WHITE PAPER

COLOR CONTRAST AND LUMINESCENCE SENSORS

THE KEY TO SUCCESSFUL AUTOMATION CONTROL

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PHOTOELECTRICS: THE KEY TO SUCCESSFUL AUTOMATION CONTROL

TAKING THE MYSTERY OUT OF SELECTING THE RIGHT PHOTOELECTRIC SENSOR FOR YOUR APPLICATION

As the demand for products in the world-market continues to push production, the requirements for high-speed automated processes capable of providing these products and components at lower cost and higher quality continues to increase. Since subjective, visual inspection techniques are clearly not conducive to high-speed inspection and control requirements, sensors have stepped in to fill this need.

Photoelectric sensor selection is a key component to a successful and reliable automation system

One of the key components in this high-speed production environment are the sensors. These devices provide the evaluation of many features and characteristics of products at rates exceeding hundreds/second. Photoelectric sensors offer non-contact verification with far higher reliability and speed than contact techniques.

Although there are many types of sensors including ultrasonic, photoelectric, capacitive and inductive, this discussion will focus on specialty photoelectric sensors. This paper is intended to guide the reader through the process of selecting the right sensor to achieve a reliable solution to their automation control needs.

HERE'S HOW PHOTOELECTRIC SENSORS WORK

The basic function of a photoelectric sensor is to react to a change in light produced by a target or characteristic of a target. The primary indication from the sensor to this change in light is a digital (on/off) signal that interfaces to external equipment for control purposes. Some sensors provide an analog signal that may be monitored externally, transferring the presence/absence decision to the control system.

Typically, the sensor is set to differentiate between two conditions or characteristics exhibited by the target, for example, detection of a light or dark mark on a label or presence/absence of an adhesive on a part. More advanced sensors, such as color sensors, react not only to the change in light produced by the target but also evaluate the color content of the light allowing multiple colors to be recognized.

All photoelectric sensors have a limited field-of-view defined by their spot size. This necessitates control of the target to guide it thought the light spot. For example, a photoelectric sensor cannot detect a 1cm^2 mark placed randomly in a 100cm^2 area without being directly "aimed" at the mark. Best results are achieved by maintaining a fixed sensor-to-target distance.

Nearly all photoelectric sensors modulate their light source to eliminate ambient light from affecting the sensor's measurement. This technique involves measuring the signal with the light source on and with the light source off, then calculating the difference. The result is a signal level that is attributed solely to the sensor's light source (i.e. ambient light is subtracted out).

Lock feature provides security against unauthorized changes to sensor's operational settings

One important feature, frequently overlooked, is the ability to "lock" the controls to prevent unauthorized changes from being made on the factory floor. Many sensors overlook this feature and as a result, adjustment of the sensor can be made by anyone at any time. There are several methods that provide the locking feature; by a pressing sensor keys in a certain sequence, by a remote line from the control system, or simply by lack of user controls on the sensor. All of these methods are effective.

SENSOR COMMISSIONING CONSIDERATIONS

Sensor commissioning involves selection of the right sensor to job, installation and evaluation. Many sensors feature a “teach” function. The teach function allows the operator to “teach” the sensor the pass or fail condition by placing a known “good” part in the sensor’s field-of-view, pressing a key on the sensor, then placing a “bad” part in the sensor’s field-of-view and again pressing a key. The sensor evaluates the two conditions and sets a threshold into its memory. Although this technique works in applications where the difference between a “good” part and a “bad” part is great, it is less useful in many other applications where the difference is more subtle. These applications are often much easier to implement successfully with a sensor that provides the user with visual feedback allowing the user to determine and set the optimum threshold level.

Visual feedback such as a display or bar graph makes set-up and commissioning easy. Multiple samples can easily and efficiently be evaluated to determine a range of variation that might be expected in normal production.

More advanced sensors provide visual feedback such as a display or bar graph that indicates the signal strength. Visual feedback aids in the set-up and evaluation process by indicating the signal strength to the operator, allowing the operator to determine where in the sensor’s range would be optimum for reliable operation. This feature is also a valuable troubleshooting aid when evaluation of marginal targets is necessary.

