Automatic Optical Inspection of DFN Components

By Detlef Beer (Viscom) & Hans-Jürgen Funke (Nexperia)

DFN (Discrete Flat No Lead) packages from Nexperia with wettable, tin-plated side pads offer a way for solder joints to be inspected by using Automatic Optical Inspection (AOI). Nexperia (formerly NXP Semiconductors) and Viscom have investigated how the new wettable side pads impact on inspections of solder joints using AOI and AXI methods. The investigation also looked at the effects of excessive and lean soldering on inspection results.

Leadless components are used for a growing variety of applications, and the trend is also reaching discrete semiconductors (transistors and diodes). Nexperia offer a wide range of leadless packages for Discretes, Logic and MOSFET devices. For these products, the leadless packages are known as DFN packages (Discrete Flat No Leads), and have the following advantages over conventional leaded packages:

- Increased electrical performance on minimum PCB area
- Less occupied area on the PCB at comparable performance
- Optimized heat dissipation
- Lower package height (important for portable devices)

The challenge of using conventional Automatic Optical Inspection (AOI) to inspect these packages is that solder performance cannot be inspected reliably because the joints are underneath the products. The only option is then to inspect with Automatic X-ray Inspection (AXI). In response to demands from customers, Nexperia has developed DFN packages with tin-plated side pads which can be wetted by solder, enabling the resulting solder fillet to be inspected with conventional AOI systems. In addition, the higher shear force increases the mechanical stability of the solder joint.

Fig. 1: Comparison of packages with and without tin-plated side pad

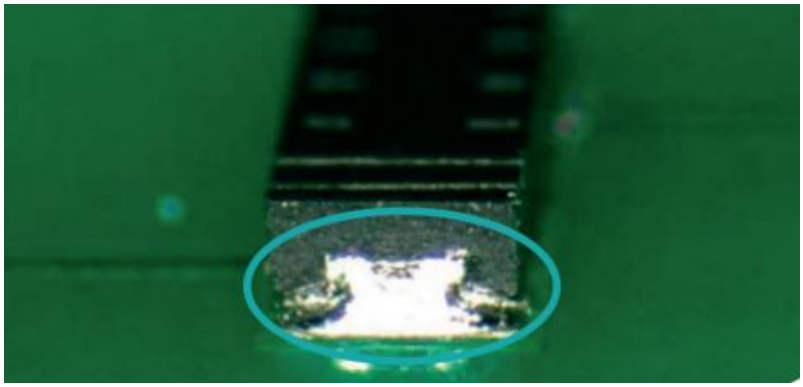

Fig. 2: DFN with tin-plated side pad

Leadless DFN packages – testing with AOI

Nexperia joined forces with Viscom, a world-leading supplier of AOI and AXI solutions, to investigate AOI inspection of leadless packages with tin-plated side pads. Table 1 lists the packages which were investigated.

Packages with tin-plated side pads

Package	SOD / SOT number	Length in mm	Width in mm	Height in mm
DFN1006D-2	SOD882D	1.0	0.6	0.37
DFN1608D-2	SOD1608	1.6	0.8	0.37
DFN1010D-3	SOT1215	1.1	1.0	0.37
DFN2020MD-6	SOT1220	2.0	2.0	0.65

Packages without tin-plated side pads

Package	SOD / SOT number	Length in mm	Width in mm	Height in mm
DFN1006-2	SOD882	1.0	0.6	0.5
DFN1010B-6	SOT1216	1.1	1.0	0.37
DFN2020-6	SOT1118	2.0	2.0	0.65

Table 1: DFN packages with, and comparable packages without, tin-plated side pads

Four package sizes were placed and soldered on optimal solder pad layouts. In the first step, failure-free paste printing was applied. To enable a clearer distinction between good and bad solder joints, components were also soldered on pads with errors in paste printing. X-ray images were then made using the X7056 inline inspection system, and AOI inspection capability was verified using the Viscom Standard-AOI system S3088 flex. In the second step, a process variation was simulated by changing the solder paste volume within the common tolerance range of -50% to +150%.

