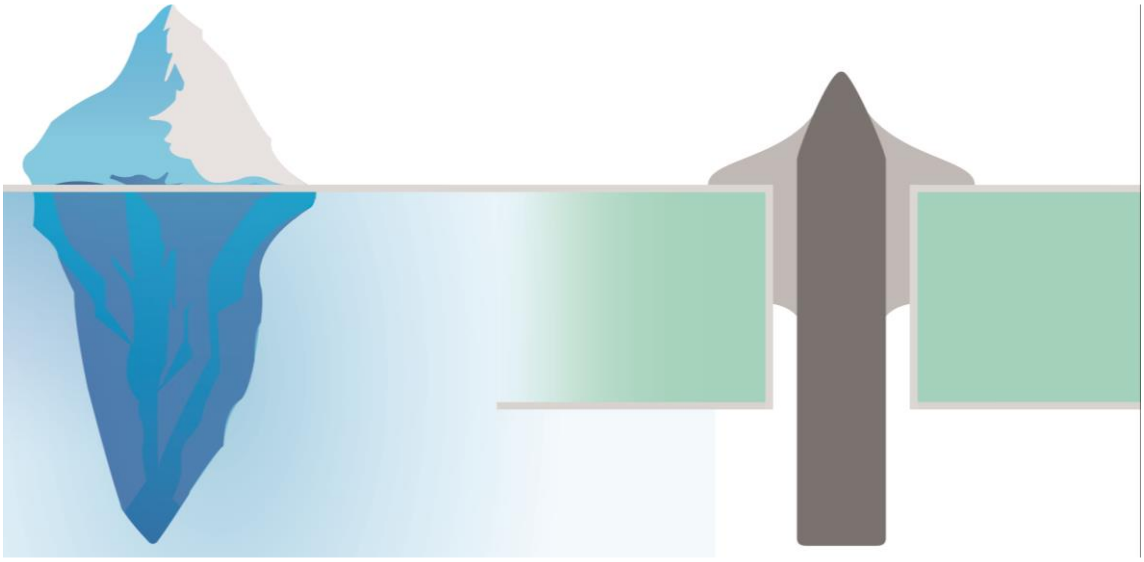
Not just the tip of the iceberg

In-line solder penetration testing on THT / THR connectors using 3D X-ray inspection.



THT lives!

Through-hole technology (THT) is probably the oldest assembly technology in the field of PCB manufacturing. However, even in this modern age of surface-mounted technology (SMT), it still has its place. Even today, wired components are still often assembled using wave soldering – in keeping with the tradition of times past. This has the disadvantage that additional manufacturing equipment is needed, however, because devices for THT production are required in addition to the SMT systems. It is therefore advisable to use reflow soldering for connectors and other wired components. To this end, through-hole components were devised for automatic assembly and for high thermal loads in the furnace; the term through-hole reflow (THR) was coined. With this technology, it is now possible to process components in through-hole technology within the SMT process. But how can these solder joints be reliably tested? What technology is needed in order to be able to assess the solder penetration, for example? These questions are answered below. X-Line 3D, the in-line 3D x-ray system from GÖPEL electronic, is discussed specifically here, which enables fast, accurate and reproducible assessment of solder penetration in the production line cycle.

Pressekontakt:

GÖPEL electronic GmbH
Matthias Müller
Goeschwitzer Str. 58-60/66
D-07745 Jena

Tel: +49-3641-6896-739
Fax: +49-3641-6896-944
E-Mail: press@goepel.com
URL: www.goepel.com

GÖPEL electronic GmbH • Göschwitzer Str. 58/60 • 07745 Jena, Deutschland

Tel.: +49-3641 - 6896 - 0
Fax: +49-3614 - 6896 - 944
E-Mail: sales@goepel.com
www.goepel.com

Acceptance criteria for THT/THR solder joints

Figure 1 is a schematic representation of a THT solder joint in cross-section. The solder delivered by the flow of solder from the solder wave flows from the solder source side (solder side) to the solder target side (component side), due to capillary action. In so doing, it wets the connecting surface of the solder side, surrounds the pin and forms a solder meniscus on account of the protrusion of the pin on the solder side.

