mask defined (SMD). The “effective” solder pad is equal to the copper area that is not covered by the solder mask. This situation is illustrated in Fig 3a (left column). In case of a SMD pad, the copper will normally extend 75 µm down to 50 µm underneath the solder mask on all sides. In other words, the copper dimension is 0.1 mm to 0.15 mm larger than the solder mask dimension. These values may vary depending on the class of PCBs used. This allows for tolerances in copper etching and solder mask placement, during PCB production.

If the solder mask layer starts outside of the solder lands, and does not cover the copper, this is referred to as NSMD. The “effective” solder pad is equal to the copper area. In case of a NSMD, the solder mask should be at least 50 µm away from the solder land on all sides. In other words, the solder mask dimension is 100 µm larger than the copper dimension. These values may vary depending on the class of PCBs used. The main requirement is that the solder mask is sufficiently far away from the copper, such that – with the given tolerances in solder mask application – it does not extend onto the copper. A NSMD footprint is shown in Fig 3b (right column).



a. Solder Mask Defined solder pads (SMD)

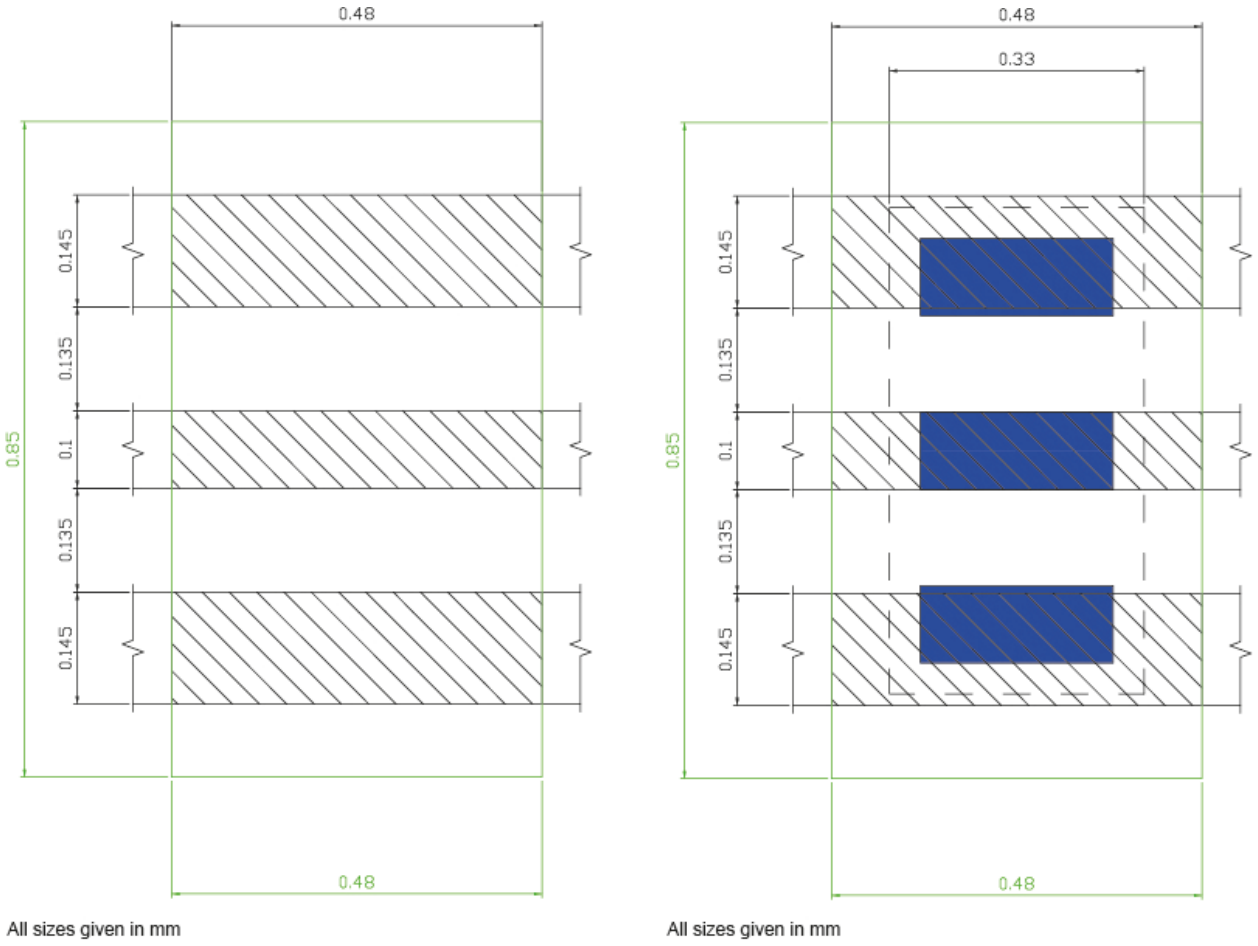
b. Non Solder Mask Defined solder pads (NSMD)

