SICK AG WHITEPAPER

3 TECHNOLOGIES FOR PCB DETECTION

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SICK
Sensor Intelligence.

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Introduction

The electronics industry is at the forefront of industrial progress, yet faces many difficult market pressures. It must innovate – quickly, reliably, and economically – while maintaining the lowest possible error rates. High-tech machines and production sites need to be equipped with state-of-the-art sensors in order to satisfy market requirements for quality and cost-effectiveness.

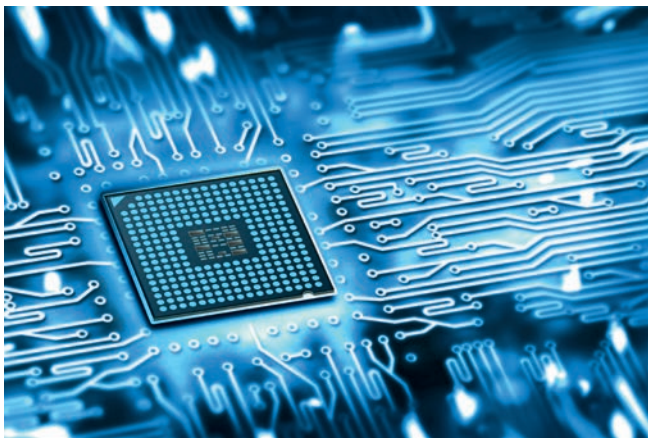

Figure 1: At the forefront of industrial progress: the electronics industry.

Current trends continue to increase the significance of electronics in all areas of life. A variety of additional electronic components in the automobile is the basic prerequisite for autonomous driving and electromobility. Household devices, from the washing machine to the refrigerator, are becoming more intelligent in line with the “smart home” trend. And in industry, the significance and number of electronic devices such as sensors, cameras, servers, etc. are growing due to the driving force of Industry 4.0.

The electronics industry consists of a variety of fields – from chip production to PCB production, complex mounting and inspection processes for computers, smart phones and other mobile devices.

Nearly every electronic device contains a PCB. Often, several PCBs are required for the device. During manufacturing, the PCB goes through several process steps before it is added to the electronic device during assembly. Different sensor solutions play a role in this. However, it is not only highly complex 2D or 3D camera solutions, for example, for inspecting SMT components, that are important. As the PCB board goes through various stages of production, such as from a bare board to fully populated with components, various technologies need to be used for detection and positioning. The optimal use of these technologies ensures that a wide range of requirements can be satisfied in order to optimize processes and machines.

This white paper describes three sensing sensor technologies for detecting PCBs as well as their requirements, advantages, and disadvantages.

Challenges in detecting PCBs

In every automated process step of PCB production, the detection of PCBs is a basic prerequisite for enabling effective quality control and additional process steps. For high production yields, it is important that all stages of production are being utilized simultaneously. At certain process steps, not only is the detection of PCBs key, but also precise positioning is important during the entire production process.

The requirements for the solution used can vary greatly, however, depending on whether the detection is done in a magazine, a con-veyor unit, during solder paste screen printing, in an SMD pick and place machine, or during inspection. Different solutions can also be necessary within the same type of machine, for instance, based on varying circumstances concerning the installation space or the background, or due to the shape of the PCB panel.

