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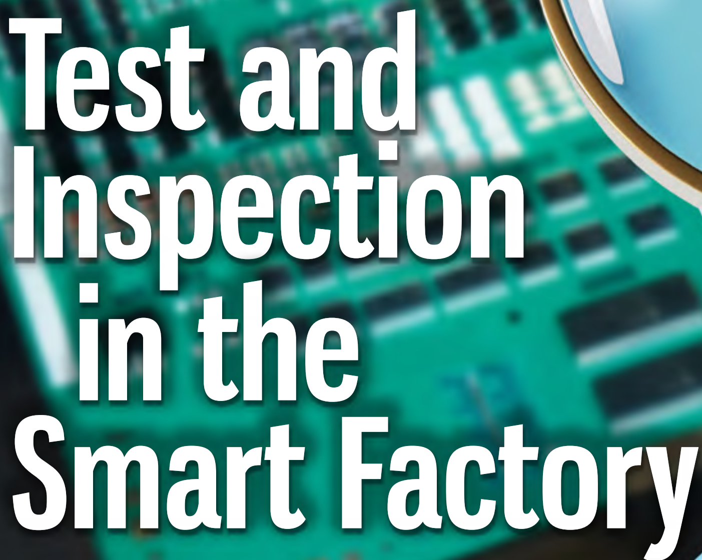
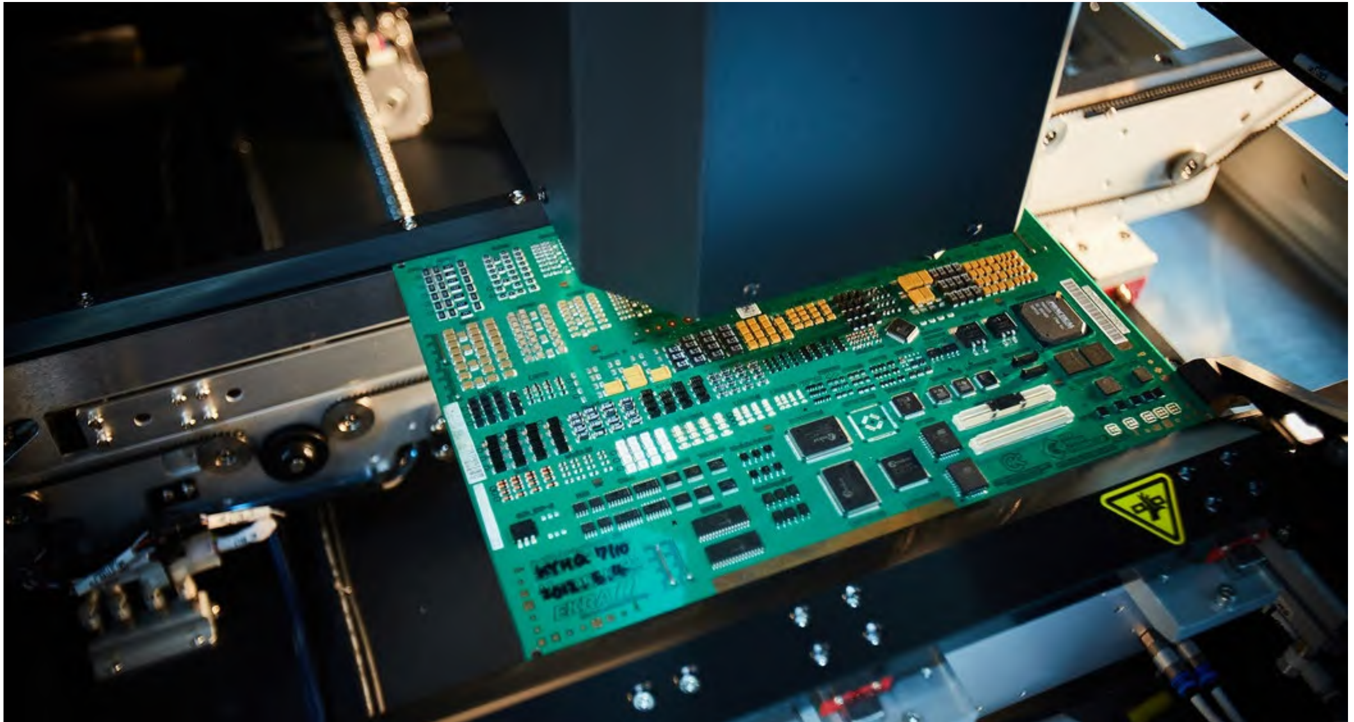


Test and Inspection in the Smart Factory



Using True 3D Inspection Data as a Process Control Tool in the Smart Factory

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Automated 3D solder paste inspection (SPI) and automated optical inspection (AOI) systems have become an integral part of the printed circuit board assembly (PCBA) process. These systems are increasingly important for electronics manufacturers because they help ensure high-quality production results. With board complexity increasing, inspection technology becomes even more critical. While most manufacturers base quality decisions on a "good-bad" comparison of reference images, variables like surface finish, board condition, and component proximity can easily influence these image-based decisions.

