Background Suppression– Challenges and Solutions

When using photoelectric sensors in retro-reflective and thru-beam modes, the maximum sensing distance is easily controlled. In retro-reflective mode, the distance between the reflector and the sensor determines the range. Likewise, in thru-beam applications, the distance between the transmitter and receiver controls the sensing range. However, when using photoelectric sensors in simple diffused mode (a.k.a. proximity mode), precise control of the sensing range is not possible even if the sensor being used offers a sensitivity adjustment. In applications this can cause problems because shiny objects well beyond the sensor's specified sensing range are detected. It is not uncommon for a standard diffused mode sensor with a specified range of 15 inches to falsely detect a piece of metal, Plexiglas or other highly reflective object that is 6 feet or farther away from the sensor. To solve this problem, a special type of diffused mode sensing known as background suppression is available, which enables users to precisely control the sensing range in diffused mode. A fixed and controllable sensing range is one of the biggest advantages of background suppression sensors, but the technology brings a lot more to the table.

In diffused mode sensing, the sensor uses the target to reflect light back to it, eliminating the need for a secondary device such as a reflector. In applications, targets can vary greatly in color, which will directly affect the range of the sensor. This varying sensing distance is known as black-white differential. The black-white differential is simply the difference in distance between where a diffused sensor detects a 90% reflective white card vs. a 6% reflective black test card under the same conditions. Sensor manufacturers normally provide black-white differential data in the form of a graph so that customers have a guideline when applying them to the application. Figure 1 shows a typical black-white

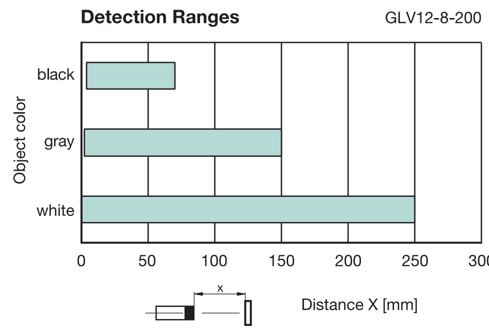


Figure 1. Effect of Color on Diffused Sensing

differential graph for a standard diffused mode sensor. As you can see from figure 1, color has a significant effect on the sensing range. The black-white differential for the sensor from figure 1 is approximately 190mm. The dramatic reduction in sensing range is due to the fact that standard diffused sensors recognize a target based on the light reflected back to the sensor's receiver. The received light must be strong enough to overcome any ambient light or any electrical noise at the sensor's receiver. If the target is black, it absorbs large amounts of energy and therefore must be close to the sensor in order to return enough of the emitted light to be detected. Now let's take a look at figure 2, which shows a black-white differential graph for a background suppression sensor.

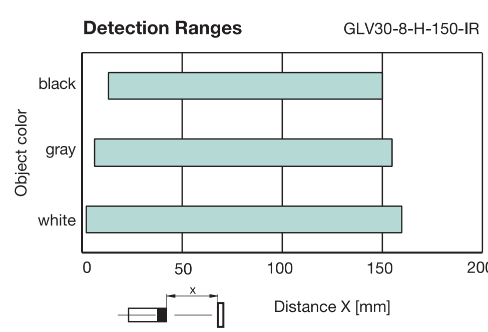


Figure 2. Effect of Color on Background Suppression Sensing

As you can see in figure 2, diffused mode with background suppression is far less sensitive to target color. For this sensor, the sensing range is almost identical for black and white targets. The black-white differential is only 10 mm, which is far less than the 190 mm seen in the standard diffused sensor from figure 1. The sensor depicted in figure 2 shows the black-white differential for a sensor with an infrared light source, however, background suppression sensors can use either visible red or infrared (IR) light sources. The obvious benefit of visible red is that alignment from the photoelectric sensor to the target is simplified, because a bright, clearly defined light spot on the target can be seen. Using an IR light source means that this visual aid is no longer available. However, infrared's advantages lie in its higher power and superior color insensitivity. As infrared is more efficient than visible red and can be driven by larger current pulses, it has a higher optical power output and can operate at longer sensing ranges. Background suppression photoelectric sensors with IR sources have smaller black-white differentials compared to similar sensors with visible red sources.

