Pre-Reflow, Inline, 3-D Inspection

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The smart choice for your application?

Manufacturers of today's advanced electronics-based products know that simultaneously meeting the goals of producing a cost competitive product, while continuing to meet or exceed their customers' quality expectations, is important. Inline inspection during surface-mount assembly, a process that can help ensure quality and reduce costs of scrap and rework, can help to meet those goals.

In general, inline inspection is most valuable when used to detect defects close to the fault source, allowing for quick detection, correction and enhanced process control. The three primary areas for inspection deployment are inspection of solder paste immediately after screen printing since paste placement and volume are critical to the formation of quality solder joints, inspection of component placement inspection before reflow and post-reflow inspection, which often includes some type of solder joint checking. This article focuses on the use of automated inspection technology for component placement inspection before reflow.

Inline inspection of component placement has become more popular as component sizes have shrunk, boards have become smaller and more densely populated, placement rates are faster and cycle times are shorter. Errors such as missing, misaligned or incorrectly rotated components can cause over one-half of all defects that are found after reflow. The advantages of inspecting for these types of defects before reflow include lower rework costs, better process control and the capability for improvement of the placement process to further reduce defect rates.

Inspection cycle time is critical for inline applications. Inline automated systems must be fast enough to do the job within the allowed cycle time. Because product life cycles are getting shorter, and many different products are often run on a single surface-mount line, short programming times and product changeover times are also important.

Right Place for Inline Inspection

Many of the defects that occur during surface-mount manufacturing can be traced to poor solder paste screen printing or to poor component placement. The key to getting the best payback is to do inspection as soon as possible after the potential source of the defect. If the majority of solder joint problems on a printed circuit board (PCB) are caused by poor solder paste printing, then solder paste inspection can help identify defects as they occur and eliminate rework costs later in the process. If component placement defects such as missing or misplaced components are causing problems, then an inline system after the component placement machines and before the reflow oven will find these types of defects when they are easy to fix.

In-process inspection and defect detection is the most effective way to provide data that will enable prevention of defects in the surface-mount assembly process. Before reflow, moving components into their correct position or adding components if any are missing is an easy process. Rework done after solder paste reflow can require special tools and training, and in some cases the danger exists of damage to the PCB or components. Solder joints formed during rework, or touch-up, are potentially less reliable than solder joints formed during the original reflow process. In addition, inspection directly after the critical process step shortens the feedback loop and allows engineers and operators to correct any problems sooner.

In contrast, post-reflow inspection systems at the end of the line or in-circuit test (ICT) may be used to check final product quality, but any defects found after reflow are difficult and expensive to repair. A component placement error or screen printing problem may create many defective boards before the problem is identified by post-reflow inspection. Because a time lag exists between the process step that caused a defect and the detection of the defect, post-reflow inspection is less effective for real-time process control, and isolation of the defect source may also be more difficult.

Component Inspection Capability

A critical aspect of any inspection system is the robustness of the inspection. If inspection results in too many false calls, line operators will have to check the system results too often and will quickly lose confidence in the inspection results. Poor robustness for component placement inspection is often caused by variations in the board or in the components. A system that is sensitive to changes in the color or finish of the PCB, or a system that relies too heavily on special lighting techniques, may have problems when the board finish or color changes or if the lighting changes.

At a minimum, an inspection system should measure the position of each component in x, y and theta and also check device polarity. The positions of each device should be compared to computer-automated design (CAD) data to see if component positions are within tolerances. Devices outside of tolerance should be identified, and measurements used to update statistical process control (SPC) charts.

3-D vs. 2-D Inspection

Generally speaking, two technology types are available to perform inline component placement inspection. The majority of component placement inspection systems use either grayscale or color CCD cameras. The cameras collect images of the PCB, and the images are analyzed to determine if any defects have occurred in each area. Camera-based systems can be very fast, but, because they rely on the brightness of light reflected from the PCB, they can be sensitive to changes to lighting conditions or changes in materials. Most systems that rely on cameras for image collection have programmable lighting to create optimal images of each site or component. As board complexity increases, problems with lighting contrast or shadowing may arise. As each image becomes more complex, the image processing becomes more difficult and the cycle times can drop.