SIDEBAR:

Viscom testing equipment

Fig. 3: Viscom AOI system S3088 flex

Fig. 4: Viscom AXI system X7056

The **Viscom S3088 flex AOI** system was developed to detect defects reliably and economically. This flexible platform with scalable modular camera technology can handle inspection tasks from prototypes to large volumes. OnDemandHR permits the resolution to be switched between 23.5 and 11.75 µm/pixels. The high resolution of 16.2 and 8.1 µm/pixel in angular view guarantees positive recognition of critical defects, such as fine pitch lifted leads. The system also supports color analysis in orthogonal and angular view.

The Viscom X7056 inline x-ray system provides selectable resolutions of 5, 7 or 10 µm per pixel for X-ray inspections. Depending on the application, 3-D, 2.5-D or 2-D X-ray technologies are used to achieve the highest inspection depth and short cycle times. With optical 8M camera technology, the system delivers the inspection depth of Viscom AOI systems with comparable throughput. With its simultaneous optical and X-ray inspection, the X7056 sets new standards in quality assurance, achieving fast inspection and minimum handling time. Being fully modular, the system can be used either as a combined system or AXI-only.

Test results: major advantages for wettable side pads

The example of the DFN2020 packages (SOT1220/SOT1118) (Figs 5, 6) show the differences in results in x-ray inspection (Figs 7 to 10) and AOI (Figs 11 to 18) with orthogonal and angular views for components with and without wettable side pads. The x-rays show the differences in pad layouts and solder joint characteristics. The discontinuities marked in red indicate voids in the solder pads. The shape of the voids depends on the solder process, but has been neglected for this investigation purposes because of the variation between investigated samples, and because there is no correlation between the solder pad layout and package design.

Fig. 5: DFN2020MD-6 (SOT1220) with tin-plated wettable side pads

Fig. 6: DFN2020-6 (SOT1118) without wettable side pads

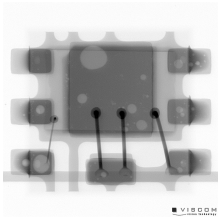

Fig. 7: DFN2020MD-6 (SOT1220) with tin-plated wettable side pads (1-D191) Solder paste printing without fails

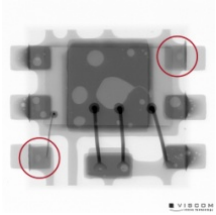

Fig 8: printing with failDFN2020MD-6 (SOT1220) with tin-plated wettable side pads (3-D160): Solder paste

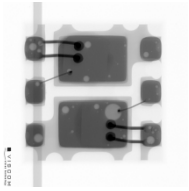

Fig. 9: DFN2020-6 (SOT1118) without wettable side pads (2-D294): solder paste printing without fails

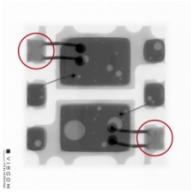

Fig. 10: DFN2020-6 (SOT1118) without wettable side pads (4-D260): solder paste printing with fails

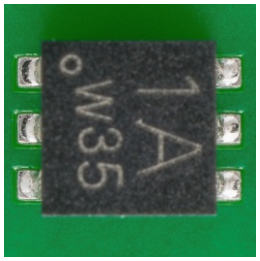

Fig. 11: DFN2020MD-6 (SOT1220) with tin-plated wettable side pads (1-D191): Solder paste printing without fails

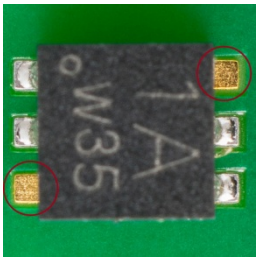

Fig. 12: DFN2020MD-6 (SOT1220) with tin-plated wettable side pads (3-D160): Solder paste printing with fails

