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Combining 2D and 3D AOI: The Most Effective Inspection

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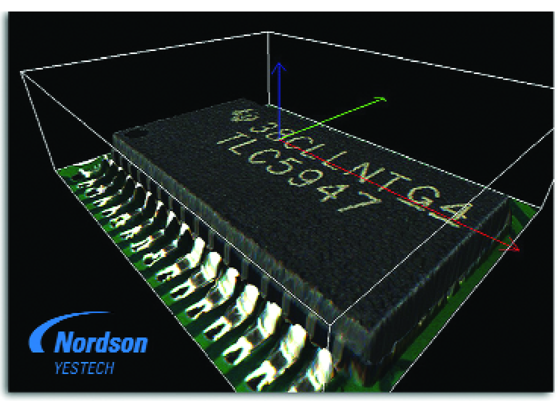
Automated optical inspection (AOI) has become an essential tool in today's surface-mount-technology (SMT) manufacturing environment. Growing trends towards the use of smaller components, more advanced component packaging, finer lead pitches, and higher printed-circuit-board (PCB) densities increases the need for AOI. It provides a way to inspect for common defects, such as missing or wrong components, incorrect component orientation, poor solder quality, and lead bridging. Coplanarity issues are also prevalent on smaller chip components (i.e. 01005), leaded devices, and BGA packaged devices.

In order to attain the highest level of quality assurance (QA), high-precision AOI capability is essential. Combining AOI methods, using both two-dimensional (2D) and three-dimensional (3D) inspection strategies, is proving to be the most effective solution for thorough inspection coverage in today's advancing manufacturing environments.

Before exploring the latest 3D AOI technology, it may help to understand widely accepted 2D AOI systems that have been in use for many years. Technological advancements have enabled 2D AOI to become widespread, if not mandatory, at most SMT manufacturing plants. There are several key factors to take into account when considering 2D AOI:

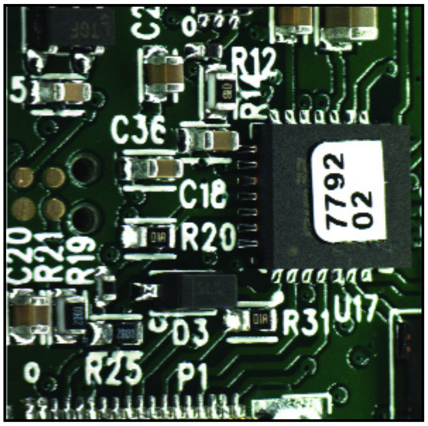


3D processed image captured with Nordson Yestech's FX-940 3D AOI system.

- Camera/Optics. Pixel counts, optical and digital magnification are important factors that determine the capabilities of an AOI system. The pixel size is determined by the properties of the imaging sensor (i.e., a 9.0 MegaPixel camera) and the optics of the AOI system. The use of a telecentric lens allows for a consistent magnification across the entire field of view (FOV). An AOI system should be equipped with enough magnification to provide the required resolution for accurate image processing. A tradeoff, however, is that higher magnification results in reduced FOV. A smaller FOV means that additional images must be captured during an inspection (compared to a system with a larger FOV) which will lead to an increase in cycle time. The proper camera and optics configuration should be determined based on the size of the components to be inspected, the complexity of the assemblies to be inspected, and the cycle-time considerations.
- Lighting. Multiple lighting directions and colors allow for improved image quality and ensure the identification of various defect conditions. Today's advanced AOI systems are commonly equipped with multiple-tiered, multicolored, programmable light-emitting-diode (LED) lighting. This results in a consis-

tent uniform image within the FOV, with enhanced contrast and stability.

For many years, 3D inspection has been commonly used for the inspection of solder paste depositions on PCBs. In recent years, 3D inspection technology has been emerging more and more on AOI systems. 3D AOI methods serve as an effective tool for volumetric and coplanarity inspections. These inspection methods can provide details on the height information of lead tips, BGAs, chip components, reflowed solder fillets or, essentially, critical dimensional information on any height-sensitive component.



2D side-angle image taken on Nordson YESTECH's FX-940 AOI system.

The common methodology used in most 3D AOI systems is Moiré 3D phase-shift image processing. In this application, multiple projectors are used to digitally project multiphase digital fringe patterns (i. e., vertical lines) on a specified FOV. A 2D camera is then used to capture the pattern of lines and any line distortions due to component(s) with heights greater than the PCB surface. Through phase-shift analysis, a 3D height map can be created, and the height can be measured on any point of this FOV. Finally, a color 2D image of this FOV can be applied to the height map to provide a realistic 3D rendered image.