Data generated from 3D measurement systems, however, supplies meaningful insights about the process and can help manufacturers eliminate the root cause of a defect. As such, manufacturers must trust the data from the system and use that data to help transform, monitor, and control the PCBA process. Yet, for these systems to make the leap from inspection to process control—and ultimately to automated process optimization—the data must be reliable, repeatable, and relatable.

In this competitive world, manufacturers place challenging demands on process solutions. They want to monitor and adapt the process to achieve zero defects by accessing all the data anytime, anywhere. What's more, manufacturers want process optimization. However, this has been difficult to achieve for 2D, 2.5D, and quasi "true 3D" systems that cannot reliably offer accurate information by providing real true 3D data. It is also impossible for these systems to accurately measure and quantify shape, coplanarity, solder amount.

To overcome these deficiencies and challenges, a true 3D system measures every aspect of the component and solder joint per the IPC-610 standard, while generating a signif-

icant set of reliable and accurate measurement data. True 3D utilizes all measurement data, but not all 2.5D and 3D systems work this way. The 2.5D and most 3D systems rely on non-measurement-based 2D technology while incorporating a small amount of 3D capability to simply provide 3D images and—in some cases—basic measured values.

The Smart Factory

Data—especially from inspection and test systems—is the foundation for Industry 4.0 and smart factories, so advanced systems must evolve from simply judging pass/fail situations into highly intuitive, dynamic decision-making systems. This emphasizes the need for reliable, repeatable, and relatable data.

Artificial intelligence (AI) engines can empower systems to help manufacturers analyze and optimize the PCBA process by managing process data from connected SPI, pre-reflow AOI, and post-reflow AOI systems. Ideally, the AI system collects all inspection and measurement data from equipment in the line and then delivers information anywhere within the network with an intuitive, web-based user interface.

Communications

The machine-to-machine (M2M) communication standards—guided in part by Industry 4.0—are altering the manufacturing process by improving metrics like first-pass yield and throughput with autonomous process adjustments that increase board quality and reduce production costs. As part of this path, certain process control software suites like KSMART can revolutionize data collection and analysis and—more importantly—PCBA process optimization.

Of course, simply collecting reliable and repeatable measurement data is not enough on its own to realize a smart factory. The system must also instantly analyze the data with relevant indicators like yield rate, no-good (NG) analysis, parts per million (PPM) analysis, Gage R&R (repeatability and reproducibility), offset analysis, and other key metrics. When combined, these metrics allow manufacturers to compare board performance and identify process deviations from critical process steps like printing with an SPI, placement with a pre-reflow AOI, and reflow with a post-reflow AOI (Figure 1).

Measurement-Based Inspection

Process optimization is desired by every manufacturer, as well as equipment suppliers, including automated inspection providers. However, it has been difficult to realize due to the limitation of two-dimensional (2D) imaging, which was the de facto standard for the past 25 years. It is difficult for 2D AOI systems to identify defects on a curved and reflective solder joint, and 2D and 2.5D AOI systems do not generate reliable measurement-based data.

Every aspect of the 2D/2.5D inspection process relies on contrast, not quantitative measurement. As such, 2D/2.5D AOI users must either scrap or repair defective boards, which increases costs and eliminates process improvement opportunities. At the same time, the results from these non-measurement-based systems limit the application of AI to improve all aspects of the inspection environment.

The introduction of 3D imaging to the inspection market solved many of the problems. By measuring components and solder joints, and then offering critical height information to the

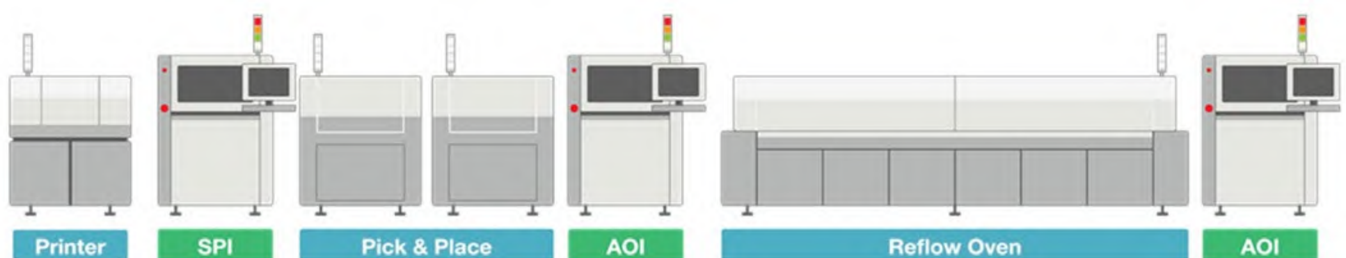


Figure 1: An example of a line configuration to improve yield with multipoint data correlation.

