The Elegance of Line Scan Technology for AOI

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More is better?

There seems to be a trend in the AOI market: more is better. On the surface this trend seems logical, because how can just one single downward- looking FOV (field-of-view) camera circled by a ring light detect production errors in solder quality, lifted leads…head-in-pillow defects?

And the answer seems simple enough: employ additional cameras, surrounding the downward-looking principle camera, and position them at oblique angles so that they can provide a "side view" of the region of interest, capturing images of defects that seem undetectable from overhead.

But drilling deeper into this solution uncovers several questions:

1) There are some AOI systems on the market that tout using up to eight cameras. So, how many cameras are enough?

2) How does an AOI system process the images generated by these multiple cameras to produce useable inspection data? Typically, most AOI systems with side view cameras perform only image comparison on side view data. In other words, they use a "golden" image generated from one or multiple samples as a model and compare that golden image to the current area of interest. But what happens if the area of interest is good, but there is a difference in color or lighting, or board-to-board, lot-to-lot variations? Will the same golden image work on the same component package type placed anywhere on the PCB…in any orientation? In other words, can one use the same component library no matter where the component is located, or what taller components surround it (shadowing issues)? Does a multiple camera system take more time to program and debug? Does increasing the number of cameras increase the number of false failures or false calls?

3) How sensitive is the calibration and alignment of the optical system on an AOI using multiple cameras?

4) How reliable is an AOI system using additional cameras? Does attaching more sensitive hardware make it more prone to mechanical and electrical problems in a production environment?

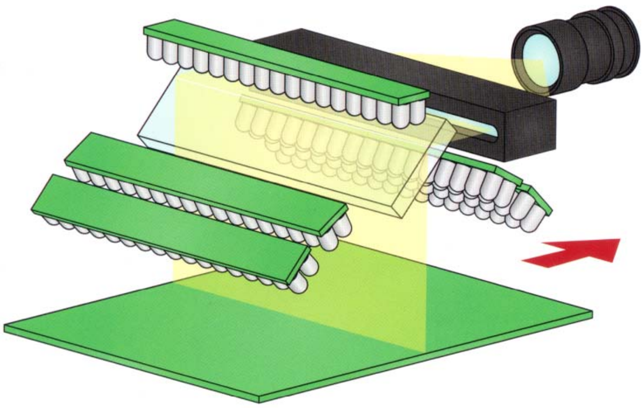
5) How does adding more cameras (and more images to process) affect the inspection speed?

6) What does the additional hardware - as well as the software to support it - add to the price and operating cost of the AOI system?

Line Scan Technology may offer an elegant alternative to multiple camera AOI systems. Since the mid-1990s, SAKI Corporation has employed this reliable yet flexible machine vision concept in over 7,000 AOI installations worldwide, mostly in high-production environments across Asia. This paper will provide an explanation of Line Scan Technology and how it's being applied in AOI to solve difficult inspection problems such as soldering and lifted lead defects without the use of additional imaging hardware.

What is Line Scan Technology?

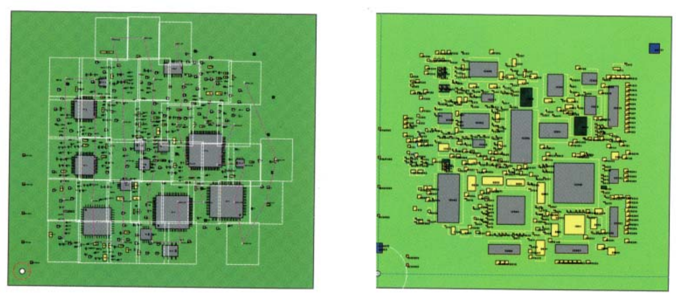
SAKI's Line Scan Technology (LST) drives a high-resolution linear CCD array sensor over the PCB surface rapidly capturing the complete PCB image. Scanning a 460 x 550 mm (18" x 20") PCB takes 10 seconds. The scanning speed is unaffected by the number of components on the PCB, and smaller PCBs take less time to scan. The lighting system for SAKI's LST contains over 3000 LEDs, arranged in multiple banks, generating Toplight, Sidelight and Lowlight Illumination. During each scan, the LED lighting is modulated several thousand times to produce over twenty different lighting schemes, providing remarkable flexibility for finding just the right contrast for any inspection problem.