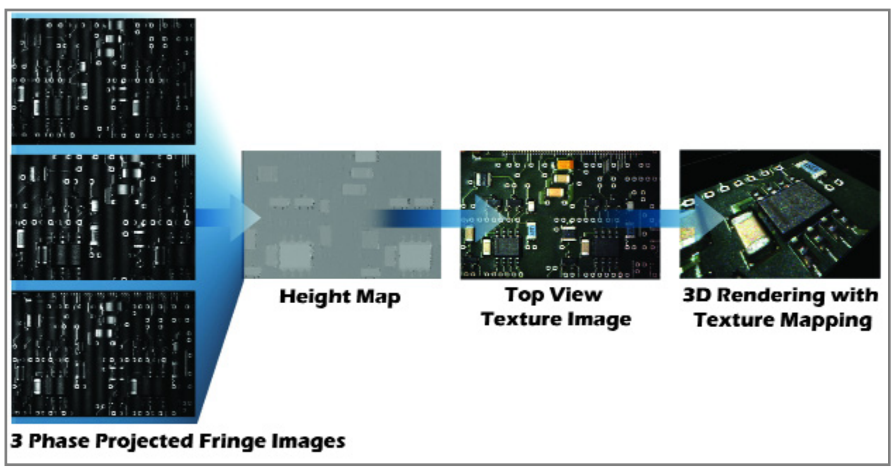
Digital projectors represent a mature technology that has been in use since the early 1990s, and is now being used in a variety of applications. The numerous technological advancements of digital projectors have allowed manufacturers to optimize the dynamic range projection capability. For example, through the control of appropriate software, the projectors can be digitally programmed to project fringe patterns at multiple frequencies for greater inspection flexibility.

As 3D inspection becomes more widespread, the question arises whether 100 percent 3D inspection will be the most effective strategy for inspection, without the aid of 2D inspection. Many believe that this is not the case, and that 2D inspection still serves as a viable tool for comprehensive inspection coverage on PCB assemblies. However, 2D inspection approaches have limitations, and that is where 3D inspection can shine.

2D Inspection

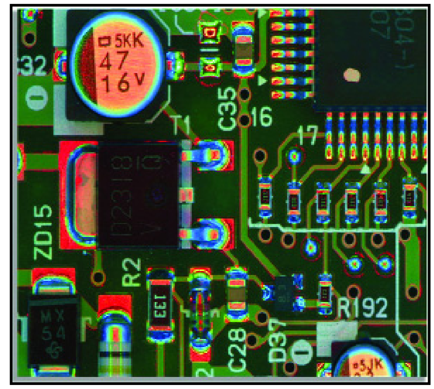
One of the first advantages to note when comparing 2D and 3D inspection approaches is the ease of programming 2D systems versus 3D systems.

Since 2D inspection approaches have been around for many years, much time has been spent on the development of software interfaces and image processing to simplify the programming process. In addition, inspection cycle times are significantly faster since fewer 2D images are captured and processed. The camera, optics, and lighting used in a 2D system allows for inspection flexibility, where assemblies with small and tall components (i.e., SMT and through-hole assemblies) can be inspected at the same time. Inspection for printed nomenclature, polarity marks, and even color, can be trained and inspected easily in 2D. Multiple side-angle 2D cameras can also be used to inspect solder quality on J-Lead devices, and even part or polarity markings printed on the sides of through-hole components. Finally, the cost of a 2D system is lower in comparison to a similar 3D system.



A 3D AOI inspection process uses the Nordson YESTECH FX-940 system.

Since true volumetric height information cannot be measured, 2D inspection systems are limited compared to 3D systems. The coplanarity of height-sensitive devices, such as BGA packages and leaded components, can be inspected in 2D using multi-angled colored lighting and side-angle cameras.



This 2D image uses YESTECH's Fusion RGB, multi-angled colored lighting.

However, these methods will be susceptible to an increase in false calls, a need for additional programming and cycle time, and possible escapes.

3D Inspection

The primary advantage of 3D inspection over 2D inspection is that it provides true volumetric height information. Coplanarity on lifted leads and other height-sensitive devices can be detected without difficulty. Since height data can be measured, AOI programmers can specify the precise height tolerance acceptable for a particular component. Using 3D inspection for coplanarity detection also provides a significant reduction in false calls versus the use of 2D inspection.

However, there are also disadvantages of using 3D inspection systems. 3D inspection approaches cannot check for printed part nomenclature, polarity marks, or color. Even with the use of multiple digital projectors, shadowing issues may still occur depending on circuit-board layout and the varying heights of adjacent components.

Typically, additional programming steps are required to train components for inspection by a 3D system. The use of 3D inspection also results in increased cycle times, due to the extra time required by the projectors to project the multiple fringe patterns needed for image processing. Lastly, because 3D AOI inspection is an emerging technology, there is an increase in machine costs compared to 2D-only AOI systems.

As the industry trends towards smaller components, more advanced packaging, and increased PCB density, it is even more critical that AOI effectively covers the entire spectrum of defects. Clearly, established and widely accepted 2D AOI approaches and emerging 3D AOI technologies each have advantages and disadvantages. But using both 2D and 3D AOI approaches in combination makes the best uses of both methods, using one's strengths to overcome the other's weaknesses. Ultimately, adopting a combined inspection strategy of both 2D and 3D inspection methods in a single AOI system can provide the highest level of QA in today's ever advancing manufacturing environments.

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