TECHNICAL CONSIDERATIONS FOR SELECTING DISTANCE-BASED PHOTOELECTRIC SENSORS

TECHNOLOGY BRIEF

As anyone who has bought or sold real estate can attest, the three most important things about a property are often location, location, and location. Similarly for sensing, sometimes the critical attribute is an object's location. For example, simply detecting the presence of a hopper doesn't indicate if it is filled to the correct height. Or detecting that an overhead crane is there isn't helpful when its position is what determines when it should move, slow down, or stop.

Photoelectric sensors that just detect the absence or presence of an object may not suffice for every application. Over the years, an assortment of photoelectric sensors that are distance based has evolved to address more challenging application requirements. This advanced class of sensors doesn't just determine the presence of something, but also its position.

Three methods have emerged as front-runners of distance-based photoelectric sensing. Each has its own strengths and applications in which it excels.

Background suppression (BGS)

The oldest and simplest method is called background suppression, or BGS. BGS sensors detect based on the *triangulation* of light that is reflected from an object back to the sensor's receiver. Light from the sensor is reflected at different angles based on the distance the object is from the sensor. When something is close to the sensor, the angle is larger than when something is farther away. And because the angle of the reflected light changes, it results in the light reaching different parts of the sensor's receiver. See Figure 1.

Multipixel array (MPA)

While BGS has been in existence for several decades, a newer technology has emerged as an outgrowth of BGS. Multipixel array (or MPA) products are based on a variation of BGS technology. In both BGS and MPA photoelectric sensors, the sensor emits light, which is reflected by an object back to the sensor's light-sensitive receiver area. And the triangulation of that reflected light determines where it contacts the receiver, which is then used to determine distance. But the difference between the two is that a BGS sensor uses two receiver elements, while an MPA sensor uses more than that number of receiver elements, often over 100 receiver elements per array.

One sensing threshold is set for a BGS sensor. The threshold is determined by the distance at which more of the reflected light begins to fall on the "near" element receiver rather than the "far" element receiver. However, in an MPA sensor, the distance-based sensing is determined by where on the receiver array the majority of the reflected light is centered. (See Figure 1.) With MPA sensors, multiple switching thresholds or windows are possible for more complex application requirements.

MPA also offers a higher level of control and configuration than BGS models because there are more configuration options available. Unlike BGS with just one distance threshold, now it is possible to set multiple simultaneous thresholds or even sensing windows with user-defined minimum and maximum sensing distances.

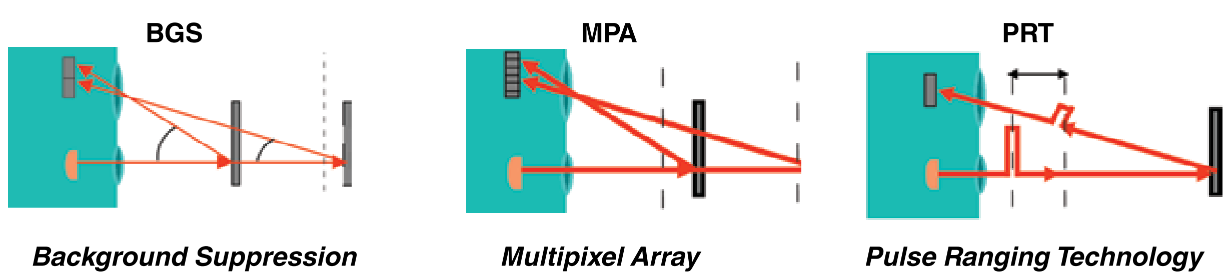

Figure 1. *Three methods of distance-based photoelectric sensing*

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Because both BGS and MPA sensors detect *where* light is reflected instead of *how much* light is reflected—as is the case with conventional sensors—they are also remarkably insensitive to variations of objects' reflectivity or color.

Pulse Ranging Technology (PRT)

Last, but certainly not least, in the trio of distance-based sensors are those that employ Pulse Ranging Technology (PRT) sensing. PRT sensors are either diffuse, meaning they emit light that is reflected from the object to be sensed back to the sensor's receiver, or retroreflective, meaning they emit light that is reflected from a corner-cube reflector back to the sensor's receiver. But unlike the previous two technologies, PRT technology uses only one receiver element. A timer in the sensor determines how long it takes—after it emits a short burst of light—for the light to make it from the sensor to the object and then be reflected back to the sensor again. Calculating this time duration and using the speed of light in air as a constant then determines the distance from the sensor to the object. See Figure 2.