Line Scan Technology

FOV vs. LST

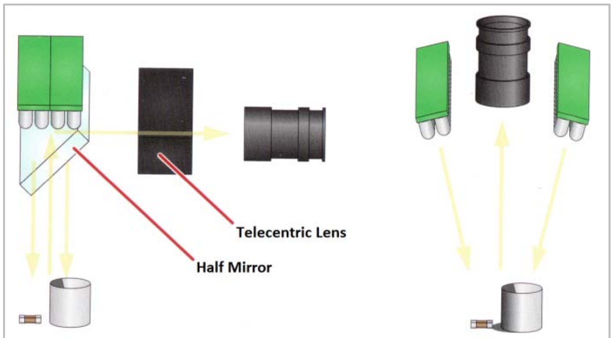
The principle sensor used in conventional AOI system design – whether or not side cameras are included – is a downward-looking large area array CCD camera. Typically, this camera is surrounded by ring lighting projected at an oblique angle. In order to inspect a PCB, the camera is positioned over multiple areas of interest, gathering snapshots. Depending on the camera's Field of View (FOV), the size of the PCB and its component density, data acquisition can take anywhere from a few seconds (small, sparsely populated assemblies), to several minutes (large, densely populated assemblies). In contrast, LST scans at a constant speed, collecting the complete PCB image in one single, rapid motion.



FOV Inspection   LST Inspection

Co-axial Toplight is born

Since different components have different heights – and some are much taller than their neighbors – SAKI realized that the best illumination for solder inspection was from a light source projected directly perpendicular to the PCB surface. Any other off-axis illumination would lend itself to creating shadows, as the heights of taller components blocked the light from reaching the smaller ones, which could increase the number false calls, creating more programming and de-bugging work. SAKI also discovered that good solder fillets reflected overhead lighting or "Co-axial Toplight" much differently than cold solder or no solder, and that the contrasting reflections could be used to clearly distinguish "Good" vs. "No Good" solder. Further refinement in SAKI's Co-axial Toplight concept introduced telecentric optics, increasing the sensor's Depth of Field, and removing parallax associated with other highly focused optical

