Axiom Electronics

*Ensuring Reliability Series*

# Critical Factors in Ensuring Solder Joint Integrity

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*By Rob Rowland, Axiom Electronics Director of Engineering*

**Solder joints provide the electrical and mechanical connections between substrates and components so solder joint integrity is essential to ensuring a printed circuit board assembly (PCBA) can perform its functions reliably. Both design and manufacturing processes play a role in ensuring solder joint quality. While design determines product reliability, manufacturing processes ensure that solder joints conform to the industry-driven workmanship standards that define acceptable vs unacceptable structure. Process control is major element in ensuring acceptable solder joints. However, the challenges of shrinking PCBA and package size also drive a need for a robust inspection strategy. This whitepaper looks at both key design elements and the role of inspection and test in ensuring solder joint integrity.**

*Figure 1 – Axiom uses x-ray inspection to set up processes and inspect mission critical products.*

## Key Design Elements

Reliability starts with the design of the substrate. For SMT components the land pattern design is critical. If they are not designed to IPC standards or the manufacturers' recommendations it may not be possible to create reliable solder joints. If the land pattern is too small there may not be enough solder volume to create a robust solder fillet. If the land pattern is too big, most of the solder may end up on the board instead of around the leads or terminations.

For through-hole components the lead-to-hole ratio is critical. Depending on the board thickness, the hole should be .012" to .020" larger than the lead. Solder flow and hole fill during soldering improves significantly when the proper hole size is used, otherwise hole fill may be insufficient. How a hole is connected to a power or ground layer is also important. A thermal relief design should be used to connect to these layers, otherwise too much heat will be lost during soldering and the result will be insufficient hole fill.

Axiom Electronics' design for excellence (DFX) process analyzes designs for issues that may impact manufacturability, testability or other critical areas.

## Manufacturing Process Considerations

Manufacturing must develop the assembly and soldering sequence for the SMT and through-hole components. For SMT assembly, the solder volume is controlled by the stencil used in the solder paste printing process. Stencil designs usually require some fine tuning to achieve the desired solder paste volume. Within SMT there are many different types of components and they require different solder paste volumes. In some cases, this makes stencil design very challenging. A unique reflow soldering profile must also be developed to melt the solder and form the solder joints.

Through-hole solder joints are created by hand, wave or selective soldering. The goal is 75% or greater hole fill. This can be fairly easy to accomplish or very difficult depending on the board thickness, the lead-to-hole ratio and thermal relief design.

**The Role of Inspection and Test**

Three methods are used to inspect populated PCBAs. Magnified visual inspection should be done by trained and certified inspectors. Automated Optical Inspection (AOI) of visible solder joints is done with machines capable of 2D or 3D inspection. Traditional 2D AOI machines usually make acceptability decisions by comparing inspection images to a reference image. Advanced 3D AOI machines make acceptability decisions based on true 3D measurement of solder joints and components. Different methods and techniques are used to inspect hidden solder joints on ball grid array and leadless components. These include:

- Conventional 2D transmission X-ray inspection, which is used for QC inspection and process monitoring to determine if the solder joints are acceptable per workmanship standard. This method is useful for inspecting hidden SMT solder joints, thermal pads and barrel fill.

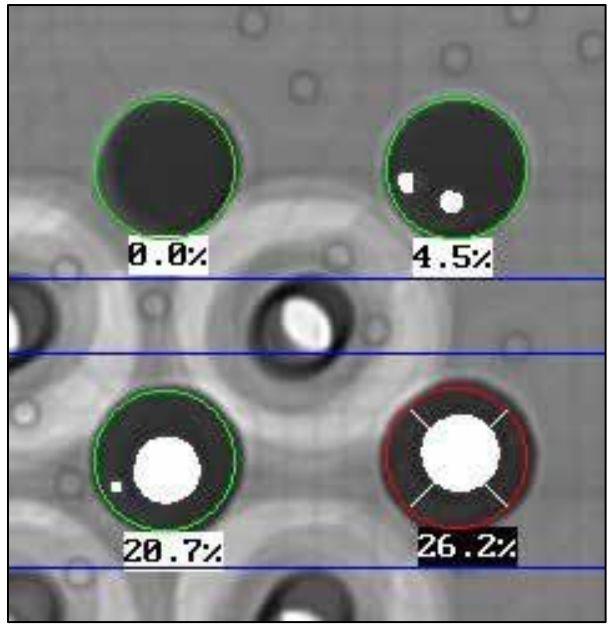


*Figure 2 – Voids in BGA Solder Joints (< 25% is acceptable per IPC-A-610).*

- Advanced 3D computed tomography (Planar and True CT) X-ray inspection, which is used for process development and failure analysis to determine if the solder joints are acceptable per IPC-A-610.
- Void calculation is used to calculate the percent of voiding in BGA solder joints and BTC thermal pads. This calculation is used to determine if solder joints are acceptable per workmanship standard for voiding (Figure 2).
- Through-hole (TH) Measurement is used to measure the barrel fill percent on TH parts. This calculation is used to verify the solder joints are acceptable per IPC-A-610 requirements for barrel fill (Figure 3).