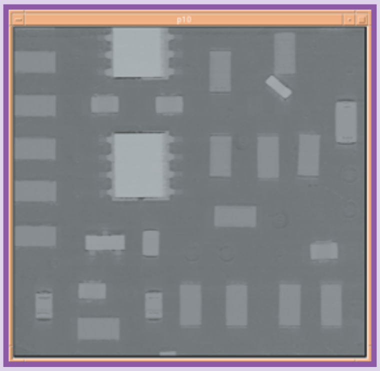


FIGURE 1: This image shows features displayed at 3-D height data, in which taller features are lighter and lower features darker. The use of collected height data produces results that do not vary with changes in color or lighting.

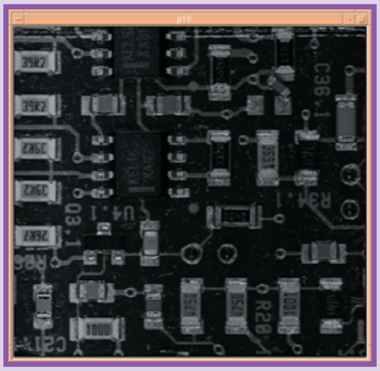


FIGURE 2: The data shown in Figure 1 can also be displayed in 2-D form, which produces a picture similar to one produced by a grayscale camera.

Laser-based component inspection systems use a laser scanner to create a three-dimensional (3-D) image of the PCB. This 3-D image is based on the height of the PCB surface and of the components and is less sensitive to changes in component color. Laser scanning systems also provide the ability to produce a 2-D grayscale image, similar to the image from a CCD camera. This image can be used in situations of little height contrast, such as in locating board fiducials or in identifying component leads in solder paste. Laser scanning also provides accurate position measurements of the components. These measurements are important to help reduce the number of false calls and to provide the information needed for optimal process control.

3-D Laser Scanning Detail

With a typical inline system using a laser scanner for component placement inspection, the board is held still during inspection. The system projects a very low-powered laser onto the PCB and measures the position of the reflected beam using position-sensitive detectors. The laser scanner moves over the PCB, collecting height measurements that are used to create each 3-D image.

Figures 1 and 2 are images that were acquired with a laser scanner. Figure 1 is a 3-D image, and Figure 2 is a 2-D grayscale representation of the same inspection data. In Figure 1, the taller objects appear brighter. The color or reflectivity of the PCB or component has no effect on how it appears in the image. The bodies of components are the brightest objects in the scene because they are the tallest objects. The copper pads and traces are less bright, and the PCB material is the darkest of all. The position of components can easily be determined from this 3-D scene.

Cost Savings from Inspection

An inline component placement inspection system can pay for itself in several ways. Defects detected immediately after component placement are much less difficult and expensive to repair than the same defects if they are found after solder reflow.

Inline process control is an important aspect of continuous quality improvement and may offer the greatest potential for cost savings. Many of the component inspection systems available offer a variety of built in SPC tools.

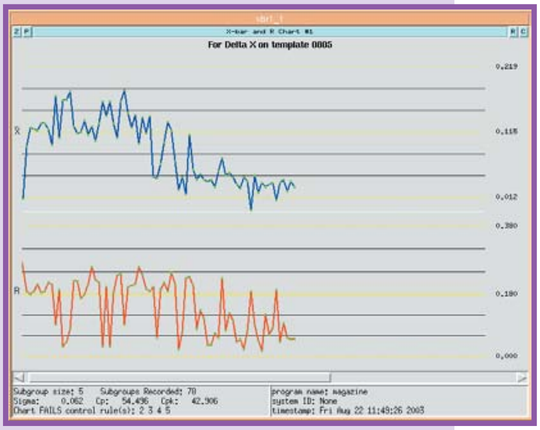
Correctly identifying defects on each PCB is important, but process control capability can help to eliminate the causes of component placement defects and to reduce the number of defects actually produced. Very few defects are created in the reflow oven if the solder paste deposits and component placements are within specification.

SPC Tools for Improving Quality in the Surface-Mount Process

The two SPC tools presented here are the Pareto chart and the X-Bar and R chart. When using control charts to monitor a process, understand that they do not determine whether the *product* is good or bad, but, rather, whether the *process* is performing consistently. The inspection equipment should be able to both make pass-fail judgments on each board using specification limits, as well as provide SPC tools to help prevent defects because of process variation. SPC charts (and inline inspection equipment for that matter) should do more than simply indicate that the process is changing; they should also help point to the source of the change.