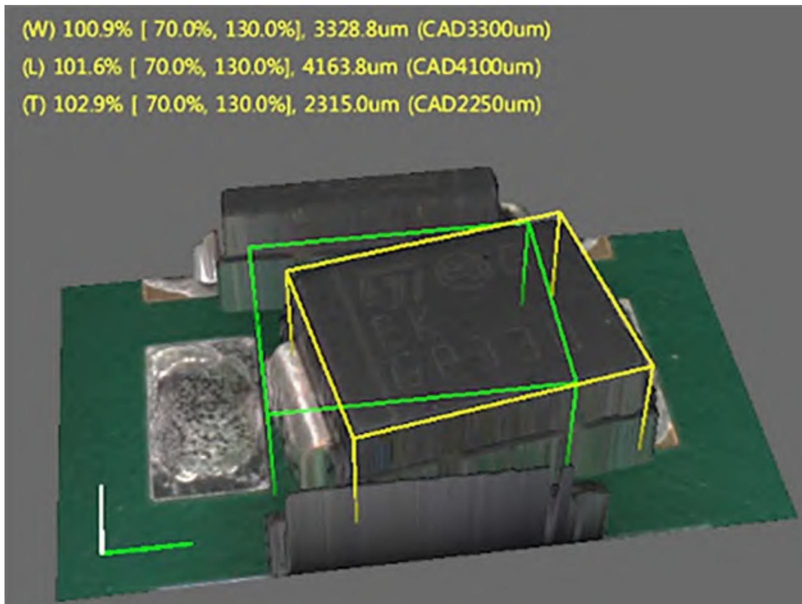


Figure 2: A practical approach to mapping the component body by using measurement technology to deliver reliable, repeatable, and relatable data.

inspection algorithms, manufacturers could locate errors like pad overhang and insufficient solder. However, the validity of the measurement data remained questionable as most of the 2.5 and 3D AOI systems still use 2D-based "blob detection" to find the component body and lead tip—a technique that is susceptible to external factors like board warpage and component proximity, etc. Since finding the component body and lead tip is the critical first step in the inspection process, if done poorly or inaccurately, it negatively affects the whole inspection sequence and contributes significantly to false calls.

True 3D inspection systems can overcome this challenge for all component types by extracting their exact body dimensions and location (Figure 2). For example, the Zenith AOI series uses a parallel computing engine to process true 3D measurements. While 2D, 2.5D, and even some 3D inspection systems combine basic 2D data with limited height and width data to offer inspection data, it is not reliable, repeatable, or relatable.

Using patented shadow-free 3D technology, the Zenith series provides superior results by measuring every aspect of the component and solder joint in accordance with the IPC-A-610 standard. It generates a significant and statistically relevant set of reliable, repeatable, and relatable measurement data. This data gives rise to industry-leading measurement-based analysis and optimization solutions like the KSMART process control software. Adept equipment suppliers can apply the data set to proprietary AI engines for continuous performance improvement.

The analysis solution collects all inspection and measurement data from all equipment with its hub and then provides the data anywhere within the network with an intuitive user interface on a web-based application. The beauty of this powerful analytical tool is traceability. Big data is the foundation for Industry 4.0, so KSMART helps advanced inspection systems evolve from pass/fail tools into highly intuitive, dynamic decision-making systems. As the gateway to the smart factory, it also ensures the highest levels of transparency by showing all conditions of the lines while providing the required documentation for changes to the job file, package, part, and more.