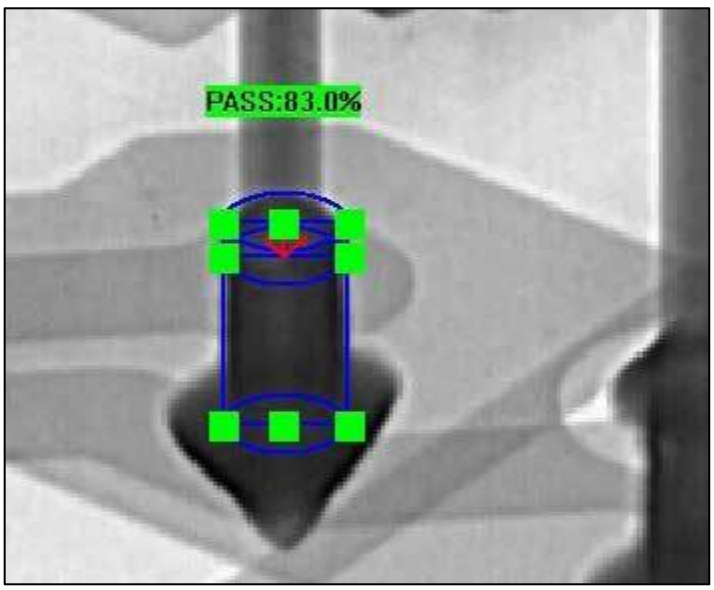


*Figure 3 – Through-Component Barrel Fill (> 75% is acceptable).*

The global standard for Acceptability of Electronics Assemblies is IPC-A-610. This standard explains and illustrates the acceptance criteria for producing soldered electronic assemblies. Within this standard three end product classes have been established, they are Class 1, 2 and 3. Class 3 is the highest level of acceptability and is commonly required for high performance and harsh end use environments.

**Understanding the Difference Between X-Ray and Computer Tomography Inspection Options**

Axiom Electronics upgraded the imaging capability of their Waygate (GE) Micromex X-ray machine (Figure 1). The computer and software upgrades expand the X-ray machine's capabilities for 2D and 3D imaging. This upgrade enhances Axiom's ability to examine hidden solder joints for product development, process control, and failure analysis. Conventional 2D transmission X-ray inspection was enhanced with the addition of Flash Filter digital image processing. Advanced 3D Computed Tomography (CT) X-ray inspection was enhanced with the addition of Planar CT and more advanced 3D image processing and visualizationsoftware.

Computed Tomography is an innovative imaging technique that uses multiple combinations of computer processed X-ray images (360 to 2160) taken from different angles to produce cross sectional images of a solder joint. The reconstructed views allow 3D inspection of a single plane or the whole component. Computed Tomography enables Axiom to see a complete 3D model of the solder joints (Figure 4).

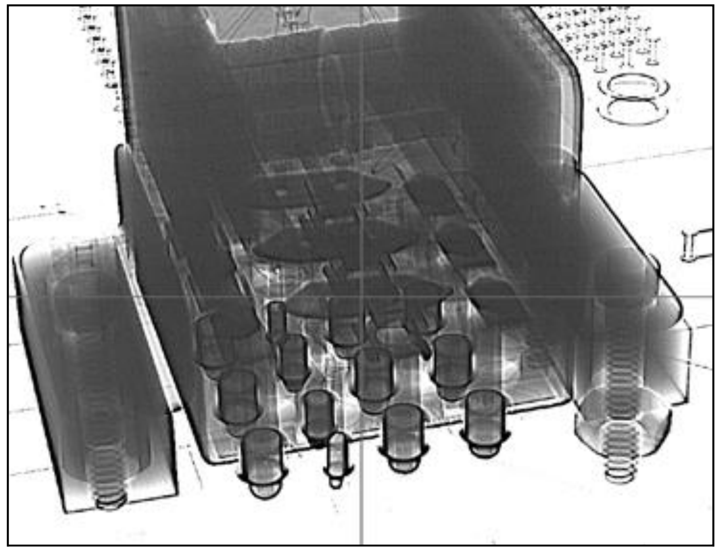

*Figure 4 – Oblique View of a Through-Hole Component.*

Conventional 2D transmission X-ray images are created when X-rays pass through an object to a detector located on the far side of the object. The high resolution 2D images are viewed from the top or in oblique views up to an angle of 70 degrees (Figure 4). The image in Figure 4 is from a Design of Experiments (DOE) for a customer to determine the feasibility of soldering this large component to a printed circuit board.