PRT is true "time of flight" (TOF) distance measurement. It is critical to note that the term "time of flight" is often misused in industry, as some manufacturers improperly use it to describe a different method of distance measurement that is more accurately called phase correlation or is chip-based technology. In phase correlation distance measurement, the reflected light is evaluated at the receiver, not based on the time it took to get from the sensor's emitter to the object and be reflected back, but rather by how much the phase angle of the light shifted as it traveled to and from the object. In other words, phase correlation geometrically calculates the distance rather than accurately measuring it, as is the case with PRT.

But phase correlation distance measurement has significant disadvantages compared to PRT distance measurement. Phase correlation sensors have a weaker LED intensity since they are continuously on, resulting in shorter sensing distances and difficulty detecting dark objects. They are also limited to short sensing ranges because they detect shifts to the reflected light's phase angle, but anything greater than 360° can

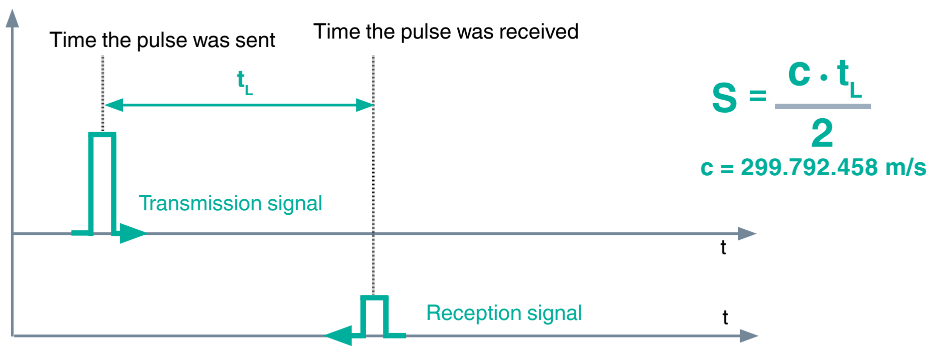


Figure 2. *Principle of operation of a PRT distance measurement sensor. The sensor transmits a short intense burst of light that travels to an object and is reflected to its receiver. The time for the reflected light to return to the sensor's receiver (t_L) determines its distance (s), with the speed of light as constant c.*

Pepperl+Fuchs Group
www.pepperl-fuchs.com
USA: +1 330 486 0001
fa-info@us.pepperl-fuchs.com
Germany: +49 621 776-4411
fa-info@de.pepperl-fuchs.com
Singapore: +65 6779 9091
fa-info@sg.pepperl-fuchs.com

be misinterpreted by the sensor. This also means they are prone to detecting background objects, especially those that reflect light at the same phase angle as light in the sensing range. For example, whether reflected light is shifted in phase by 90° or by 450°, there is no way for a phase correlation sensor to differentiate the two. This results in the detection of “phantom objects” in the background. Other strengths of PRT include its ability to ignore environmental conditions such as ambient light, temperature, and target color, and that measured values don’t drift as they do in phase correlation, even after prolonged use.

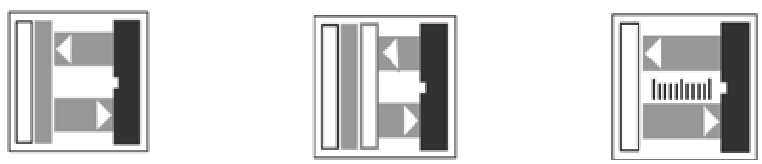
Each Technology Has Its Own Strengths

When considering whether a BGS, MPA, or PRT sensor is best suited for an application, it is important to keep in mind that one technology is not “better” than the others: each has its own strengths and may be the best product for a different type of application requirement.

When considering a distance-based sensor for an application, the first point to understand is what the sensors do. To summarize, BGS sensors use the triangulation of reflected light to two receiver elements to see if something is closer than a threshold; MPA sensors use the triangulation of reflected light to more than two receiver elements to see if something is closer or farther than a threshold or within a range; and PRT sensors time reflected light pulses to calculate distance to an object. See Figure 3.