Fig. 3. SMD versus NSMD solder pads

3.2. Solder pad design for DFN0603-3 (SOT8013)

3.2.1. Recommended reflow solder footprint

Based on the small dimensions of DFN0603-3 (0201) devices and the given tolerances for PCB manufacturing, it is recommended to use NSMD solder pads. Especially the gap between the Cu pads (with the PCB design tolerances) is with 135 µm small for a reasonable solder resist trace. In addition, such a resist trace would cause a higher tendency for tilting / rotation. Therefore, the recommended solder footprints are NSMD pads. The solder footprints with dimensions are shown in Fig 4a. Fig 4b shows the solder footprints together with the package outline.



a. Reflow solder footprint

b. Reflow solder footprint and package outline

Fig. 4. Recommended solder footprint for DFN0603-3 (SOT8013)

4. Solder stencil

4.1. Stencil recommendation

Due to small apertures and pad dimensions, a high-quality stencil should be used. E.g. for the Nexperia investigations, a stainless-steel stencil, manufactured by laser-cut and with nano coating had been used and is recommended to achieve best release performance at solder paste printing..

For the recommended Nexperia footprint (see chapter 3.2.1, Fig. 4), the optimum stencil aperture is of size 0.33 x 0.12 mm^2. Based on stencil manufacturers' experience, rounded corners with a radius of 0.03 mm will result in best solder paste release during printing and in an adequate solder volume. For stencil apertures dimension, refer to Fig. 5.

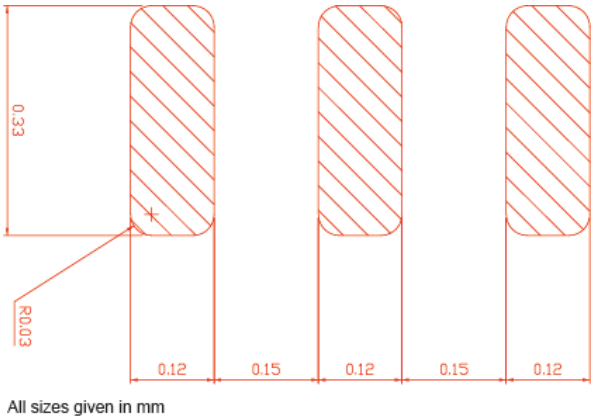
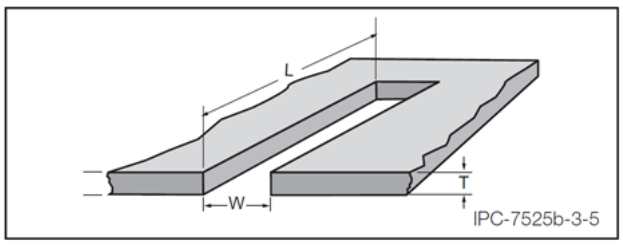


Fig. 5. Recommended stencil aperture

4.2. Stencil aperture design

Key design guidelines for stencil apertures are the area and aspect ratios. The area ratio for a common approach should be >0.66. However, for ultra-small devices like DFN0603-3, a smaller area ratio needs to be applied to achieve optimum assembling reliability. Smaller values are possible with adequate process control. Of course, it depends on the manufacturing environment and other requirements of the manufacturer.

The aspect ratio should be >1.5 which is less critical to fulfil. For an explanation of area ratio and aspect ratio, refer to Fig 6.



Cross-Sectional View of A Stencil

$$Area\ Ratio = \frac{\text{Area of Aperture Opening}}{\text{Area of Aperture Walls}} = \frac{\text{L x W}}{\text{2 x (L + W) x T}}$$

$$Aspect\ Ratio = \frac{\text{Width of the Aperture}}{\text{Thickness of the Stencil Foil}} = \frac{\text{W}}{\text{T}} > 1{,}5$$

Fig. 6. Explanation of area ratio and aspect ratio

Table 1. Area and aspect ratio for recommended stencil aperture

*Stencil thickness **T = 80 µm***

	Aperture size	Area ratio	Aspect ratio
Nexperia recommended footprint	330 x 120 µm^2	0.57	1.5

Table 1 shows the values for aspect and area ratio of the considered stencil apertures for a stencil thickness of 80 µm. It results in an area ratio of 0.57 for the Nexperia footprint recommendation. For such small area, the radius of the aperture (r = 30 µm) has been considered for the calculation.

