Whitepaper

Side-Wettable Flanks enable AOI on Leadless SMD (DFN) packages

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Quad flat no-lead (QFN) and discrete (or dual) flat no-lead (DFN) packages provide a welcome increase in component density on a PCB area by eliminating leads. However, the solder connection quality cannot be tested by automated optical inspection. This paper explores solutions to this often costly problem.

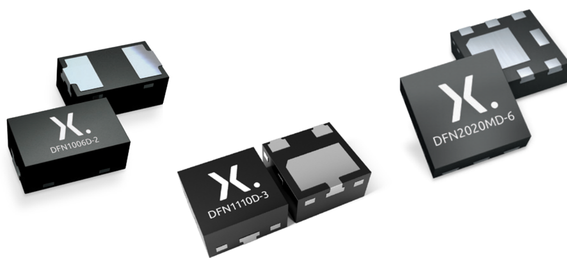

Figure 1: Example packages: DFN1006D-2, DFN1110D-3, DFN2020MD-6

Advantages of Leadless Packages

- **No space required for connections**
  - Less boardspace for comparableelectrical function
  - Or more performance at same boardspace
- **Enables heigth reduction because of flat leadframe (no leadframe for DSN)**
- **Optimized thermal performance**
  - Large heatsink under the package
  - Short disctance from active Silicon to solder connection

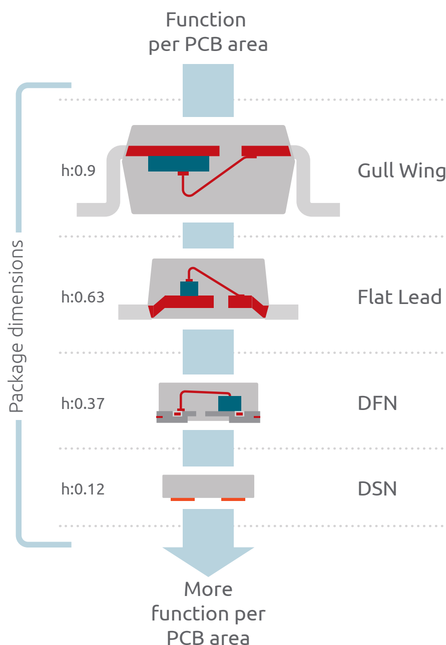

Figure 2: Advantages of leadless packages

Many applications are space-limited which has led to the development of QFN (Quad Flat No lead) packages with connection pads only on the underside, thus increasing component density on a PCB area by eliminating leads.

Such packages are used in high volume for discrete semiconductors, termed as DFN - Discrete (or Dual) Flat No leads – characterized by small size and low number of I/Os. (Figure 1). A huge variety of DFN packages is now available. As well saving space, the internal construction of DFN-packaged devices leads to a reduced thermal path (Figure 2). However, QFN/DFN packages suffer the disadvantage that the solder connection quality can only be fully inspected by costly x-ray processes, rather than Automated Optical Inspection (AOI), because the solder connection is only underneath the plastic body of the package.
The automotive industry, in particular, wishes to use AOI, so companies such as Nexperia have taken a long look at solutions to this challenge.

DFN packages are assembled in a similar manner as leaded packages except that a group of several products are molded with epoxy plastic in one shot. All QFN / DFN package leadframes consist of Cu alloy base material. Many of them are plated with a NiPdAu layer stack which is pre-applied by the leadframe supplier and which guarantees an oxide free surface for chip attach, wire bonding and, on the connection pads, for wetting with solder. Optionally, the NiPdAu layer may be additionally plated with tin. Cutting into individual devices is done after electro galvanic tin plating. Of course, this makes tin plating of the side flanks of the bottom pads which are exposed after sawing impossible. The material of the side flanks of the DFN package pads is Cu alloy (leadframe base material) which may oxidize and so a wetting with solder in the reflow soldering process depends on storage conditions and duration and therefore cannot be guaranteed.

