Seek and you shall find—

Choosing the right optical inspection system

Patrick Schuchardt, GOEPEL electronics LLC, Austin, Texas, USA

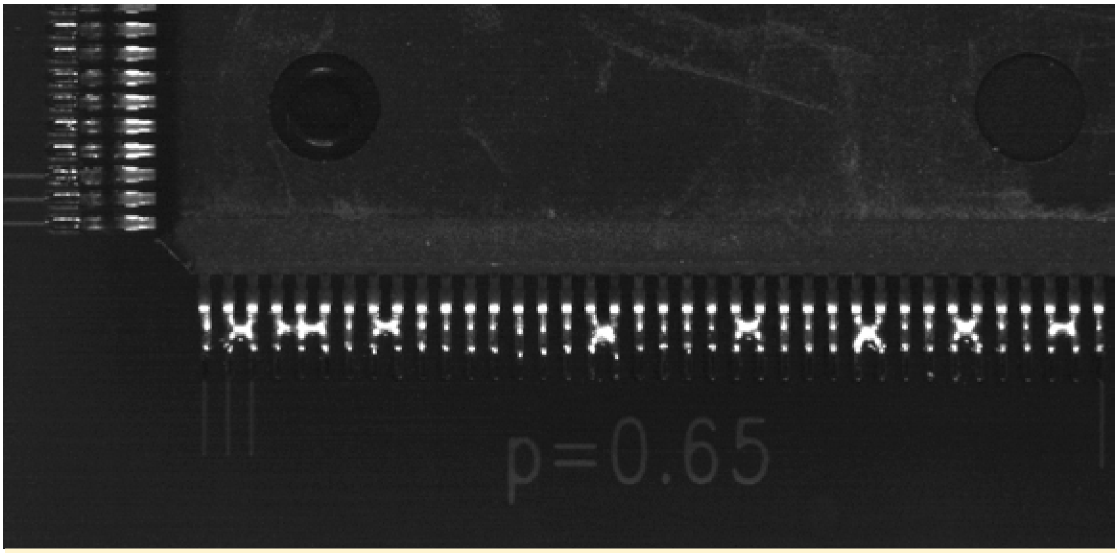

Figure 1. Short on an IC pin.

The sheer number of vendors that offer AOI systems can make finding the right solution a very challenging task. The challenge begins with differentiating the various products, which usually involves understanding the different technical terms for the exact same features on each product and then comparing the various upgrade options, the ease-of-use and programming effort and the specifics regarding service and maintenance along many other possibilities.

It is essential to read between the lines of the brochures, flyers and datasheets. Vendors will highlight their key features but will not mention capabilities that are not available in their portfolio. A careful comparison of all manufacturers is the key to finding an AOI system that will continue to meet your needs into the future.

The price on the first quote is often the main criteria for the final purchase decision, but extra costs, such as training, maintenance, software licenses or service contract, can make a big difference in the long term. As a guideline, it is always good to understand "How much this system will cost me in the next 5 years?"

In or out?

One of the most important questions regarding the machine itself is whether it should be in-line or an off-line machine. In-line systems are integrated into the existing production process and therefore needs to be able to match up with the current line-speed. Often, low-cost in-line AOI systems are the bottleneck of the whole production cycle. Off-line machines on the other hand are stand-alone or benchtop solutions, which are independent from the actual production cycle. The prices of these solutions are lower, because conveyer transportation systems and automatic PCB handling is not needed.

How fast?

The inspection speed of a system is based on several features and capabilities. First, of course, the speed of the positioning system: how fast does the camera move across the test area? Second, how many images from different positions, angles or cameras are required by the application? Third, how fast is the software: are the algorithms applied in real-time or does the systems need additional "processing time" after all images are taken? Additional elements that impact the overall inspection time include PCB load/unload speed, top/bottom inspection ability and the imaging hardware. As a guideline, vendors often advertise the inspection speeds in the form of surface area examined per unit of time. For example, cm^2/sec or in^2/sec. These should be considered average values, because they depend on the density of the populated area and the test being performed. As a result, each manufacturer might specify different inspection times for the same effective performance. The best way to determine the right value is to perform benchmarks with your own boards.