Fig. 13: DFN2020-6 (SOT1118) without wettable side pads (2-D294): Solder paste printing without fails

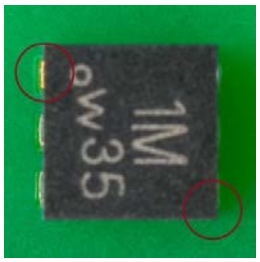

Fig. 14: DFN2020-6 (SOT1118) without wettable side pads (4-D260): Solder paste printing with fails

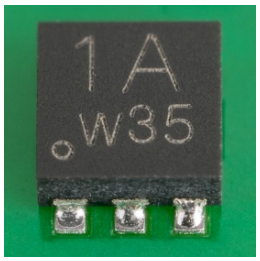

Fig. 15: DFN2020MD-6 (SOT1220) with tin-plated wettable side pads (5-D191): Solder paste printing without fails

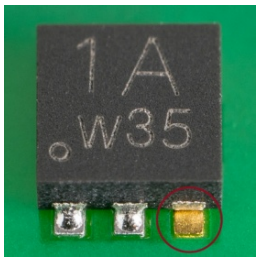

Fig. 16: DFN2020MD-6 (SOT1220) with tin-plated wettable side pads (7-D160): Solder paste printing with fails

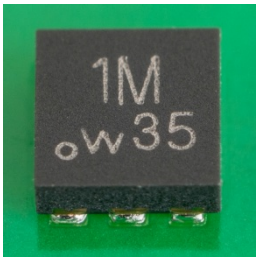

Fig. 17: DFN2020-6 (SOT1118) without wettable side pads (6-D294): Solder paste printing without fails

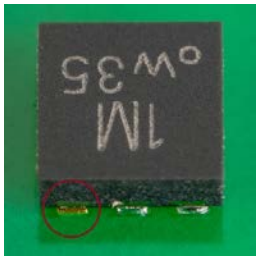

Fig. 18: DFN2020-6 (SOT1118) without wettable side pads (8-D260): Solder paste printing with fails

- The orthogonal view clearly shows the unprinted and non-wetted solder points for the DFN2020MD-6 SOT1220 package; however, this view does not permit a conclusion to be drawn about the quality of the solder joint.
- On the DFN2020-6 (SOT1118), the connection is beneath the component, and pads without solder paste printing (red circles) cannot be reliably detected.
- The angular view clearly shows the unprinted and non-wetted solder points for the DFN2020MD-6 SOT1220 package. Unlike the orthogonal view, the angular view permits a conclusion to be drawn about the quality of the solder joint.
- On the DFN2020-6 (SOT1118), the connections are beneath the component, and pads without solder paste printing (red circle) cannot be reliably detected). The solder joints have to be inspected using an x-ray system.
- Equivalent results were observed with the other DFN packages DFN1006 (SOD882D/SOD882) and DFN1608 (SOD1608).

With AOI, it was also found that an angular view makes the tilting of the package along the longitudinal axis clearly visible. This is a well-known effect in practice, and is typically declared as normal process variation. However, it makes it significantly more difficult to detect device polarity (e.g. cathode marking) with an AOI system. It was found in this investigation that packages with wettable side pads show less tilting, and that the extent of the tilt greatly depends on the solder paste deposition. An increased solder paste volume in most cases leads to increased tilting.

Impact of process variation – result with oversoldering and lean soldering

Having an optimal solder pad layout for each package and keeping the process stable are important for pseudo failure-free AOI inspection. The choice of solder paste and reflow profile needs to be just right to ensure additional wetting of the package side pads and to keep the characteristics of the solder fillet stable for the AOI inspection. This study therefore also investigated the impact of variations in paste printing. DFN2020 (Figs 19, 20) serves as an example to illustrate the results.