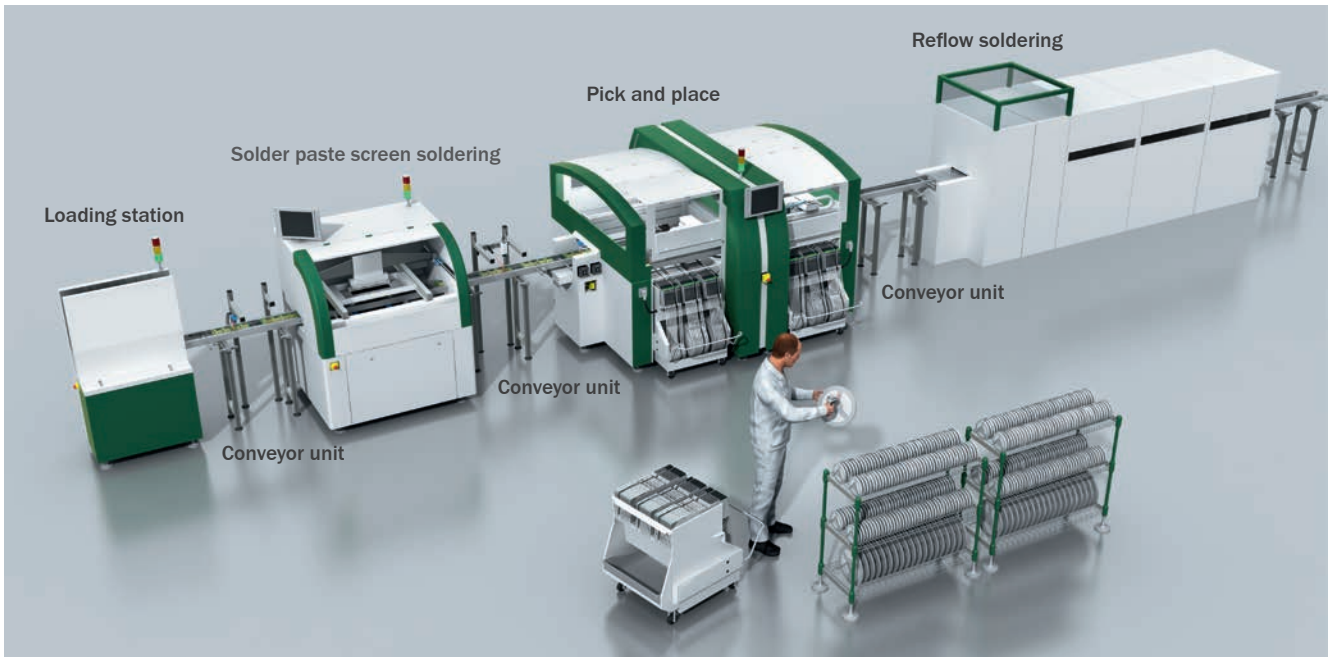

Figure 2: SMT PCB production.

Sensors installed in PCB production machines must be integrated in a particularly space-saving manner, since there is typically very little installation space available in the machine. In contrast, manufactures often have more freedom when attaching sensors for detecting the entrance or exit of the circuit board. With reduced installation space, customers need to use the small sensor form factors with the appropriate sensing distances. However, possible working distances are also important. If there are already components on the PCB, a minimum distance must be considered in order to rule out possible damage caused by collision between the component and the sensor. The component clearance needed is typically up to 40 mm. Depending on the PCB to be produced, it can also be much lower.

A side effect of tight installation space which must be considered concerns nearby reflective or changing backgrounds. Not only the sensor is located near the PCB in machines for PCB production. Backgrounds such as a reflective machine wall or moving objects can also be located in the direct vicinity. In SMD pick and place machines, for example, placement heads move right up to the PCB for placement. A reflective metal sheet or a placement head passing overhead must be taken into account when selecting a sensor solution for detecting PCBs in order to prevent false triggers and thereby machine downtime.

But it is not only the machine conditions which must be considered when selecting a sensor solution. The PCB can also influence which technology is required for reliably detecting them. Printed circuit boards often have cutouts, large holes or roundings. This means that the same sensor might detect different panel layouts at different moments. Or a printed circuit board is detected several times due to switching errors at drilled holes and cutouts. Frequent changes in the design of the produced PCB should be considered when selecting a sensor solution. This shortens machine downtime for format changes and prevents errors during restart.

Selecting the right sensor technology and solution is important, because these PCB detection and positioning application challenges in the production process affect the throughput of these lines. The following should explain which technologies best meet the various requirements.

Three technologies for PCB detection

The following technologies are compared in order to overcome the challenges of detecting PCBs as described above

- Photoelectric proximity sensors with and without background suppression or special light spot geometries
- Capacitive proximity sensors
- Ultrasonic sensors

Photoelectric proximity sensors – background suppression, line-shaped light spots, and MultiLine
Optical sensors such as photoelectric sensors are used for a variety of industries and applications. With intelligent functions and special optics, even the most challenging application demands can be met. These include challenges in PCB production such as reflective backgrounds or PCBs with holes or cutouts.

As described in the previous section, objects such as placement heads or machine walls can be situated in the direct vicinity of the PCB. Due to the principle of operation of energetic photoelectric proximity sensors, for example, reflective surfaces can cause switching errors. This risk is considerably reduced with the use of photoelectric proximity sensors with background suppression. Photoelectric proximity sensors with background suppression operate on the basis of the geometric relation between the sending and receiving elements. The sensor is set to detect the object lying on the sensing range plane. Any reflections from objects located behind the set sensing range plane which can cause false trips are ignored.