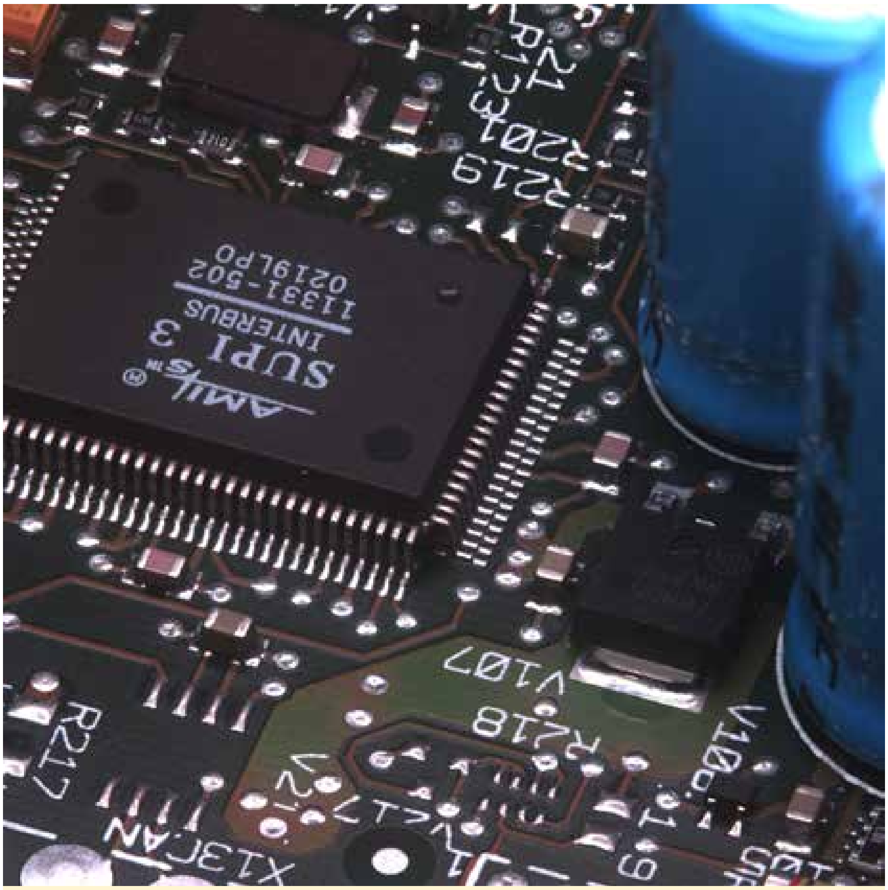

Figure 2. Angled view.

False calls rate

In the end, any speed rating is futile if the machine lacks accuracy and stable results. "False calls rate" is a well-known term for a machine's ability to find real failures with a low percentage being false calls—wrongly detected errors that should be passes. The false calls rate depends on many different factors, such as the recognition algorithm, the quality of images, or the production process. A perfectly adjusted high-end AOI machine will cause many false calls if the production of the PCB is not correct. For example, if the solder process is fluctuating, the pick and place machine is faulty, or the components vary in their appearance. An AOI system with a low camera resolution will have problems inspecting small components, for example the 01005 packages. An incorrect parameterized algorithm for solder joints will not be able to find shorts. Any of these factors can result in a high false calls rate. It is therefore not easy to say where a current high false calls rate comes from. An AOI system is, when it is well adjusted and capable of today's inspection tasks, not only an additional test step but a very good indicator of the quality of the production process. To make this information useable, a modern AOI system should be able to create failure statistics, store results, and offer interfaces to existing process control software (SPC).

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Light!