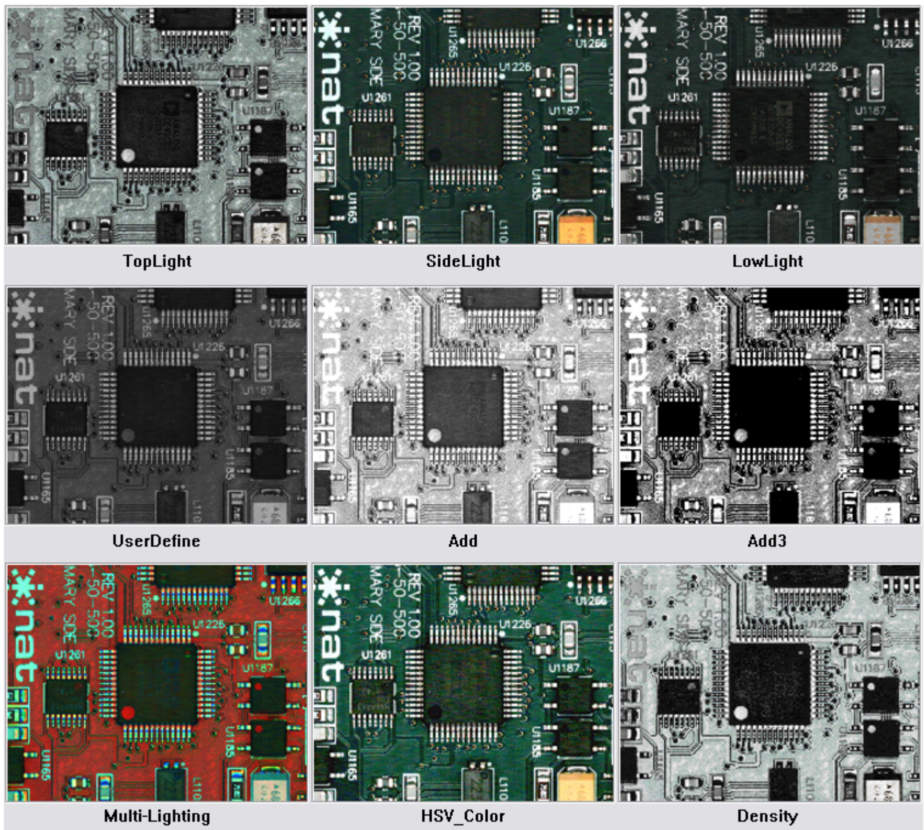


Co-axial TopLight   Ring Lighting

designs. This virtually eliminated shadowing and optical distortion altogether, enabling the use of flexible component inspection libraries that could be deployed anywhere on the PCB surface, without regard to the heights of adjacent components – a problem that can still plague a number of AOI system designs.

Which lighting is best?

While Co-axial Toplight has proven to be the best for solder fillet inspection, there are other inspection tasks that require different projection angles and illumination color to obtain the highest contrast between “G” and “NG” conditions. Tasks such as Optical Character Recognition (OCR) and Optical Character Verification (OCV) may require different projection angles – as well as data from multiple projection angles – to accurately determine that the correct part has been placed. In some cases, the color of the component is used to detect presence/absence, or the correct part. Color inspection usually requires another unique illumination setting. In some cases, the contrast of color and/or reflectivity between the component and the substrate is very subtle. This may require a special, “user-defined” lighting scenario to highlight the differences that will provide repeatable results.

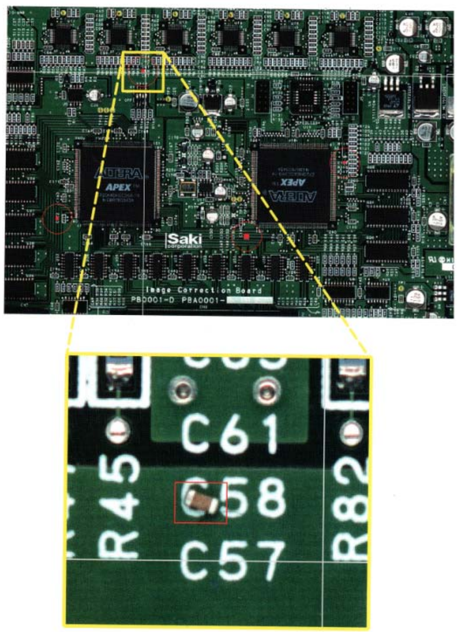


LST generates over 20 different lighting schemes with each inspection.

To enhance its Co-axial Toplight concept, SAKI added banks of LEDs to project off-axis “Sidelight”, which has been found best for color inspection and “Lowlight”, which uses a very acute projection angle, and is ideal for OCR and OCV inspection tasks. Further testing demonstrated that sometimes a combination such as “Toplight-Sidelight” or “Sidelight-Lowlight” produced superior results. Still, SAKI discovered other inspection tasks requiring even more lighting options. Rather than add more lighting hardware and creating more servicing issues, SAKI decided to solve the problem using software. Today, with each scan of the PCB, SAKI AOI systems generate over twenty different lighting schemes. Any one of those lighting schemes – plus a user-defined option that allows the user to decide the best Toplight/Sidelight/Lowlight blend –can be applied to any inspection window and algorithm used in any component library. This lighting flexibility – unique to the industry – employs a very simple electro-mechanical design to accomplish what other systems strive for using complex hardware. Furthermore, producing these numerous lighting schemes generates no impact on scanning time.