Fig. 19: DFN2020MD-6 (SOT1220) - Component D187 with tin-plated wettable side pads

Fig. 20: DFN2020-6 (SOT1118) Component D280 without wettable side pads

To test the impact of lean soldering, the solder paste volume was reduced by 50%, a volume that is in many cases acceptable in manufacturing practice. The lean soldering is clearly visible in the x-ray (Figs 21, 22).

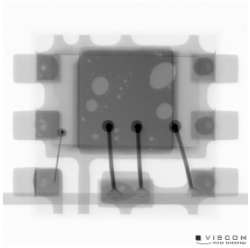

Fig. 21: DFN2020MD-6 (SOT1220) – Component D187 with tin-plated wettable side pads

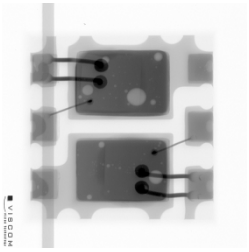

Fig. 22: DFN2020-6 (SOT1118) Component D280 without wettable side pads

The orthogonal AOI inspection for the DFN2020MD-6 (SOT1220) shows that the left side pads have been wetted completely, those on the right only partially (Fig. 23). Nothing is visible on the DFN2020-6 (SOT1118) (Fig. 24). In the angular view of the right pins, the small solder fillets are still visible on the DFN2020MD-6 (SOT1220). In the angular view of the SOT1220 left pads, a small solder fillet is detectable for the center pad. For the other pads the solder is distributed flat on the pad. Nothing is detectable on the DFN2020-6 (SOT1118) (Fig. 26).

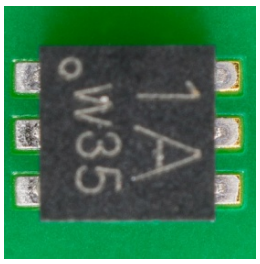

Fig. 23: DFN2020MD-6 (SOT1220) - Component D187 with tin-plated wettable side pads

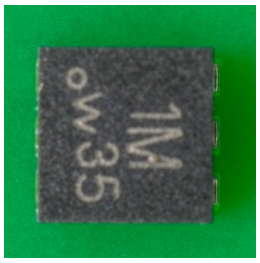

Fig. 24: DFN2020-6 (SOT1118) Component D280 without wettable side pads

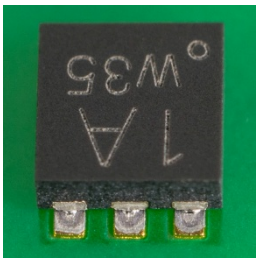

Fig. 25: DFN2020MD-6 (SOT1220) – Component D169 with tin-plated wettable side pads

Fig. 26: DFN2020-6 (SOT1118) Component D263 without wettable side pads

To test the impact of too much paste, the volume was increased to 150%, a volume that is in many cases still considered acceptable in manufacturing practice. The excess is clearly visible on the x-ray images (Figs. 27, 28). The orthogonal AOI inspection shows that the solder pad areas are overprinted. On DFN2020MD-6 (SOT1220), the characteristic of the solder fillet has completely changed (Fig. 29); on the SOT1118 the solder is squeezed out (Fig. 30). On the angular view of the right pins, the excessive fillets are clearly visible. The area between the upper edge of the side pad of the DFN2020MD-6 SOT1220 and the end of the solder pad is well filled with solder. On the angular view of the left pads, the excessive fillets are also clearly visible, and the DFN2020-6 (SOT1118) shows the excessive solder adhering to the exterior (Fig. 26).