In many areas, photoelectric proximity sensors with a single point-shaped light spot are sufficient for overcoming challenges. When detecting PCBs, the special structure of the PCB is often the reason why other light spot geometries are needed. Cutouts and reflective surfaces on the PCB make detection more difficult and result in switching errors. This can lead to costly faults and negative effects on the production process of manufacturers. Line-shaped light spots ensure that PCBs are reliably detected, since they cover a larger area, thereby reducing false trips and increasing machine availability. This combines maximum precision and high repeatability of the switching point to ensure that the switching signal is constant throughout the processing time of an object, even if gaps, grooves, or openings are present.

Large openings and holes are often created in PCB panels if the individual PCBs are mechanically produced to customer specifications. In some cases, even optical sensors with line-shaped light spots can be pushed to their limits. The solution is the WTB4-3 MultiLine photoelectric proximity sensor. Two sensors are united in one housing; their logical evaluation processes are cleverly linked. The sensor uses two parallel light lines and, after previous detection of the PCB, does not switch off until both light lines no longer detect the object. If the signal of only one light line gets lost during the passage of an object, for example due to a cutout, the output remains set. This allows for reliable detection and higher machine availability.

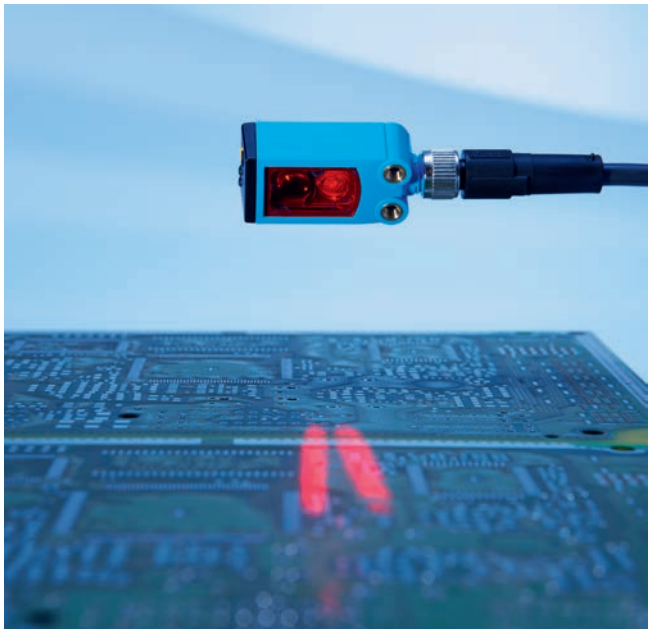

Figure 3: The WTB4-3 MultiLine from SICK. Reliable PCB detection even if large openings exist.

Capacitive proximity sensors

Capacitive proximity sensors are primarily characterized by one thing: There is nearly nothing that a capacitive sensor cannot detect. Sensors based on capacitive technology can be used regardless of the materials to be detected or their surfaces.

Figure 4: Capacitive proximity sensors from SICK.

Compared to other technologies, capacitive proximity sensors have relatively short sensing ranges in relation to the housing size. Capacitive sensors with small housing sizes, which are necessary due to the limited installation spaces in machines in the electronics industry, have sensing ranges of a few millimeters. Capacitive proximity sensors are mainly used if detection can be performed very close to the PCB or must be done at close range.

When producing PCBs, as soon as electronic components are assembled, sensors for detecting PCBs must allow for sufficient component clearance and working distance to prevent component damage. Particularly when PCBs are loaded on both sides, capacitive sensor technology is primarily used in the first process steps with unloaded PCBs. At that point, it is a reliable and space-saving solution for detection at close range, due to the lack of a blind zone and ability to detect any surface.

Ultrasonic sensors

Ultrasonic sensors can also be a good choice for the detection and positioning of PCBs.

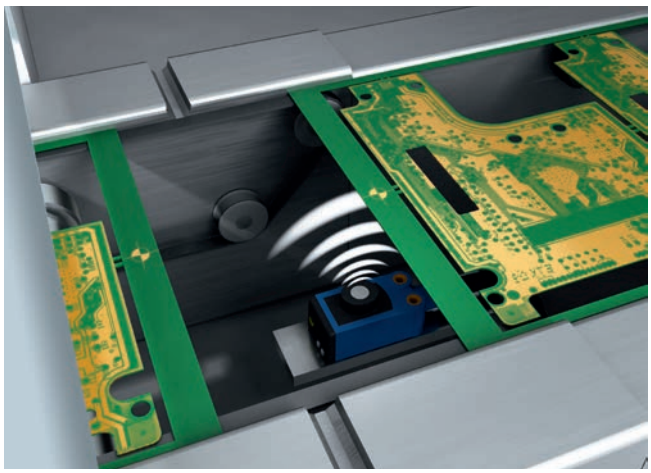

Figure 5: Reliable edge detection with the UC4 ultrasonic sensor.