Why Not Inspect the Whole Board?

In conventional AOI systems employing FOV - or FOV with side cameras – the regions for inspection are only where the camera(s) are positioned on the X/Y plane of the PCB. Usually, these regions are confined to where the PCB has been populated, since taking multiple FOV snapshots to cover the whole PCB area increases tact time. Limiting inspection to only populated regions can mean that large areas of the PCB can pass through without scrutiny. Foreign materials such as loose chips, solder balls and other debris could go undetected, causing production problems downstream.



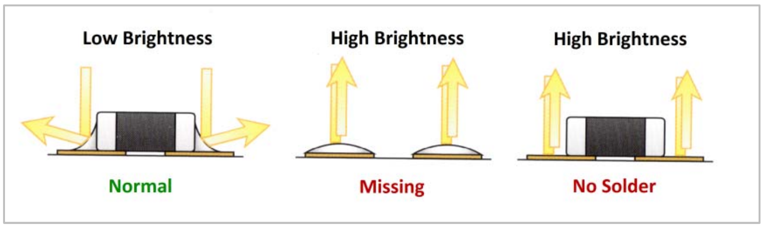
LST can inspect the full area of the PCB for debris and foreign materials.

With LST, each inspection captures an image of the entire PCB in one rapid, continuous scan. To ensure no foreign material on the PCB passes to the next process, SAKI provides an Extra Component Detection (ECD) algorithm that compares a database comprised of ten known good sample images to the inspection image, looking for irregularities across the entire PCB surface. Built-in flexibility enables the user to select size boundaries so that only variations considered problematic are flagged, minimizing false calls. This unique feature enables SAKI AOI with LST to provide a thorough and comprehensive inspection of the entire board without affecting production beat rates.

An Elegant Alternative to Side View Cameras

As discussed above, mounting side view cameras on an otherwise downward looking large FOV camera seems like a logical solution to detecting defects like lifted leads, dryjoint solder, and "head-in-pillow" non-solder problems. But what if there were solutions to these issues that didn't require additional sensitive hardware and complex software, as well as considerably longer programming and de-bugging times?

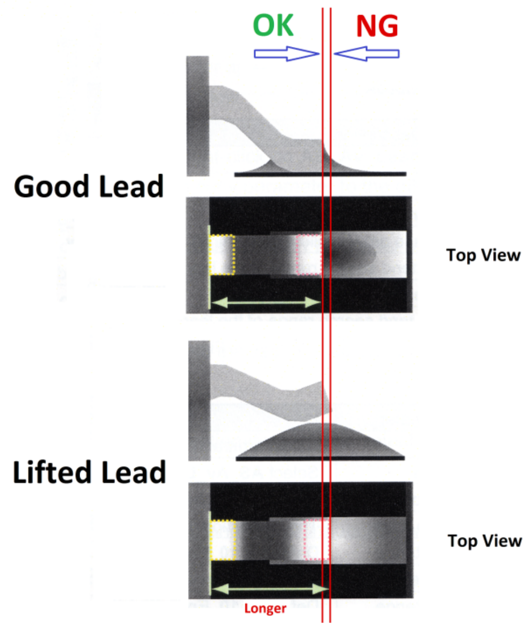
SAKI has come across its share of these defects and through many years of research and thorough testing the Company has implemented smart algorithms in its inspection libraries to accurately detect and report these production errors using the power of its LST and flexible lighting technology. Below are a few examples of how these algorithms work:



Solder Quality

With Co-axial Toplight, solder quality of components as small as 01005s can be inspected based on simple principles. When a fillet is correctly formed, light projected perpendicular to the PCB will reflect off at an angle, generating a "low brightness" condition, and produce a dark area where the fillet is formed. On the other hand, when there is no fillet - as in cases where there is no component or insufficient solder – light will reflect in an *equal but opposite* direction, as in a mirror, creating a "high brightness".