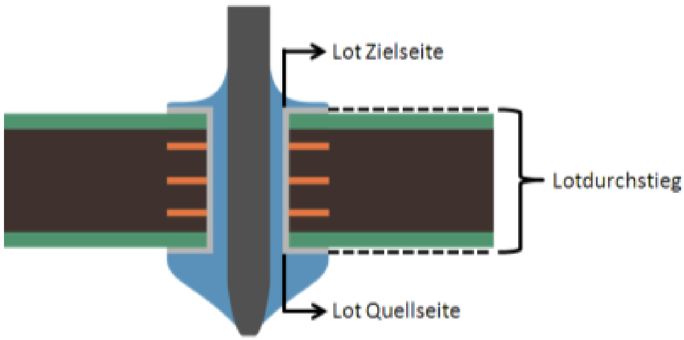


Figure 1: Schematic representation of a THT solder joint in cross-section. Ideal soldering with 100% solder penetration.

The acceptance criteria are defined in IPC-A610 in order to distinguish between good and bad solder joints after successful soldering. Table 1 gives an overview of the criteria in excerpts:

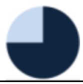
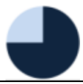
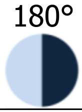
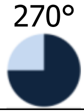
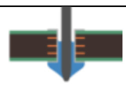
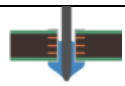
IPC criterion		**Category 1**	**Category 2**	**Category 3**
Solder side	circumferential wetting of pin	270° 	270° 	330° 
Solder side	wetted connecting surface	75%	75%	75%
Component side	circumferential wetting of pin	immaterial	180° 	270° 
Component side	wetted connecting surface	0%	0%	0%
Solder penetration		immaterial	 75%	 75%

Table 1: Overview of selected acceptance criteria for THT solder joints according to IPC-A610E

It is now necessary to select testing technology which meets the specified acceptance criteria. Based on the example of a multi-row connector (Figure 2), the following table provides an overview of the test coverage of AOI and 3D AXI systems.

Pressekontakt:
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Matthias Müller
Goeschwitzer Str. 58-60/66
D-07745 Jena

Tel: +49-3641-6896-739
Fax: +49-3641-6896-944
E-Mail: press@goepel.com
URL: www.goepel.com

GÖPEL electronic GmbH • Göschwitzer Str. 58/60 • 07745 Jena, Deutschland
Tel.: +49-3641 - 6896 - 0
Fax: +49-3614 - 6896 - 944
E-Mail: sales@goepel.com
www.goepel.com

Figure 2: Connectors shot from above and below using AOI.

IPC criterion		**2D/3D AOI**	**3D AXI**
Solder side	circumferential wetting of pin and sleeve	Yes	Yes, somewhat restricted
Solder side	wetted connecting surface	Yes	Yes, somewhat restricted
Component side	circumferential wetting of pin and sleeve	Yes	Yes, somewhat restricted
Component side	wetted connecting surface	No	Yes, somewhat restricted
Solder penetration		No	Yes
Calculation of volume		No	Yes
Presence of pin		Yes	Yes
Short circuit		Yes	Yes

Table 2: Overview of test coverage using 2D/3D AOI and 3D AXI

AOI systems are highly suited to assessment of the peripheral wetting of the pin and the sleeve and to evaluation of the wetted connecting surface on the solder side of a THT solder joint. The disadvantage of a traditional 2D AOI or an innovative 3D AOI system here, however, is that it is often only possible to assess the solder side. The reason for this is that the pins on the component side are usually concealed by the component body itself. An assessment of the solder joints on the component side is therefore not possible with an AOI system. The solder penetration also remains hidden from traditional AOI technology.

A modern 3D X-ray system such as X-Line 3D to increase the testing depth can provide a remedy. The 3D X-ray inspection not only makes the solder joints on the component side (i.e. below the component housing) visible, but is also able to calculate the solder penetration and the solder volume.