Ultrasonic sensors emit an acoustic pulse that is reflected by the object being detected. The time required for the pulse to go from the sensor to the object and come back again is measured and evaluated and converted into the respective distance. Due to this principle of operation, the blind zone must be taken into account when using ultrasonic sensors at close range. If the acoustic pulse is reflected too quickly due to a very close object, the sensor cannot detect the impulse quickly enough.

On the other hand, ultrasonic sensors can also be used for larger operating ranges. Objects in the background or reflective machine parts can make precise and reliable edge detection of the printed circuit board difficult or event prevent it. However, precise background suppression with ultrasonic sensors from SICK make it possible to detect only the PCB, even if a placement head is only millimeters away from the PCB or if multiple PCBs in magazines are lying on top of one another. With ultrasonic sensors, background suppression is achieved by time-of-flight measurement of sound.

The ultrasonic sensors also have a larger sensing zone in the shape of a cone. This feature also helps in avoiding false triggers caused by smaller gaps or holes, which are ignored by the sensor.

Three technologies – one housing

If requirements on PCB production change, for example, due to a new PCB design, modifying the technology used for PCB detection may be necessary. These product changes result in various modifications on the production lines, which can also result in changes to the sensing solutions already installed.

With the photoelectric sensors of the W4 product family (including the MultiLine product family), UC4 ultrasonic sensors, and CQ4 capacitive proximity sensors, SICK has packed three different technologies into a compact and space-saving miniature housing. The result: a wide range of application possibilities and full backwards mechanical compatibility.

The compact design for straightforward and space-saving installation even in the most restricted of spaces plus easy operation and commissioning holds true for all three. The mechanical integration of the technologically diverse sensors is identical. This makes it possible to make a modification to the application the technology used or exchange sensors without modifying brackets in the machine, for example.

Figure 6: A wide range of uses with full compatibility thanks to three technologies in one housing.

Also identical is the mechanical and electronic reliability when faced with the most challenging industrial ambient conditions or the various switching outputs and connection types. Thus, they are open to and suitable for all kinds of application possibilities and all detection tasks with sensing distances from 1 to 250 mm.

Smart automation of PCB production thanks to IO-Link

End customers' requirements on machine manufacturers are also continuously growing in PCB production. Customers expect machines that offer excellent quality and longevity and allow flexibility in production and product mix as well as in volume scale changes.

Through the use of sensors with the IO-Link interface, innovative functions can increase the flexibility, reliability, and efficiency of machines, as well as reduce the costs associated with them. Some examples of such functions are simplified device exchange or flexible adjustment of sensor settings.

Using smart sensor solutions from SICK, the automation systems can display the exact location of a failure on the HMI. Once the device has been replaced, the automation system automatically recognizes that a new sensor has been connected. The application-specific parameters (such as basic configuration settings) are written into the sensor quickly and reliably. The result is an efficient and documented actual 1:1 replacement of the sensor.

If different PCB layouts are produced, sensor parameters can be stored in the sensors or automation system without manual intervention and activated automatically when a layout change takes place, for example. This is how the sensor gets the parameters optimized to the specific application.

Even more complex functions are possible such as time measurements or counting functions: IO-Link enables high-performance detection and counting in the sensor instead of in the PLC. This, for instance, allows for the counting of the throughput of a specified amount of PCBs. These count results are then transmitted cyclically to the control, and the count value is reset if necessary.

This and a number of other intelligent IO-Link functions contribute to the machine and process optimization due to the provision of process-related data.

Selection matrix

	CQ4 capacitive proximity sensor	UC4 ultrasonic sensor	W4-3 photoelectric sensors	WTB4-3 MultiLine photoelectric proximity sensor
No blind zone	✔	X	X	X
Working distance sufficient for component clearance	X	✔	✔	✔
Even for partially reflective surfaces	✔	✔	X	✔
Precise background supression	X	✔	✔	✔
Ideal for openings and holes	X	✔	X	✔
Identical mechanical compatibility	✔	✔	✔	✔
Identical housing size	✔	✔	✔	✔

Summary

The reliable detection of PCBs is the basis for all process steps of SMD production in the electronics industry. There are many influencing factors due to different kind of machines along the process and individual layouts and surfaces of the printed circuit boards that require the usage of different technologies.

Different detection principles have individual advantages and disadvantages regarding blind zone, working distance, independence from surface changes or precise background suppression. Selecting the right sensor technology incorporated in capacitive proximity sensors, ultrasonic sensors, and photoelectric sensors for a specific application ensures high production yield and fewer rejects.

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