Another advantage of background suppression is a very small, bright and clearly defined light spot. This gives the user a high level of precision and repeatability, as well as the ability to detect small objects with the same reflective properties as the background (i.e. verifying that a piston ring has been placed in the groove of a piston). If the background suppression sensor selected has a visible red light source, the brightness of the light spot is helpful as an alignment aid.

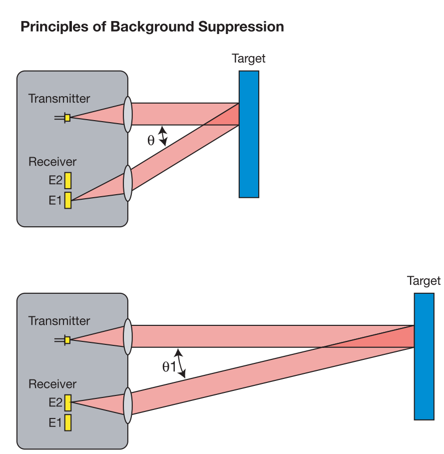
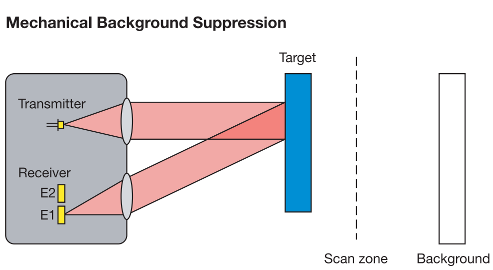


Figure 3. Principle of Background Suppression

The basic principal behind background suppression is triangulation. An LED transmits light through a lens in a straight line toward the target. The target reflects light back to the receiver lens and elements (E1 and E2 in figure 3) at some angle. The distance between the sensor and the target determines the angle in which light is reflected back to the receiver. The closer the target is to the sensor, the greater the angle of reflection. As can be seen in Figure 3's top illustration, $\theta > \theta_1$ and causes the light to be directed to receiver element E1. As the target moves away and the angle decreases, the light will be directed to receiver element E2. Which element is receiving light enables the sensor to differentiate between a target and the background. This is purely based on the distance from the sensor, not on the amount of received light.

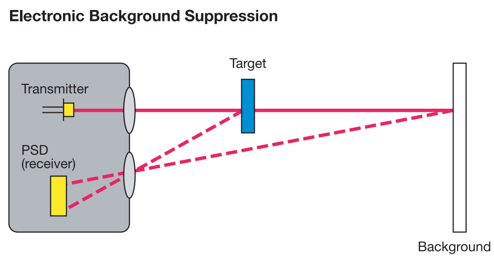
Diffused mode with background suppression can operate at a fixed or at a variable range and can be accomplished technically in two ways,



either mechanically or electronically.

Figure 4. Principles of Mechanical Background Suppression

For mechanical background suppression, there are two receiving elements in the photoelectric sensor, one of which receives light from the target and the other receives light from the background (see figure 4). When the reflected light at the target receiver is greater than that at the background receiver, the target is detected and the output is activated. When the reflected light at the background receiver is greater than that at the target receiver, the target is not detected and the output does not change state. A potentiometer on the sensor is connected to a worm gear that can adjust the angle of the receiving lens. By adjusting the angle of the lens, the focal point is being moved between the two receivers. For adjustable range sensors, this enables users to define the sensing range and ignore objects beyond the desired range. For fixed background suppression sensors, the angle and thus the focal point is defined and set by the



sensor manufacturer.

Figure 5. Principles of Electronic Background Suppression

With electronic background suppression, a Position Sensitive Device (PSD) is used inside the sensor instead of the two separate receiver elements. (See figure 5.) A PSD gives an output corresponding to where light strikes it. The principals of reflective angle relative to target distance still apply, therefore, as the distance between the sensor and the target change the focal point will move up or down the PSD. The output of the PSD is then compared to a desired value, which is the switch point. For example, if the value from the PSD is at least the value of the switch point, the sensor recognizes the received light as a target and changes state. The switch point can be externally adjusted and since the adjustment does not require mechanical parts, electronic background suppression is generally less expensive.