Nexperia does not recommend to use a stencil thickness > 80 µm

5. Solder paste

Besides stencil aperture and thickness, the solder paste used will have a significant impact on the printing and soldering performance. Solder pastes are available in different solder powder grain sizes. Refer to Table 2.

Table 2. Survey of solder paste types (grain sizes)

Type	Less than 0.5%, larger than	10% max, between	80% max, between	10% max, less than
1	160	150 - 160	75 - 150	75
2	80	75 - 80	45 - 75	45
3	60	45 - 60	25 - 45	25
4	50	38 - 50	20 - 38	20
5	40	25 - 40	15 - 25	15
6	25	15 - 25	5 - 15	5
7	15	11 - 15	2 - 11	2

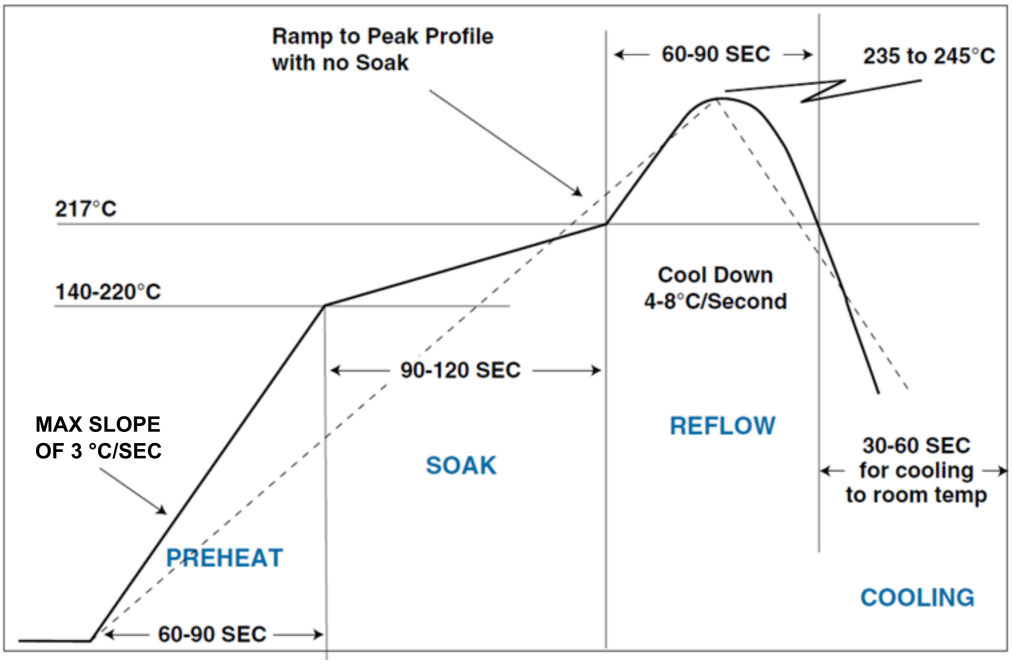
Solder paste type 4.5 was used for investigations with Nexperia solder pad and stencil aperture recommendation for the DFN0603-3 (SOT8013) package with positive results.

6. Soldering process

For soldering of DFN0603-3 packages, the following solder processes were considered:

- **Convection reflow under nitrogen atmosphere is clearly preferred**
- Convection reflow under air atmosphere also works, but:
  - Using an unfavorable layout results in DFN0603-3 packages leaning towards undefined placement (tilting, rotating, misplacement) and in solder joints showing a tendency of increased voiding
  - Solder joint surfaces are rough, flux residues often become darker and the soldering behavior may deteriorate
- Vapor phase soldering is also possible

For investigation of reflow soldering, a profile as recommended for SAC alloys by IPC-7095 was applied. The heat-up slope should be limited to max 3 °C/s for such small devices. Refer to Fig. 7. For reflow profile definition, the recommendation of solder paste data sheet should be considered as well.



Source IPC-7095C

Remark: Heat-up slope should be limited to max. 3 °C/s for DFN0603-3 devices

Fig. 7. Reflow solder profile as applied for investigation

7. Handling recommendations

Besides the PCB and stencil design requirements, the ultra-small size of the DFN0603-3 and as consequence the low weight of the component requires that some attention be paid to the pick and place (P&P) process. One effect which may cause problems during the pick and place (tape out) process is electrostatic charge. Nexperia has implemented preventive measures in ptoduction.