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Side-Wettable flanks guarantee solder wetting of side pads for low I/O DFN packages

To overcome this challenge, a solution has been developed which covers the side flanks with plated tin in the same electro galvanic plating step as used for the bottom pads. This technique is only applicable for DFN packages with up to four pads (more if multiple pads are fused together) and the pads need to be on opposite sides of the package. Plating on all four of the pad´s side flanks on a DFN package is not possible with this method. Figures 3 and 4 show detail of a DFN package with wettable flanks.

With the full tin-plated side-wettable flanks it is guaranteed that the complete side pad surface will be wetted with solder during the reflow soldering process. An important advantage is that the plating layer on the side flank is as thick as on the bottom pads - around 10µm. This guarantees a wettable surface even after long periods of storage. Examples of the optical appearance of side flanks after soldering are shown in figure 5 for a DFN2020-6 package with and without side-wettable flanks and in figure 6 for the two-pad DFN1608-2 package.

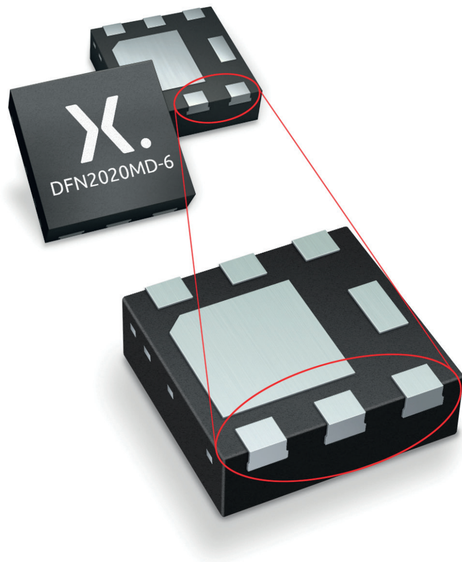
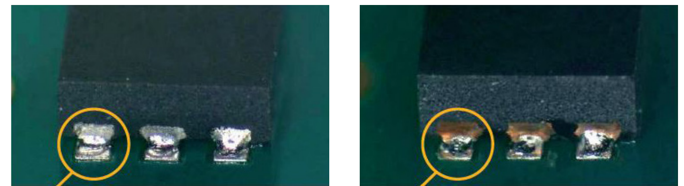


Figure 3: Detail view of side-wettable flanks - DFN2020MD-6 package



100% solder wetting solution with new 2x2 mm leadless package DFN2020MD-6

- Optimal visual solder inspection
- High-quality solder connections

- No complete wetting on side pad
- Quality of solder connection difficult to determine
- Very limited options for optical solder inspection

Figure 5: AOI example comparison of a DFN2020-6 package with SWF versus bare Cu side flanks after soldering

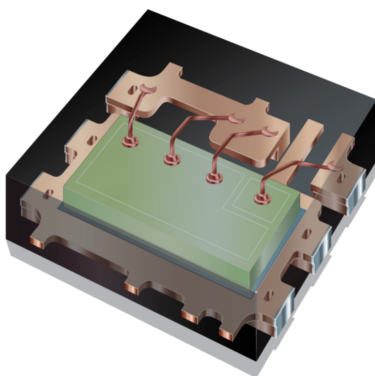


Figure 4: Cut away view of DFN2020MD-6 package

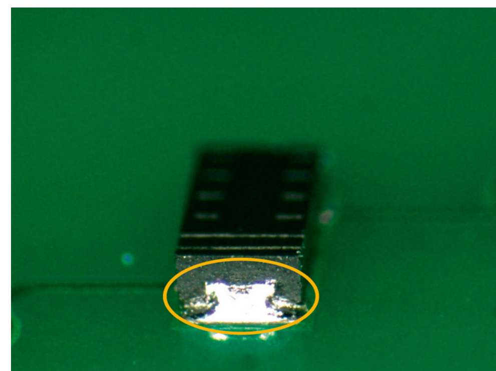


Figure 6: Appearance of side-wettable flanks (DFN1608) after soldering

AOI capability and proof

The main purpose of the side-wettable flanks, of course, is to facilitate a reliable AOI capability for DFN packages. Thus, costly x-ray inspection can be skipped.