Cost is one of the main reasons that two methods exist to accomplish background suppression, but there are also size and performance tradeoffs. Mechanical background suppression offers better optical performance and a sharper cutoff range. Mechanical background suppression is inherently more stable through temperature change, however electronic BGS has a clear advantage in heavy vibration applications. There are also definite size limitations with background suppression technology. With mechanical background suppression, the sensor needs two receiving elements and an adjustable lens. This requires more real estate within the sensor to house the additional receiving element along with the mechanism to adjust the sensor's lens. Therefore, mechanical background suppression sensors are usually housed in larger rectangular housings. To accomplish background suppression technology in miniature housings, electronic background suppression needs to be utilized. Using a PSD in lieu of mechanical parts, the sensor can be miniaturized to fit into a smaller housing.

Although background suppression brings many advantages to photoelectric sensing, it can also add some challenges. First, background suppression sensors generally have shorter sensing ranges than standard diffused sensors. This is primarily due to the background suppression sensor's precise and controllable sensing range. To achieve its exact sensing range, the sensor concentrates its LED light energy toward an exact spot instead of just flooding the light energy straight ahead like a regular diffused sensor. The photoreceiver is also positioned to accept reflected light from the same spot. This alignment gives the sensor a controllable sensing range while sacrificing some of its potential long distance capabilities.

Diffused mode sensing, background suppression included, requires a minimum sensing distance (see figure 6). If a target is too close to the lens, the angle of the transmitter light reflected from the target doesn't allow the light to reach the receiver. In other words,

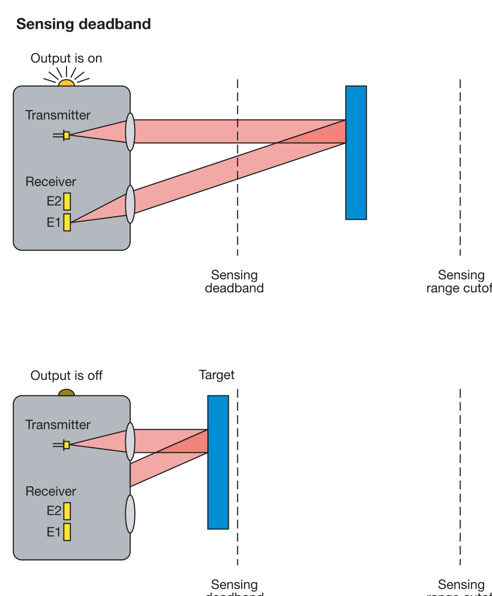


Figure 6. Sensing Deadband

the light coming from the transmitter doesn't have enough distance to make it to the receiver. If a target is within this minimum sensing range, the sensor may not detect it. The minimum sensing range, or sensing deadband, is typically under 10% of the full range of the sensor.

For background suppression photoelectric sensors that operate at a fixed sensing range, mounting and positioning must be considered for new applications. Because they have no sensitivity adjustments, fixed range photoelectric sensors offer tamper-proof sensing compared to adjustable field sensors with external potentiometers. However, when mounting fixed range units, a flexible mounting system may be necessary to "fine-tune" the sensor's distance and angle to the target for proper detection. This means the user must purchase a sensor at a preset distance and then physically move the sensor closer or farther away from the background to get the desired operation. Fixed background suppression is more difficult to install, but because of the lack of mechanical parts, a lower cost can be achieved. An alternative to this is using an adjustable range background suppression photoelectric sensor, in which an external potentiometer allows for these adjustments.