In addition to 3D X-ray technology, 2.5D X-ray imaging (oblique radiation) is also used to test the solder penetration. However, assessment of the solder penetration by means of 2.5D X-ray imaging is often very difficult, especially in the case of multi-row connectors. The pins of the individual rows are often concealed by one another. In addition, multi-row connectors are harder for the classification staff to interpret in a 2.5D image than in a three-

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Matthias Müller
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URL: www.goepel.com

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E-Mail: sales@goepel.com
www.goepel.com

dimensional sectional image in which the solder joint is always displayed from above as a slice. Another disadvantage of 2.5D imaging is that the programming is more costly. Whereas in the 3D AXI system, X-Line 3D, the solder joints are always shown normalised in plan view and uniform test algorithms can therefore be applied, in 2.5D technology the test function must always be adapted to the corresponding oblique irradiation angles.

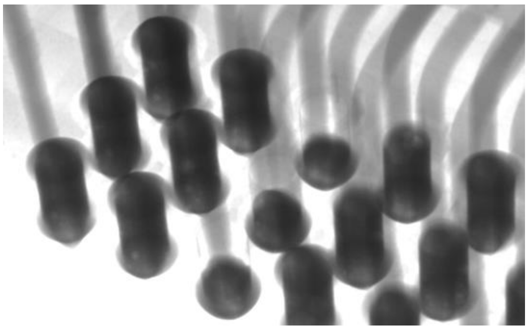


Figure 3: Connectors in 2.5D oblique radiation with easily visible defects in the solder penetration.

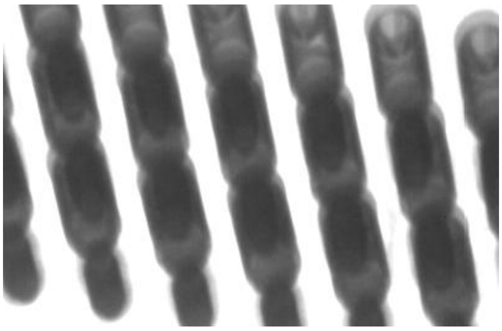
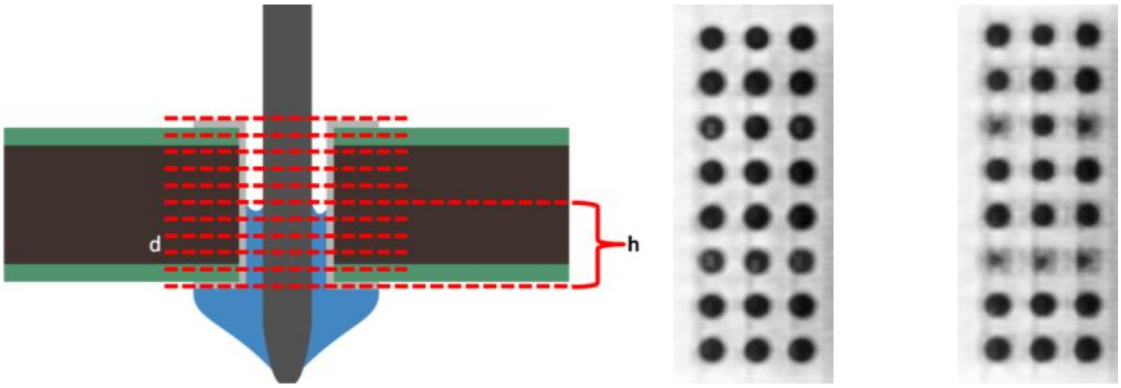


Figure 4: Connectors with many successive rows of pins one behind the other in 2.5D oblique radiation; the solder joints are difficult to separate; the cost of creating test programs is high

The salami tactic

How is THT/THR inspection carried out in X-Line 3D? To calculate the solder penetration, the THT solder joint is digitally divided into slices. In a method comparable to slicing salami, slices with the thickness “d” are generated and the area of each slice which is covered with solder is calculated. Figure 5 shows the digital section schematically.



Slice on solder side

Slice at 50%

Figure 5: Left: schematic representation of the N-sectional planes. Centre: Slice on the solder side. Right: Slice at 50%.