An often-overlooked key feature is the illumination system. At least as important as the camera and lenses themselves, the light source is the basis for a high rate of fault detection on PCBs. Flexible illumination is necessary to cover specifications for the huge range of electronic components and their fault variants. Because of their inherent long-term stability and illumination power, LEDs in various configurations and colors have become widely accepted as the norm in recent years. Illumination can be arranged or configured in a wide variety. Examples for illumination arrangements include:

Ring illumination vertically from above, mostly arranged around the lens

- Useful configuration for checking the presence of components and the quality of solder joints
- Disadvantage: in case of shorts between IC pins, false calls may occur because of fluxes or solder masks

Angled illumination from various directions and different incidence angles:

- Appropriate for solder-short checks, reduces false calls
- Enables high-contrast display of laser labeling, a precondition for the effective utilization of true-OCR functions as well as polarity check

Illumination with different colors:

- Enables high-contrast display of colored polarity marks as well as distinguishing components from the PCB background
- Causes reduction of fault slip and false calls rate

Additionally, for different board materials or component colors, a brightness control is necessary for certain test tasks. Because of the huge number of permutations possible for illumination settings, there are numerous parameters that must be provided and the AOI software must make this as fast and easy as. A reliable AOI system series unites all possible variations listed above, and provides easy access to these features via predefined settings based on the test task. Even better if there is a special illumination design developed to allow a safe solder-short check at minimum pitches despite possible contamination by fluxes or solder masks The user can select between different color varieties that provide safe detection of incorrect polarity, i.e. colored marks.

Pixelmania

A typical optical inspection system has at least one top camera with a main illumination module, but often test tasks require additional features such as angled view cameras to inspect from a 45˚ angle. One common application is the inspecting of solder joints of IC Pins, especially J-leads. Sometimes obstacles such as THT com-

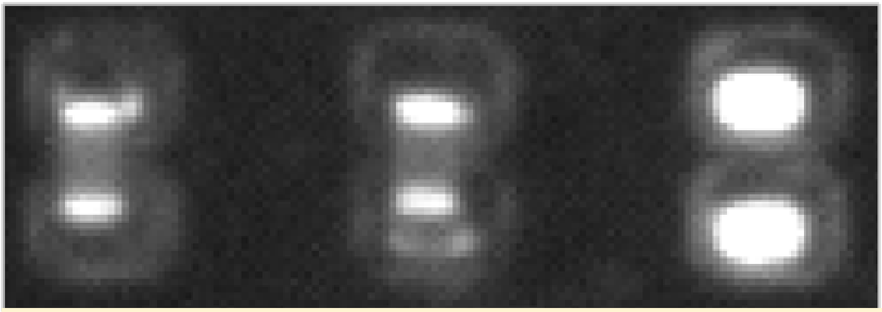

Figure 3. Image capturing with common lens.

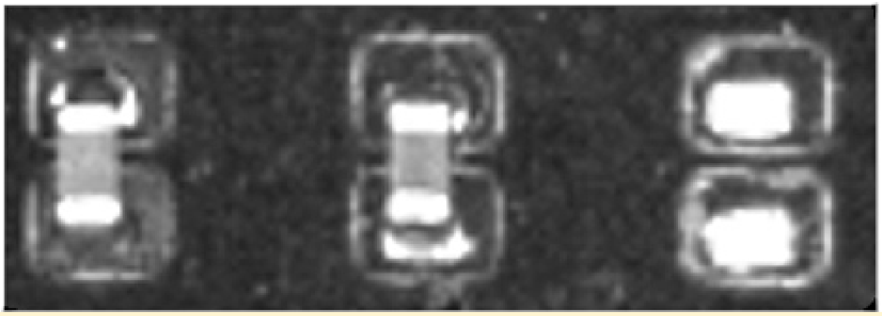

Figure 4. Image capturing with pixel adapted lens

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ponents or heat sinks block the view to certain areas of the board. Vendors try to solve this problem by adding more than one angled view camera to the system with the effect that there are currently up to 8 fixed cameras possible. GOEPEL electronic has developed a better way by letting the angled view camera rotate around the object. The module named "Chameleon" can rotate with a step size of 1˚ and a total of 360˚.

Standard camera resolutions range from 1 up to 16 megapixels, but focusing on only the camera itself would be a mistake. Increasing the resolution of the camera alone will not necessarily lead to more detail in captured images. One possible solution for these increasing requirements is adapting the lens to the camera being used. Specifically, the lens has to be designed to the pixel size of the applied camera in terms of its optical resolution capability.

Another important feature for a modern AOI system is the use of telecentric lenses, which avoid the typical distortion of non-telecentric lenses.