Each technology has its own inherent benefits, so different applications call for different distance-based sensors.

BGS has a major advantage in its simplicity of setup and operation. Installing a BGS sensor in an application is often a matter of just mounting it. Many models are tamperproof, meaning they have no adjustment controls such as sensitivity adjustment potentiometers or pushbuttons. Those that do have a sensitivity adjustment typically have just a potentiometer, which is turned clockwise to increase sensitivity and the sensing distance. A simpler setup means faster installation and changeover, as it is not necessary to re-learn how the sensor is programmed.



Technology	Background Suppression	Multipixel Array	Pulse Ranging Technology
How does it work?	Triangulates reflected light to differential diode	Triangulates reflected light to array	True time-of-flight calculation using reflected light pulses
What does it indicate?	If an object is closer than a defined distance	If an object is closer or farther than a defined distance or in defined window	Distance to an object
Why use it?	To sense object while ignoring background or color variation	To customize sharply-defined sensing thresholds and ranges	To measure distance

Figure 3. *Comparison of BGS, MPA, and PRT distance-based sensing*

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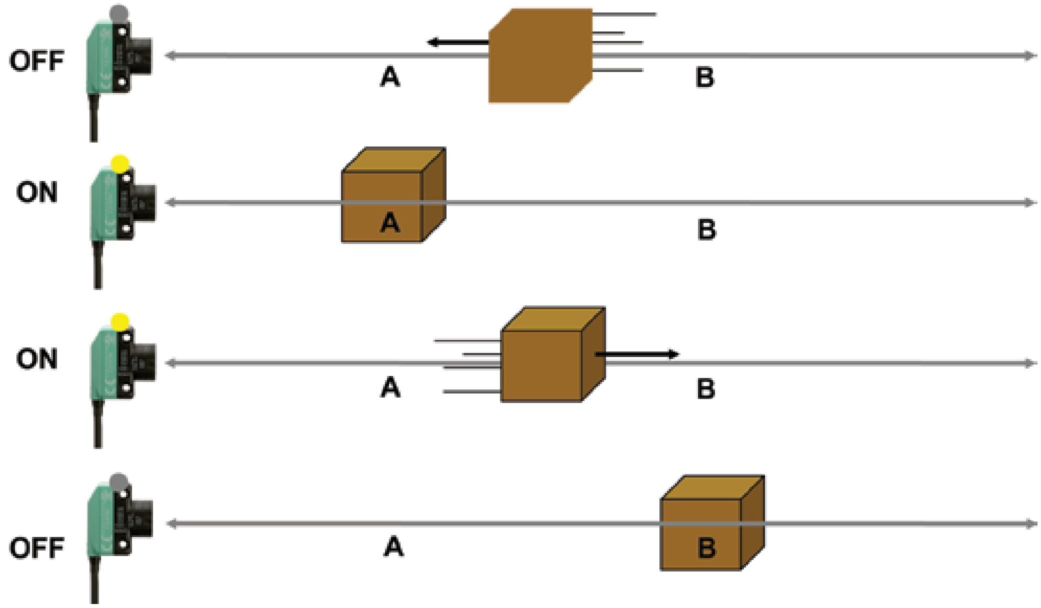

Figure 4. *Example of switching hysteresis*

Another benefit of using BGS sensors is its tight switching hysteresis. Compared to MPA sensors, BGS offers a shorter differential between the switch-ON point and the switch-OFF point. To understand hysteresis, consider Figure 4. In it, an object can be moved towards a sensor just to the point at which it is detected, which is A. Then the object can be moved away from the sensor face just to the point at which it is no longer detected, which is B. The switching hysteresis is the difference between the two, or B - A. Hysteresis can be beneficial for many applications, as it provides more sensing stability, especially if an object is detected toward the limit of the sensing distance. But when something is behind the object to be sensed, it is best to minimize the hysteresis and use BGS sensors.

Yet another benefit with BGS is the breadth of the product offering. More BGS sensors are available on the market than the other two types combined, so it is more likely to find a housing and sensing characteristics that are best suited for an application.