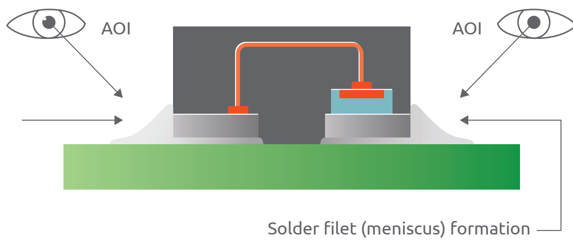
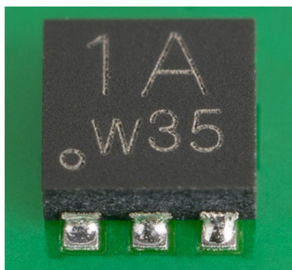


Figure 7: AOI enabled DFN package with Side-Wettable Flanks (SWF)

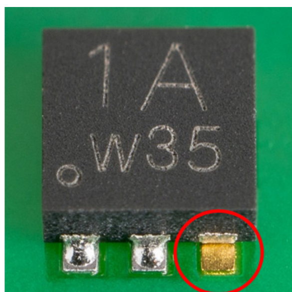
A condition that must be considered is that the PCB solder pad size must be extended to be larger than the package dimension to allow space for the solder to build a meniscus or filet. The solder footprint recommendations of suppliers which offer packages with side-wettable flanks include this extra space.

To examine the suitability of Nexperia's side-wettable flanks for AOI inspection, multiple test boards were built with solder footprints modified to accommodate the SWF package. The printed solder paste volume has been modified deliberately - on some PCB solder pads no solder was printed (see example figure 8). Working with a leading AOI equipment vendor, it was confirmed standard AOI techniques are able to reliably identify soldering failures using the DFN packages with SWF after reflow soldering.

DFN2020-6 with SWF

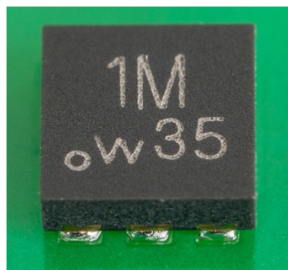


Solder paste printing without fails (a)

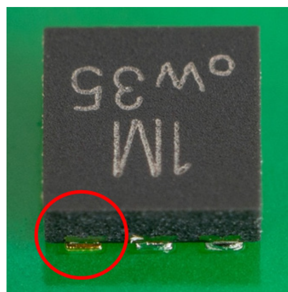


Solder paste printing with failure (b)

DFN2020-6 without SWF



Solder paste printing without fails (a)



Solder paste printing with failure (b)

Figure 8: Example of solder failures on test board

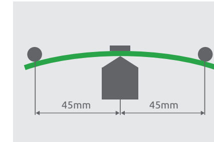
Additional benefits of low pin count DFN packages with side-wettable flanks

An additional benefit of DFN packages with side-wettable flanks is that the mechanical robustness of the bond to the PCB is improved when compared with devices without side-wettable flanks.

Improved mechanical robustness

Maximum shear force
Optimized for high shear forces for robust soldering

Maximum board bending
Very high board bending capability for designs with flexible PSBs



Minimum tilting angle
Reduced tilting angle for ultra flat PSB designs

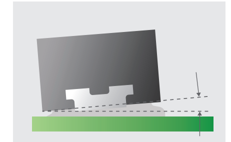


Figure 9: Board level robustness improvements of DFN packages with side-wettable flanks

As shown in Figure 9, the shear force required to dislocate the package off the PCB is increased due to the meniscus that is formed after soldering. Shear force data for a DFN2020-6 package with and without side-wettable flanks have been collected. Overall, 80 samples each had been sheared on the PCB after soldering. The results show that the shear force is improved by about 10% with side-wettable flanks: also the standard deviation is improved (see Figure 10).