Use of telecentric lenses produces extremely high quality and dramatically reduces the distortion found in the vertical view at each position of the inspected area, resulting in a significantly reduced debug effort during test program creation and also a reduced false call rate in production tests. This system characteristic proves to be a decisive benefit particularly for higher components but also multi-pin and fine-pitch ICs,

Software

AOI vendors use typically two different ways for detecting failures. The first approach is to store images of good samples and simply compare the current camera image with the recordings. The user can set certain quality thresholds and adjust the system in order to define the pass/fail threshold.

The far superior approach is the use of neuronal networks. Attributes and test parameters are stored and the system learns with each new teaching process. This principle is more flexible and faster over the time.

In order to provide a fast and easy start for a new user, vendors typically provide component libraries in which test parameters, dimensions and variations of the most common components are predefined.

GOEPEL electronic's OptiCon systems also include such ready-to-use library entries. Despite the huge variety, test programs can be created and optimized in the shortest time; making for rapid deployment to production.

All inspection parameters can be changed on four different levels: for a single component on the PCB, a model type in the current test program, in all new test programs or in all new and existing test programs. The OptiCon concept is based on the important goal to obtain a stable, reliable test program within the shortest time, and to provide flexible adaptation possibilities to allow for specific quality requirements and supplier conditions.

Flexibility and options

A flexible system configuration is not just about the system software and its parameter management; it also includes the possibility to integrate additional modules. Because of the high variety of electronic assemblies likely to be seen in a production environment, add-on modules can be very helpful to increase fault coverage. Possible additional optional components to achieve higher fault coverage are:

- Camera for THT with an enhanced clearance of 50mm for safe inspection of tall components (e.g. encased-electrolytic capacitor)
- Laser height measurement system that allows co-planarity inspection with micrometer range accuracy (e.g. for BGA components)
- Camera with angled view that enables inspection of critical components (e.g. shorts and solder joint inspection at PLCC and SOJ components)
- Boundary Scan add-on that consists of the 1149.x controller and the software to perform Boundary Scan test on the PCB
- Solder paste inspection camera that can be added next to the main camera to increase the test coverage before the pick & place step
- Integrated barcode reader for board tracing and quality control purposes

Decision process

A typical process begins with an online search or trade show visit, and continues with the contacting of the vendors and a so-called paper benchmark, where the customer asks certain questions about technical specifications, prices, maintenance and support. A real-time benchmark could follow these first steps where the customer visits the vendor with his own board, often prepared with faults, where programming effort, false calls rates and accuracy can be assessed and a general impression of the machine can be developed. A visit to the vendor can also provide an impression of the company and people involved. The results of both benchmarks in combination with an official quote and the experience and instincts of the test engineer should lead to a smart purchase decision. As a last step, it is not uncommon to rent or borrow an AOI system for a certain amount of time, typically four weeks, before purchasing to help assure the right final decision.

Conclusion

The selection of an AOI system means a lot of work based on the many different criteria and options. It is important to know which features are needed now and in the near future. That basically depends on the PCB itself and the test requirements for the components used and includes questions about inline or offline, required speed, accuracy and options. Special attention should be placed on the image recording module and illumination unit since they are critical for high-flexibility with a high mix of PCB types. An effective and user-friendly library management environment allows time-saving handling of newly learned PCBs, which is necessary for a high variant diversity.

It is essential to compare the different vendors for their strengths and weaknesses and the best way to discover this is to perform benchmarks. Besides the available options at the time of purchase, it is interesting to know what update options are possible in six to 24 months. It is also important to understand the requirements and costs for maintenance and how well the vendor can assure fast and comprehensive technical support.

Patrick Schuchardt graduated from the University of Applied Science at Jena, Germany in 2004.

For 3 years he worked as production and quality control engineer in Hong Kong, supervising and adjusting the production lines of reed relays, reed sensors and PCBs.

In 2007 he started working with GOEPEL electronic GmbH as an Application engineer in Plymouth, MI, providing technical support for the automotive customers in North America.

Since 2009 Patrick is supporting JTAG/Boundary Scan customers of Goepel Electronics LLC in the US and Canada and is currently organizing the sales and support activities for the Automated Inspection department from the US headquarter in Austin, TX.