During extensive P&P trials, it was observed that a relative humidity below 30% in the production area leads to increased P&P (tape out) errors caused by electrostatic charging. Therefore, the environment should be controlled to >30% RH. In any case the feeders should be carefully connected to ground to avoid electrostatic charging.

Another observation is that feeders of some P&P suppliers require inserts or springs below the carrier tape. For embossed carrier tapes of such small components the inserts require a gap for the carrier tape pockets to achieve a smooth indexing without vibration. In this case, P&P machine suppliers should be contacted for recommendations.

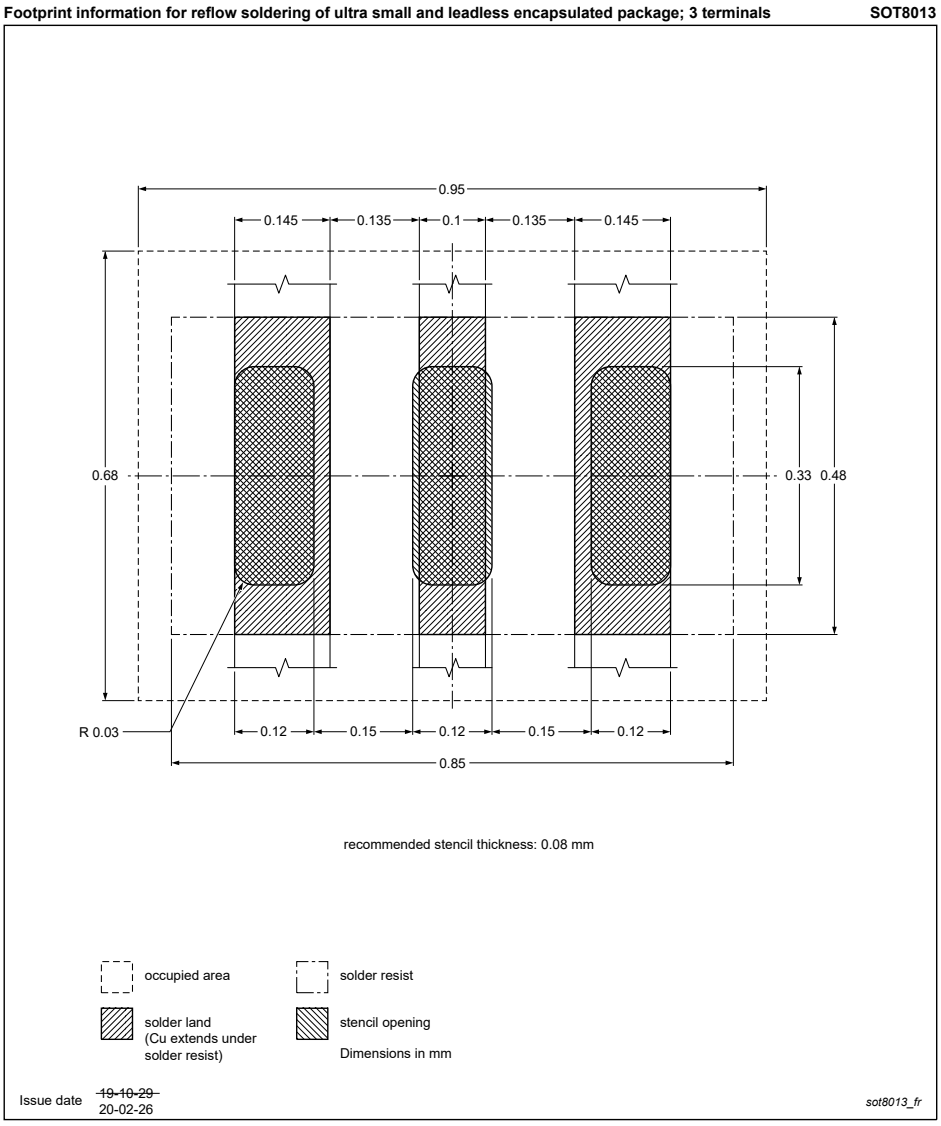
It was found that it is beneficial for an optimum tape out yield if the cover tape peel-off position is as close as possible to the pick-up position of the devices. That prevents any rotation of products due to mechanical movement and vibrations. A risk for rotation was still observed even the products covered by a metal plate after cover tape peel-off.

Manual handling by tweezers (e.g. for PCB repair) is strictly not recommended.