The Value of Accurate 3D Data

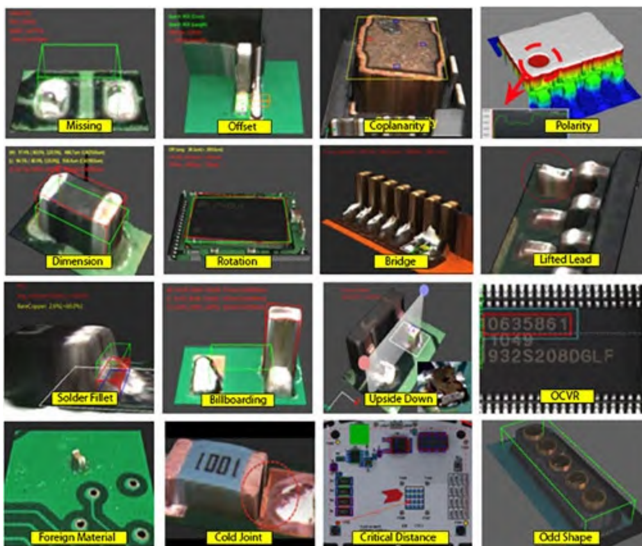
Manufacturers should not settle for anything less than reliable, repeatable, and relatable measurement data in the PCBA process. Data is the most crucial element for success and

Figure 3: The inspection machines can be the sensors.

improvement, especially when leveraging AI solutions. Experts link the effectivity of deep learning to the quality and quantity of the data used to address many different requirements from many fields. Most advanced inspection system providers want to use AI to deliver smarter inspection systems.

However, it has been difficult to realize due to the limitations of 2D and 2.5D imaging. Not only is it difficult for 2D/2.5D AOI systems to identify solder and dimensional-related defects, but these systems cannot also generate reliable measurement-based data. Every aspect of 2D inspection relies on 2D features like contrast, binarization, and reflection; thus, it is extremely challenging to correlate to the quantitative measurement of 3D objects.

Suppliers must measure the true 3D information of components and solder joints. If properly accomplished, the AOI can offer very valuable data, thus becoming the most reliable "sensor" on the line (Figure 3). Companies can only guarantee the validity of 3D data if the system uses true 3D technology to extract the exact body dimensions for all components types. "Blob detection" is simply not reliable and compromises the data; it also contributes significantly to false calls.



Accurate full 3D AOI data-based inspection.

The combination of multipoint measurement and process data collected from SPI, pre-reflow AOI, and post-reflow AOI systems, combined with data from printers, mounters, and reflow ovens will allow manufacturers to deliver an AI-powered, zero defect, self-healing line. Indeed, the quality of data is more important than the quantity of data to create effective and reliable solutions with high value proposition. Yet, it is the combination of reliable data, along with a statistically relevant quantity of data, that delivers the next level of relatable results.

Connect the Data

A single inspection system has limits and cannot manage and optimize a complete line while in isolation. Knowing this limitation, advanced companies have been working with the industry to connect its inspection systems with other process equipment like printers and mounters to streamline total communication and realize a zero-defect future. Looking inward, companies must design and deliver suitable process controls for seamless communication across their own core set of equipment, consolidating the individual machines to deliver a synergistic effect.

Realizing a smart factory means taking a practical approach to processes and systems while examining areas to improve productiv-