To calculate the solder penetration, a minimum allowable slice area is then defined in mm² in the THT test function of the X-Line 3D. A check is then carried out slice by slice to determine whether this minimum area is achieved. If the area is under the minimum, this is

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Matthias Müller
Goeschwitzer Str. 58-60/66
D-07745 Jena

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URL: www.goepel.com

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www.goepel.com

the stop criterion for determining the solder penetration. The penetration height "h" (mm) is then calculated by the machine and, in the event of any faults, this measurement is displayed beside the X-ray fault image on the GÖPEL repair station/classification station. In addition to determining the solder penetration, the system is also capable of calculating the solder volume (mm³). In order to do this, N-slices with the thickness "d" are generated between the solder and component side as before for determining the penetration, and the individual volume is calculated for each slice. Finally, the sum of the volumes of all the slices gives the total volume.

In the case of a THR solder joint, the solder source side and solder target side are reversed. The acceptance criteria remain the same, however. Inspection of THR solder joints is therefore easily possible. However, due to the degassing of the flux of the solder paste during the soldering process, in the case of THR solder joints there is often a relatively high proportion of air pockets within the solder joint. This is where the use of the X-Line 3D X-ray system is predestined to be able to detect breaks in the solder penetration.

Programming has never been easier

As a result of the intuitive design of the system software XI-Pilot and the combination of 3D X-ray examination and AOI in one equipment system (X-Line 3D AXOI), setting the parameters for the THT/THR solder joint inspection is incredibly easy. To enable better orientation, the programmer can work on a coloured AOI overview image, with the CAD data for the assembly superimposed thereon in a semi-transparent form.

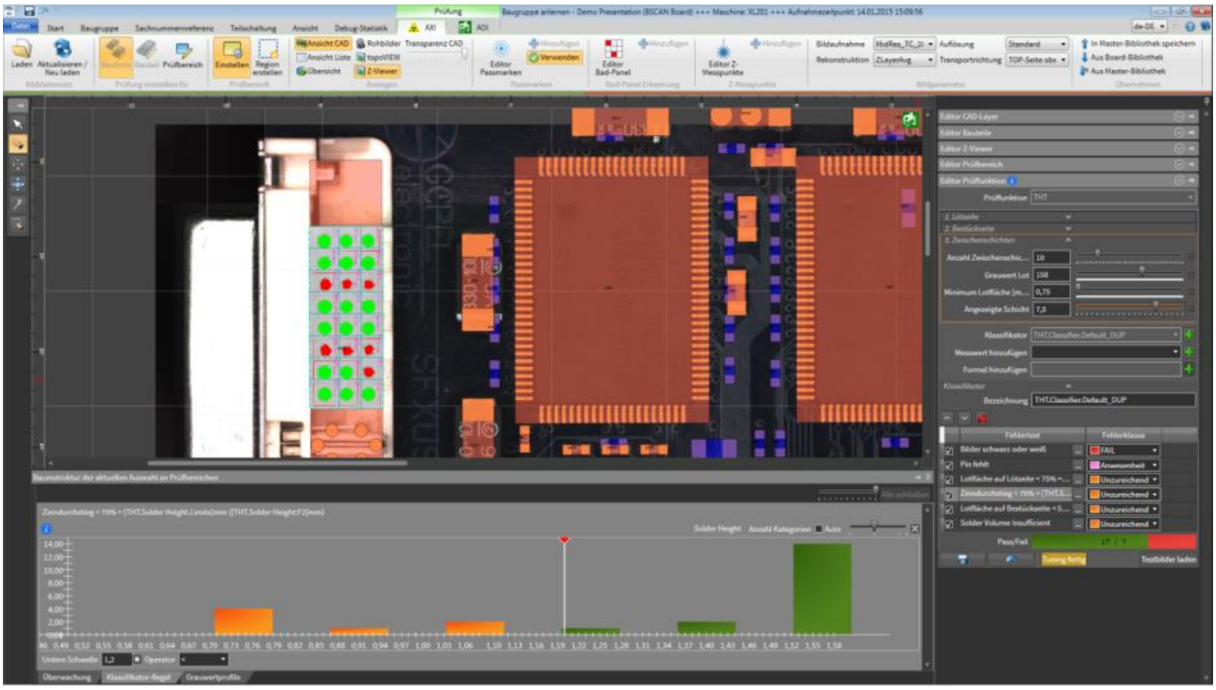

Figure 6: Intuitive programming interface of the system software XI-Pilot

Pressekontakt:

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Matthias Müller
Goeschwitzer Str. 58-60/66
D-07745 Jena

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URL: www.goepel.com

GÖPEL electronic GmbH • Göschwitzer Str. 58/60 • 07745 Jena, Deutschland

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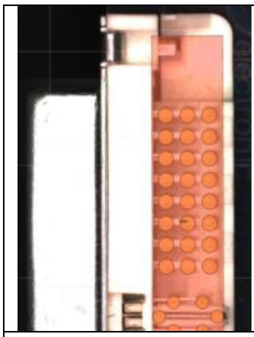
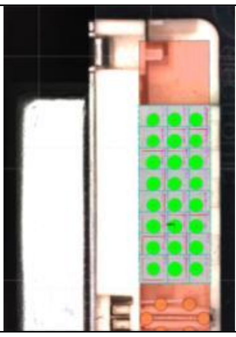
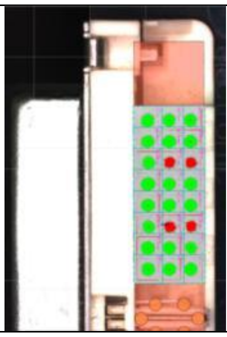
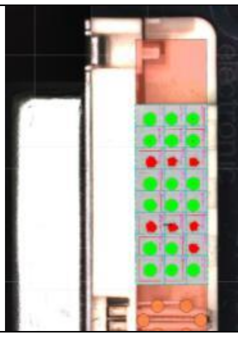
In order to set the parameters for the THT test function, only the corresponding connectors need be selected; the X-ray images (slices) are then displayed precisely above the AOI image. The parameters for the test function are then set using a few slide controls in order to enter the geometry of the THT solder joint and the necessary grey-scale value thresholds. This demonstrates another advantage of 3D X-ray technology: the solder joints are always shown in normalised plan view. This means that a single component library can be used. In addition, an integrated debugging statistics tool helps programmers to compare measured values from N-module inspections with each other and to optimise measurement thresholds.

			
AOI image with connector and CAD data	AOI image and X-ray slice image of the solder side (0% slice)	AOI image and X-ray slice image at 50% slice 4 pins are missing	AOI image and X-ray slice image at 75% slice 7 pins are missing

Fast, faster, X-Line 3D

The patented image capture concept of the X-Line 3D enables THT/THR inspection in the production line cycle. All the X-ray images required for the 3D reconstruction (oblique radiation images) are captured in motion (scanned) and computed in real time (reconstructed). This scanning image capture is 3-4 times faster than in systems with planar stop-and-go image capture technology. As a result, large assemblies with numerous connectors can also be inspected within the clock cycle.

Summary

To test the solder joints of THT/THR connectors, an in-depth look is necessary in order to ensure that it is not just "the tip of the iceberg" that is considered. A pure AOI system is not sufficient for fault finding if IPC guidelines are to be met. 3D X-ray technology enables conclusions to be drawn about the solder penetration and the solder volume, among other things. X-Line 3D enables a precise assessment of these criteria, while at the same time meeting the high demands of the production line cycle.

Pressekontakt:

GÖPEL electronic GmbH
Matthias Müller
Goeschwitzer Str. 58-60/66
D-07745 Jena

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E-Mail: press@goepel.com
URL: www.goepel.com

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Tel.: +49-3641 - 6896 - 0
Fax: +49-3614 - 6896 - 944
E-Mail: sales@goepel.com
www.goepel.com

Author:

Andreas Türk is responsible as division manager for Automatic X-ray Inspection Systems at Göpel electronic.

Pressekontakt:

GÖPEL electronic GmbH
Matthias Müller
Goeschwitzer Str. 58-60/66
D-07745 Jena

Tel: +49-3641-6896-739
Fax: +49-3641-6896-944
E-Mail: press@goepel.com
URL: www.goepel.com

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www.goepel.com