Shear force average and standard deviation

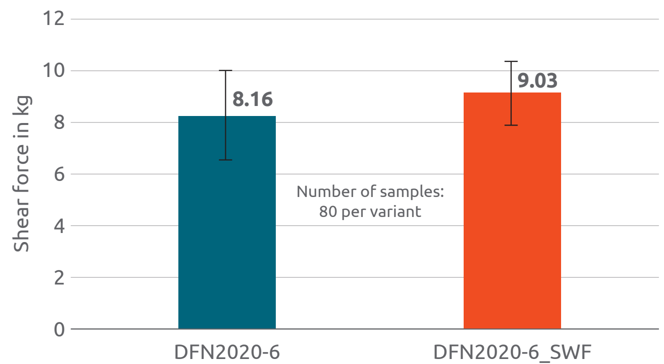


Figure 10: Shear Test on PCB for a DFN2020-6 package with and without side-wettable Flanks

Board bending tests also confirm an increased robustness for DFN devices with side-wettable flanks which is a result of additional features at the package solder pads that achieve a better anchoring to the plastic body. Summarizing the data, it could be proven that board bending depth for the DFN1006-2 package with SWF is up to 14 mm. For some passive chip components of same size the bending depth is often specified with 1mm.

Side-Wettable Flank solutions for DFN packages with more than six I/Os

For DFN/QFN packages with multiple I/Os (above 6) and leadframe thicknesses of 200µm and above, one alternative is to use dimples on the side pads. Dimples are pre-etched and NiPdAu plated together with the bottom pads by the leadframe supplier. Device separation is done at a point between two adjacent packages in the middle of the etched dimples. The wettable feature size formed by the dimples is smaller than for the galvanic tin plating solution described previously. Usually packages with side-wettable flanks made in this way will be delivered with NiPdAu pad plating, i.e. without additional tin plating on the pads. Figure 11 gives an example of such a package without, on the left, and with the dimple feature, on the right picture.

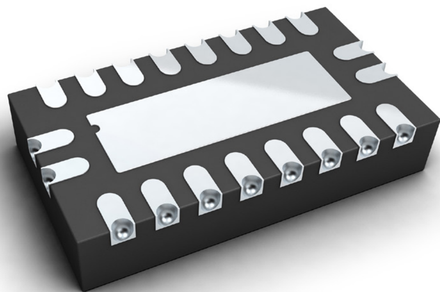


Figure 11: Example of multi I/O DFN/QFN package with dimples to achieve wettable flanks

Another alternative is partial separation of the DFN packages after the molding but prior to tin plating, also known as the "saw plate saw" method. Sawing is performed just to a depth to partially expose the side flank. This means that the pads are still connected by the remaining metal part of the pad flanks ensuring that the continuity of the leadframe is maintained for the galvanized plating process. Full device separation, with a thinner saw blade, is done after tin plating. Due to the necessary sawing tolerances, this method is - like the dimples alternative - only suitable for leadframes greater than 200µm thick. Note that the complete height of the side flank is not covered with tin.

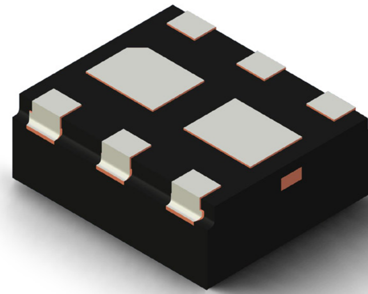


Figure 12: Example of multi I/O DFN/QFN package with step cut approach to achieve wettable flanks

Nexperia offers leadless packages with the side-wettable flank option across its full product portfolio, including Logic and ESD protection devices, MOSFETs, diodes and bipolar transistors. Today, 11 package versions are available, and the portfolio is growing. A video at www.youtube.com shows how Nexperia's leadless packages are meeting the requirements of the automotive industry. By featuring side-wettable flanks they allow a visible solder joint to develop enabling automatic optical inspection. At the same time, they help save space in vehicles with increasing semiconductor content due to more electronic functions while maintaining the high safety and reliability standards needed in automotive applications.

For more information visit: www.nexperia.com

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