Another challenge presented by background suppression sensing relates to the direction of movement of the target. When a target with two contrasting colors, such as black and white, is positioned at the sensing range cutoff, the more reflective side of the target can reflect more light back to the far receiver than it does to the near receiver. As this border of the target passes through the light beam, the sensor output can turn OFF momentarily. This outcome, called the Pepita effect, (see figure 7), can happen if a sensor's light spot is simultaneously on two contrasting colors or surfaces at the cut-off distance and if the sensor is not properly oriented with respect to the black-white border. The Pepita effect can also be seen with extreme variation in reflectivity or contour of a target. The fix for the Pepita effect involves either rotating the sensor 90 degrees so that the sensing axis is aligned horizontally instead of vertically or moving the sensor closer to the target.

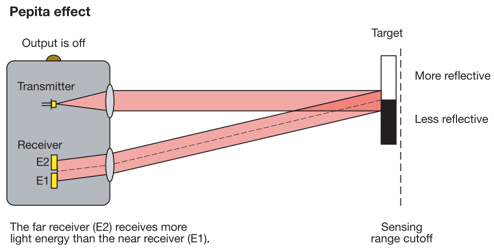


Figure 7. Pepita Effect

Another peculiar phenomenon with background suppression sensors is the cross-eyed effect (see figure 8). This is another scenario where a background suppression sensor can be tricked. The cross-eyed effect happens when a specified target is smaller than the background suppression sensor's LED light spot. Since the target is unable to block the sensor's light beam, the majority of the light energy passes around the target and hits the background surface. Therefore, most of the light is reflected off the background back to the sensor, which causes the sensor to believe there is no target present. To prevent this effect, specify a background suppression sensor with a light spot diameter that is smaller than the target.

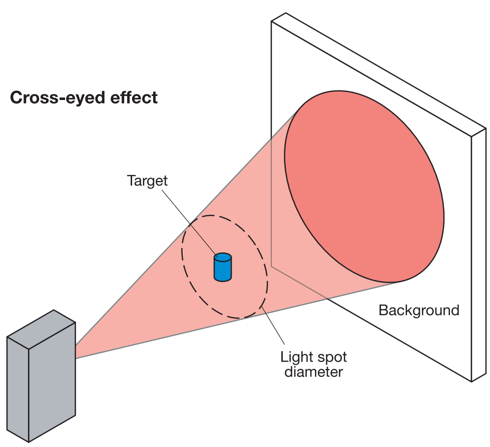


Figure 8. The Cross-Eyed Effect

A final challenge arises with background suppression sensors called the blinding effect (see figure 9). This occurs when too much light is reflected back to the sensor. If too much light is returned, the photoreceivers are oversaturated with light. As a result, the sensor cannot be properly adjusted between the near and far distances. This can happen when a background suppression sensor is aimed at a reflector, a mirror, or perpendicular to a very shiny object.

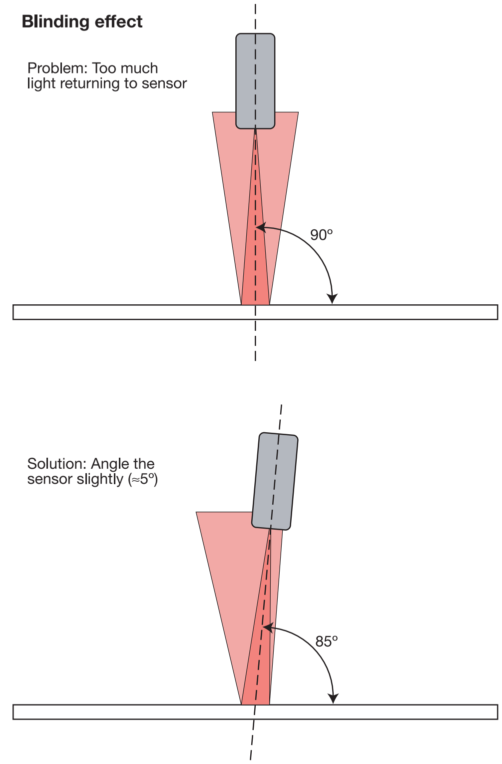


Figure 9. Blinding Effect

To remedy this problem, simply angle the sensor slightly (~5 degrees) so it is not perpendicular to the target/background. This will cause less light to shine directly back to the sensor and not overwhelm the photoreceivers.

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