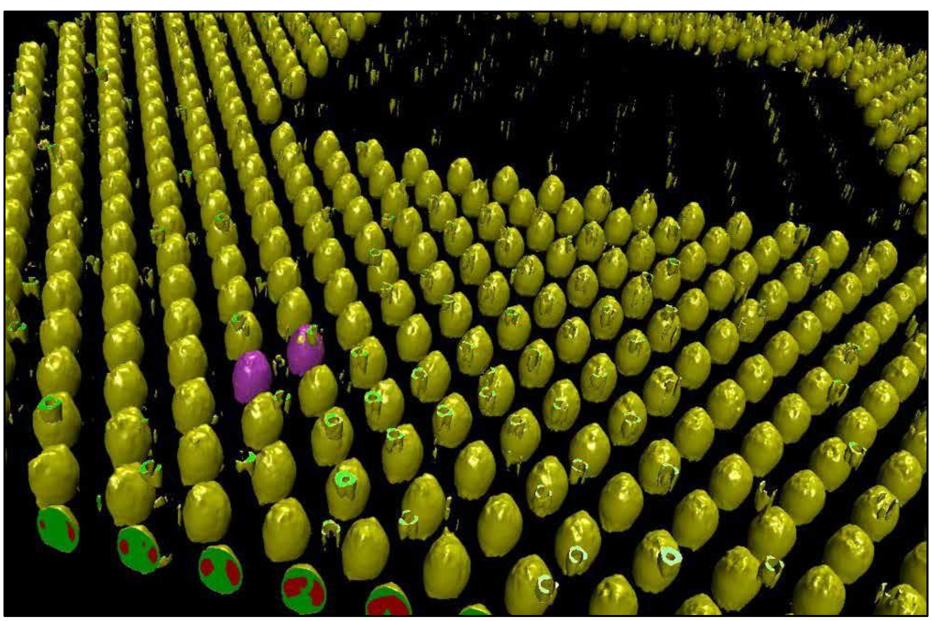

*Figure 5 - 3D CT Image of BGA Solder Joints.*

The image in Figure 5 is from a failure analysis investigation of a large BGA. Conventional 2D X-ray images were inconclusive so Computed Tomography was used to get a full 3D view of the solder joints.

The X-ray machine is typically used for, but is not limited to, inspecting components with hidden solder joints for solder shorts and solder opens, solder joint size and shape, BGA head-on-pillow defects, voids in BGA solder joints and BTC thermal pads, and plated-through-hole barrel fill. The X-ray machine can be operated manually using a joystick or it can be programmed to take and save images automatically. Figures 7 and 8 illustrate defects found in the inspection process.

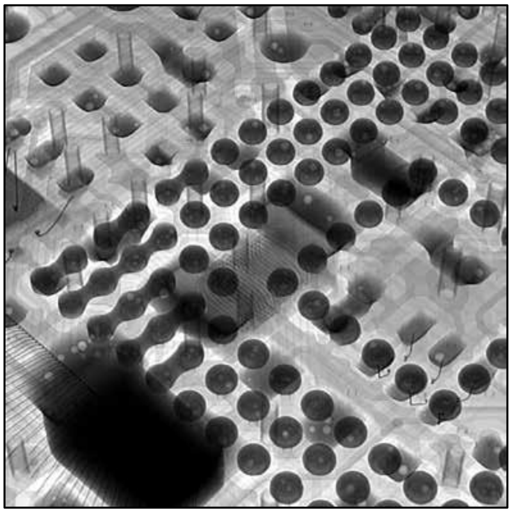

Figure 7 -- X-ray image of BGA solder shorts.

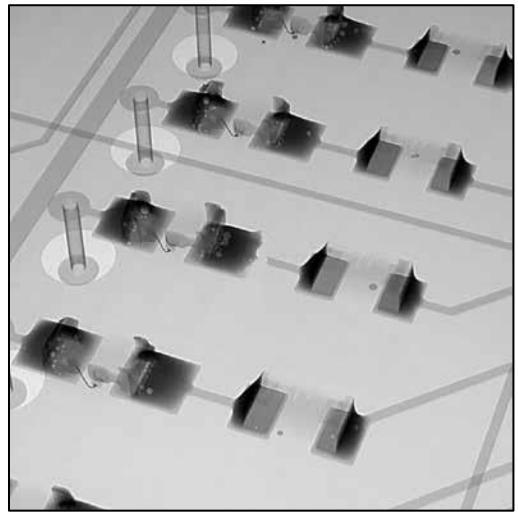

Figure 8 -- X-ray image displaying open trace.

Axiom Electronics continually looks for ways to improve and enhance product manufacturing, inspection and test. The 2D and 3D Computed Tomography x-ray technologies delivered by the Waygate (GE) Micromex X-ray upgrade helps Axiom consistently deliver quality products to its customers.

***About Axiom Electronics***

*Axiom Electronics is a leading electronics manufacturing services (EMS) company founded in 1990. Based in Hillsboro, OR. Axiom provides sophisticated electronic manufacturing services to a wide range of OEMs in high reliability sectors such as military/aerospace, instrumentation, communications, test and computer systems.*

***Rob Rowland, Director of Engineering***

*Rob joined Axiom in 2013. Previously, he was the Senior Manager of Processing Engineering at Radisys Corp. for 15 years. Rob serves on numerous IPC task groups including IPC-7095, design and assembly process implementation for BGAs; and the IPC-7093, design and assembly process implementation for bottom termination components. Rob was also the director of the technical committee for the SMTA International conference for 20 years. He received the SMTA Founders Award and the SMTA Member of Technical Distinction Award, along with IPC awards. Rob graduated from Weber State University, Ogden, UT, with a BS in manufacturing engineering.*

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