Real-time SPC charts should be flexible enough to allow analysis of individual devices, package types or package classes such as ball grid arrays (BGAs) or quad flat packs (QFPs). X-Bar and R and Pareto charts can be used together to know *when* the process is changing. More importantly they can also help the user understand *why* the process is changing.

X-Bar and R charts are a means to graphically monitor the process and to determine if it is in control (experiencing only normal random variation within an acceptable range) or out of control (changing due to some external influence). The X-Bar and R chart pictured in Figure A automatically tests several control rules that are traditionally used to determine when a process is out of control. For example, one of the rules tests whether nine or more consecutive points have occurred on one side of the process mean, which can indicate a shift is occurring in the process. The chart pictured in Figure A also tests an important statistic called process capability (CpK). Cpk indicates whether the process, given its natural variation, is capable of producing product within desired specification limits.



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Subgroup size: 5     Subgroups Recorded: 70
Sigma:      0.062   Cp:    54.496   Cpk:    42.906
Chart FAILS control rule(s): 2 3 4 5
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program name: magazine
system ID: None
timestamp: Fri Aug 22 11:49:26 2003
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FIGURE A: A X-Bar and R chart tracks the measured height data for a particular feature.

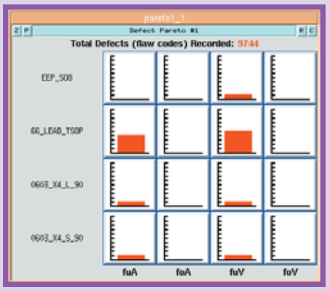
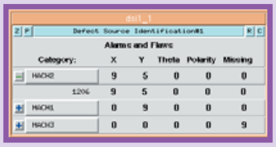


FIGURE B: A defect Pareto chart allows an operator to click on an individual Pareto bar to reveal detail on counted items.

When an X-Bar and R chart fails, understanding why the variation in the process is occurring may be difficult. The inspection equipment should be supplying measurement data that can help. Pareto charts such as the ones pictured in Figures B and C provide more concrete analysis of inspection data. These charts can provide the information needed in a distilled format. A Pareto chart sorts and counts problem occurrences and presents them graphically to help isolate the most frequent or worst problems. To be most useful for SPC analysis, a Pareto chart should allow counting of measurements that fall outside SPC control limits, not just measurements that fall outside specification limits.



Alarms and Flaws

Category:	X	Y	Theta	Polarity	Missing
− HACH2	9	5	0	0	0
1206	9	5	0	0	0
+ HACH1	0	9	0	0	0
+ HACH3	0	0	0	0	9

FIGURE C: The detail from a selected bar in Figure B relates measurement data back to the performance of the placement equipment.

Many of today's surface-mount boards require high-speed, high-accuracy component placement. Inline component placement inspection systems are needed to identify the defects as they occur and to reduce expensive rework after soldering. Inline inspection tools provide understanding of the placement process and the opportunity to improve surface-mount manufacturing yields. Detection of solder paste and component placement defects can help eliminate the need for expensive post-reflow inspection systems.

SPC methods can be used to trace problems back directly to their source so preventative action can be taken. Real-time SPC charting can show the positions of components as they are placed to indicate when a system is drifting or the placements are becoming less precise. A consistent shift in one direction may indicate a problem with a motion system or a damaged placement mechanism. SPC tools such as Pareto charts can show the most common types of defects as well as identify the components on which they occur. Several defects occurring with a particular device may indicate a problem with a feeder.

Process characterization is another valuable service provided by component placement inspection systems. Testing the capability of a machine for its intended application is an important part of any new product introduction. Data from a proven, automated system assures that you have the accuracy and amount of data required to make valid engineering decisions about equipment and processes. Some manufacturers use their automated inspection systems to verify the correct operation of each placement machine after it has been serviced.

Conclusion

Inspection equipment should not be placed inline with the expectation that process improvement will then occur automatically and without effort. To achieve the highest quality as well as cost savings, a company must commit to the effort, staff and training that will allow them to utilize their data and build a knowledge base to improve production quality. Placing inspection equipment inline provides important defect detection capability to eliminate costly scrap and rework. Even more importantly, inline inspection equipment provides the right data and tools for SPC analysis and hence supports the goal of continuous quality improvement. ■

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