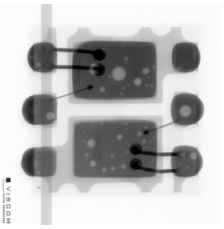

Fig. 27: DFN2020MD-6 (SOT1220) – Component D169 with tin-plated wettable side pads

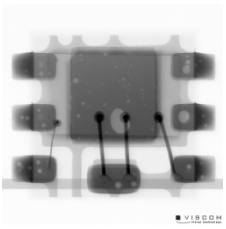

Fig. 28: DFN2020-6 (SOT1118) – Component D263 without wettable side pads

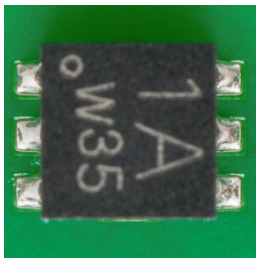

Fig. 29: DFN2020MD-6 (SOT1220) - Component D169 with tin-plated wettable side pads

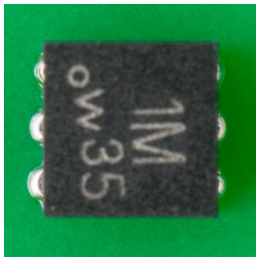

Fig. 30: DFN2020-6 (SOT1118) Component D263 without wettable side pads

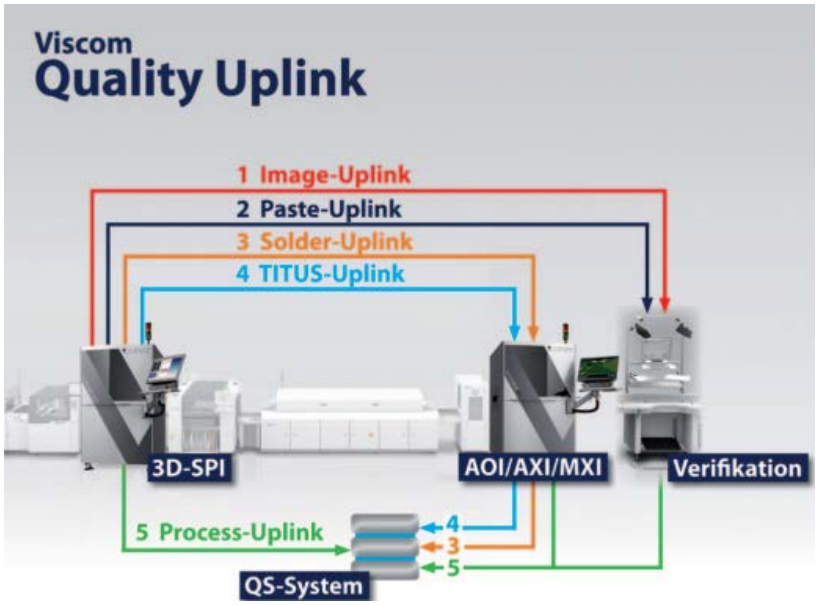

Fig. 31: Viscom Quality Uplink

Summary

The study shows that DFN packages can be reliable inspected in line with an x-ray inspection system. The VISCOM AXI system X7056 offers a proven solution for this purpose

The AOI-Inspection of DFN packages with Sn plated wettable side pads is possible. Following pre-conditions needs to be fulfilled:

- Use of the right packages (e.g. the packages DFN2020MD-6 [SOT1220], DFN1006D-2 [SOD882D], DFN1010D-3 [SOT1215] and DFN1608D-2 [SOD1608] by Nexperia as evaluated in this investigation)
- Application of the appropriate PCB solder pad layouts which fit to the packages as listed above
- For the solder joint inspection with an AOI system angular cameras with a suitable viewing angle need to be applied (Recommendation: Angle ≤ 50° to the PCB surface). In addition the PCB layout may not cause the solder joints to be hidden (e.g. covered by other components).

It was also found that process parameters, especially solder paste printing, have a major impact on the appearance of the solder joint. The commonly accepted tolerances of ±50% for solder paste volume should be reduced. The aim must be to fulfil the IPC 610 criteria of "visible good wetting" (3D AOI inspection would not be a solution, either). In scenarios such as this, the Viscom Quality Uplink (Fig. 31) is an advantage. The study shows that DFN packages with wettable tin-plated side pads as specified above can be reliably inspected using the Viscom 8M sensor system. The new Viscom XM sensor, with its ability to perform orthogonal and angular inspections in parallel without cycle time loss, offers the optimal solution.