The main benefit of MPA sensing is its balance between the simplicity of BGS sensing and the higher-level control of PRT sensing. It therefore can appeal to both users who want a simple sensitivity adjustment potentiometer and those who want more control and intricacy to set up multiple switching thresholds and sensing windows. As such, MPA acts as a “bridge” technology between BGS and PRT. MPA sensors enable multiple sensing modes, such as background evaluation sensing, window sensing, and hysteresis sensing modes. Also cost-wise, MPA sensors are an economical way of sensing over longer distances without a mechanical adjustment.

The big benefit of using PRT sensors is that they provide continuous distance data. Unlike BGS and MPA, which indicate when an object is within a defined area, PRT indicates the actual distance from the sensor to the object. For example, a BGS sensor can tell if something is closer than 250 mm, an MPA sensor can tell if something is between 250 mm and 312 mm, but a PRT sensor can also continually tell the distance is to the object, such as 259 mm, 307 mm, etc. PRT sensors provide the most flexibility, with the ability to get either digital or analog outputs for objects based on a defined threshold or window.

Pepperl+Fuchs Group
www.pepperl-fuchs.com
USA: +1 330 486 0001
fa-info@us.pepperl-fuchs.com
Germany: +49 621 776-4411
fa-info@de.pepperl-fuchs.com
Singapore: +65 6779 9091
fa-info@sg.pepperl-fuchs.com

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Each Technology Has Ideal Applications

Like their benefits, the ideal applications for the three distance-based sensing technologies also vary.

BGS sensors are best suited for applications in which a presence check is needed in a small area. In the tight confines of a small machine, it is critical to only detect the intended object and not any other machine parts. BGS offers the simplicity of single-point detection, the ease of no or limited controls, and the precision and color insensitivity required by many processes with varying components. Examples include detecting cookies in a plastic tray, verifying the presence of a hole in a molded assembly, or sensing filters inside a nozzle head.

Other applications for BGS sensors include providing a tightly-controlled leading edge trigger, such as when a barcode must be read or a package must be transferred to another conveyor line, stack height monitoring, such as monitoring the high or low levels of a stack of cardboard, and collision avoidance, such as detecting objects a certain distance in front of an automated guided cart.

MPA sensors can provide the same functions as BGS sensors with some additions. Because multiple distances can be set, it is possible to enable tension control of a web of material. The near distance monitors when the web is too taut and thus must be loosened so the material isn't damaged, and the far distance monitors when the web is too loose and the slack must be reduced. Also possible are stroke height control of dancer arms and web break detection. In web break detection, a sensing window is programmed so that the objects in the sensing foreground and background are ignored. This is especially relevant if the web rips, and paper falls onto the face of the sensor. In this case, the paper in the foreground is not detected. And if the paper rips and disappears completely so that a machine panel is exposed, then the panel in the background is also not detected. (See Figure 5.)

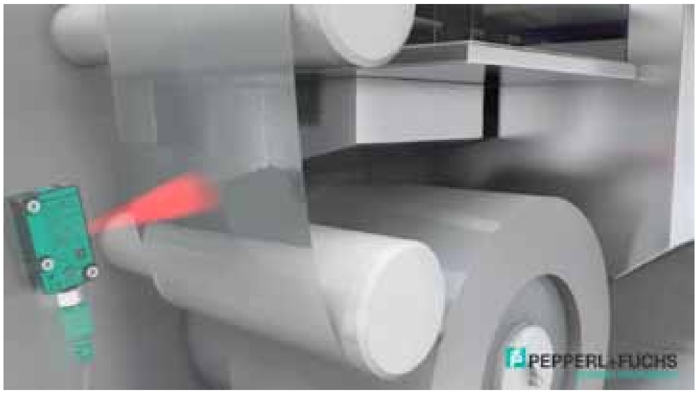

Figure 5. *MPA sensor in window sensing mode to detect a web of paper*

Applications for PRT sensors include all of the aforementioned ones for BGS and MPA as well as whenever distance should be measured. That can include determining the distance from a stationary controller to a stacker crane in an automated storage and retrieval system or of an overhead crane. It also covers measuring the dimensions of pallets or cartons by positioning PRT sensors on each side of the carton and measuring these distances, which can be used to calculate the volume of the pallet or carton. ◙

Jeff Allison,
Product Manager – Photoelectric Sensing
Pepperl+Fuchs, Inc., Twinsburg, Ohio
jallison@us.pepperl-fuchs.com
330.486.0100

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