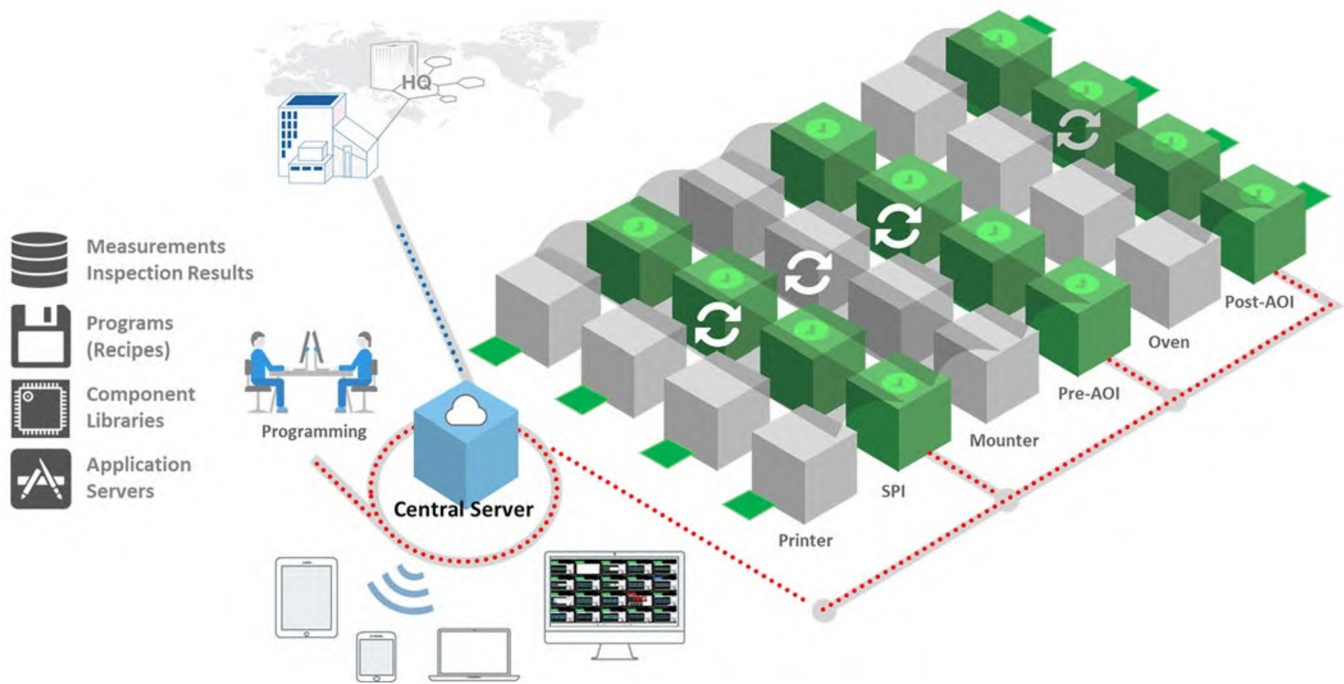


Figure 4: Factory connectivity example using KSMART.

ity. Using true 3D measurement data generated during multipoint inspection helps manufacturers define the source of inefficiencies and boost line efficiency. We use a software module called LINK@KSMART to deliver multipoint data correlation and images from SPI, pre-reflow AOI, and post-reflow AOI. The tool then uses real data management and monitoring, so operators can determine actionable insights to optimize processes in real-time.

The multipoint solution connects all systems within a line to consolidate all the inspection results, which helps correlate data between the processes and detect the source of any process anomalies. This effort streamlines production with a regular data-based review, diagnosis and optimization of printing, and pick-and-place and reflow processes via linked inspection results. Finally, it provides multipoint review images, trend charts, and inspection results to correlate results from printing, placement, and reflow process steps. The connectivity of all systems within a line help define correlations between the distinct circuit board assembly processes (Figure 4).

Working with other suppliers in the SMT line, true 3D inspection systems provide the data to unleash the true power of connectivity. With M2M connectivity, the line can optimize the PCBA process by exchanging real-time measurement data from SPI, pre-reflow AOI, and post-reflow AOI systems with other machines in the production line. The inspection machines can feed real measurement data like offset, volume, height, area, and warnings to other systems, while analyzing trends for process optimization and tolerance deviations.

Using this advanced communication, for example, the inspection systems can feed correct placement position values to mounters, which ensures components are in the targeted position. This improves process repeatability by automatically adjusting component placements and catching the shifting trend to make fur-

ther position corrections. Manufacturers need to aggressively empower M2M connectivity to realize a smart factory.

Industry Communication Standards

These days, companies have a strategic focus on the smart factory concept. Its inherent ability to transform massive amounts of data into actionable information that manufacturers can use to transform their production floor is paramount to process improvement. With its open standards and broad industry collaboration, the IPC Connected Factory Exchange (CFX) initiative helps suppliers and manufacturers alike effortlessly exchange data between production equipment and systems, like the 8030 SPI Series and Zenith AOI Series. This connectivity benefits manufacturers with a straightforward approach to collect and feed information to systems for analysis that will increase process efficiencies.

Equipment suppliers must leverage developments and relationships with other leading equipment suppliers to advance plug-and-play, future-proof connectivity options for its customers. Working together will harness the true power of connectivity and optimize the process by exchanging real-time SPI and AOI measurement data with other machines in the production line. For instance, our systems feed real measurement data such as offset, volume, height, area, and warnings to other systems, while analyzing trends to optimize the process and identify trends. There must be a focus on IPC-CFX and IPC-Hermes-9852 initiatives to advance the electronics manufacturing industry.

Conclusion

Industry 4.0 is altering the manufacturing process by improving metrics like first-pass yield and throughput by applying autonomous process adjustments that enable self-correcting and self- healing production lines. Far beyond an automatic line changeover, this communication is allowing the equipment to automatically adjust production parameters to improve board quality and lower costs by eliminating rework and scrap.

More importantly, when manufacturers integrate multipoint inspection like SPI, pre-reflow AOI, and post-reflow AOI, they can optimize the assembly process to improve quality, reduce defects, and minimize costs. These inspection solutions are laying the foundation for a smart factory while revolutionizing process optimization. SMT007

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You can't deliver quality products if you don't excel at ordinary operations. With best-in-class inspection, Koh Young's advanced 3D inspection technology and solutions optimize your PCBA manufacturing process. We ensure that you can improve your productivity and quality, while sustaining the flexibility to overcome current and future challenges.

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