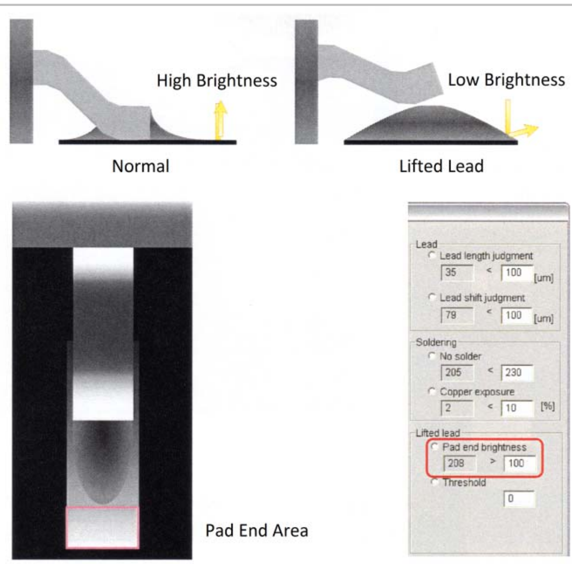
In SAKI's inspection libraries, high and low thresholds for brightness can be set for each inspection window. In addition, several windows can be used for one inspection task, and configured with conditional jumps. In this way, one component library, "0805smc" in the above example, can be used for part numbers with the same component package size and type, even though the component color, PCB color, solder brightness or surrounding reflectivity levels may vary. This produces faster program and de-bug times, in addition to lower false call rates.



With LST, lifted leads appear longer than good leads.

Component Lead Inspection

The necessity to detect lifted lead conditions is probably the driving force behind implementation of side view cameras in AOI. That being said, SAKI's LST can accurately detect lifted leads using a number of principles that work in conjunction– without the additional hardware, software and operational expense of using side view cameras.



Lifted Lead Inspection - The Brightness profile of the pad end area is also a symptom of a lifted lead.

Lead Length – From a perpendicular, overhead view, a lifted lead will exhibit a different length than its neighbors. By making a comparison – either using a measured length value as benchmark, or comparing the length of an individual lead to the length of its neighbors – the length of a component lead is a *symptom* of its condition, either "OK" or "NG". The length of the lead is measured from the body to the tip of the lead foot. As with other SAKI algorithms, acceptable thresholds are user-selectable, providing a robust inspection while reducing false calls.

Lead Tip/Pad Solder Quality – Another symptom of a lifted lead condition is the quality of the reflowed solder on the pad. As shown below and when using Toplight illumination, the reflective characteristics of the remaining pad of a good solder fillet and that of a pad with no lead attached exhibit very different brightness conditions.

Therefore, taking stock of the lead length, as well as the reflectivity of the solder fillet and reflectivity of pad end, a lot can be learned about the condition of a component lead solder fillet.

Using Brightness to check solder quality/lead conditions

Conclusion: The Elegance of Line Scan Technology

In scientific circles, the word "elegant" is used to describe an idea or concept that combines simplicity, power and a certain ineffable grace of design. SAKI's Line Scan Technology is an example of an elegant yet comprehensive approach to AOI design, without relying on the use of multiple cameras and sensors that add significant hardware expense and increased programming time, while providing fewer opportunities for reliability issues. This paper has provided only a broad conceptual glimpse into the capabilities of LST, which in practice uses a combination of these as well as other "smart" algorithms to provide accurate, high-speed inspection capability. In today's 'rough and tumble' manufacturing environments, production tools that are proven to be powerful yet simple are keys to efficiency and economy.

About the Author: Since the mid-1980s, Mike Riddle has worked in electronics inspection and test, helping companies with leading edge technologies find their paths to market leadership. Customer-focused and growth-oriented, Mike has held various roles in business development, marketing, sales and international distribution. He is currently serving as AOI Product Manager for ASC International.You can learn more about Mike by visiting: http://www.linkedin.com/pub/mike-riddle/12/491/710