8. Summary

8.1. Recommended solder footprint and stencil aperture

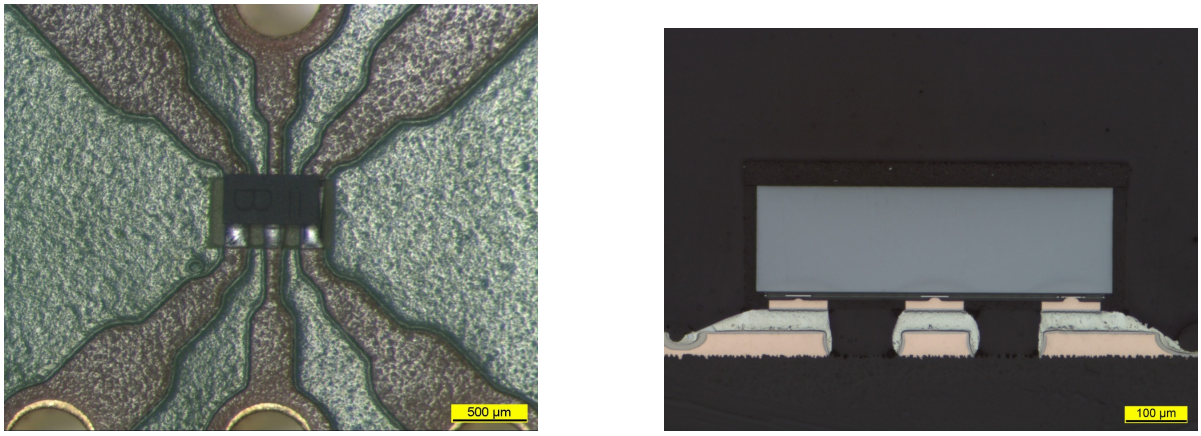
The recommended solder footprint including stencil aperture for DFN0603-3 (SOT8013) is shown in Fig. 8.



Recommended stencil thickness: 80 µm

Fig. 8. Solder footprint and stencil aperture

8.1.1. Real device on recommended solder footprint



a. Top view b. Cross section

Fig. 9. DFN0603-3 soldered on recommended footprint, paste T4.5, stencil T = 80 µm

8.2. Further recommendations

8.2.1. Stencil layout and solder paste

- Stencil thickness of 80 µm in combination with Type 4.5 or 5 solder paste (refer to Table 2) is recommended
- A no-clean paste with a J-STD-004 classification “L0” is recommended
- A stencil aperture dimension as shown in Fig. 5 and Fig. 8 is recommended
- The combination of solder paste and PCB solder pad surface finish needs to be evaluated to achieve an optimized solder paste print result
- To get best printing (and soldering) results, the cleaning cycle of the stencil should be well controlled
- A stainless-steel stencil, manufactured by laser-cut and with plasma coating should be used.

8.2.2. Solder pad design

- NSMD pads are strongly recommended.
- Conductor (Cu trace) between solder pads on PCB is not recommended.
- Accuracy of PCB solder pad dimensions has significant impact on solder result. A tolerance of at least ≤ 10% is recommended.

8.2.3. Soldering process

- Convection reflow under nitrogen atmosphere is preferred
- Convection reflow under air atmosphere also works, but:
  - Using an unfavorable layout, products lean towards undefined tilting and rotation and solder joints show a tendency of increased voiding
  - Solder joint surfaces are rough, flux residues often become darker and the soldering behavior may deteriorate
- Vapor phase soldering is also possible

8.2.4. Handling recommendations

- Manual handling with tweezers (e.g. for repair) is not recommended
- Feeders of P&P machines: if inserts are required underneath the carrier tape, a gap in this insert for the carrier tape pocket should be implemented.
  Some feeders require a spring underneath the carrier tape.
  The cover tape peel-off position should be as close as possible to the device pick-up position.
  A reduction of feeding speed can help to improve tape out yield.
  Ask P&P machine supplier for further recommendations.
- Feeders should be carefully grounded to avoid electrostatic charging
- Relative humidity for P&P should be >30%
- The placement force of P&P machine should be 1N to 2N
- Keep control of thawing time of solder paste bundle to avoid too much humidity in paste
- Keep control of the time from solder paste printing until pick & place and reflow to avoid flux drying

9. Revision history

Table 3. Revision history

Revision number	Date	Description
1.0	2020-04-01	Initial version for DFN0603-3, SOT8013
2.0	2020-04-29	Replaced figure 9 with high-resolution pictures

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