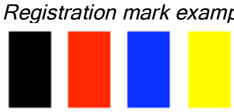
CONTRAST SENSOR

Contrast sensors provide a method of detecting a difference in contrast between presence and absence of an object or mark. Contrast sensors are available in a wide variety of spot sizes ranging from a few millimeters to 25mm or more. Many contrast sensors utilize a red or green LED light source and often both. Since different colors absorb different amounts of light, the wavelength of the light source can be specifically selected to provide the highest contrast. Unfortunately, this approach is not very flexible, requiring a specific background and mark color. Sensors that provide both a red and green light source offer a greater degree of flexibility, but require a fixed selection of one or the other light source in operation, frequently accomplished automatically using the teach function.

Broad-spectrum while light source provides the versatility to detect any color target on any color background

The most versatile of the contrast sensors are those that provide a broad-spectrum while light source. These sensors provide good differentiation on all color and background combinations. This type of contrast sensor allows for quick changeover in production by simply adjusting the threshold level to a previously established level.

Registration mark example



Other, specialty contrast sensors provide large light spots allowing contrast sensing at extended distances exceeding 300mm. One such sensor provides a 457nm blue light source with coaxial optics to achieve reliable long-distance operation. One application for this style sensor is sorting boxes from totes on a conveyor.

COLOR SENSOR

Color sensors separate the reflected light from a target into its constituent red, green and blue components. Each of these signals is then evaluated to determine whether or not they are within the range of the tolerances set for specific color recognition. A color recognition channel allows the specific characteristics of the target to be associated with a discrete output line and stores these values in the sensor’s internal memory. Response time for these sensors can be as fast as 300uS. Spot sizes can vary from several millimeters to 25 millimeters.

Color sensors integrate the signal over the entire area of the light spot. Therefore, if the light spot were positioned spanning two colors, the sensor would “see” the combination of the colors as opposed to each color separately. This is important to consider in applications where the target has a texture or pattern such as wood grain or multi-color crosshatch often used in automobile seat covers. While a small light spot would not be suitable, a large light spot, with its ability to average the signal over a large area would likely do the job.

Windows™ based application program provides extensive control of sensor settings such as illumination level and individual red, green and blue tolerance settings for color recognition channels

Color sensors are available with a wide variety of features ranging from simple teach functionality to a full featured GUI interface that allows real-time display, access to tolerance settings for each color and general sensor controls. While simple applications such as sorting based on a few very different colors can often be accomplished with the lower end color sensors, many others will require more comprehensive control of settings provided by the full-featured sensors.

Color sensors are effective in monitoring of color consistency in applications such as textile production, plastics and other continuous output processes.

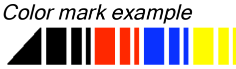
COLOR MARK SENSOR

Color mark sensors are designed to detect color marks at high-speed. Due to the need for fast response on these types of sensors, they do not typically identify a specific color. Instead, they react to a change from the background color and provide a discrete output signal indicating the presence of a mark. Color mark sensors provide spot sizes from <0.5mm circular spot to 2mm x 5mm rectangular spot. Sensors that utilize rectangular shaped spots require careful mounting of the sensor to orient the spot in the proper orientation to the mark and are limited to detecting larger marks while a smaller, circular spot size is suitable for use on 0.5mm wide and larger marks.

Key to successful implementation of the color mark sensor is a careful analysis of the particular requirements of the application. Best results are achieved by selecting a sensor with a spot size that is no larger than the smallest mark being detected. This will provide the highest level of contrast.

Small spot size combined with fast sensor response allows reliable detection of 0.5mm wide marks at process speeds exceeding 2000ft./min.

Color mark example



Target speed is also a major factor in the selection process for color mark sensors. Many processes such as printing and converting require precise detection at high production speeds. For example, a 1mm wide mark moving at 2000ft/min. translates into linear travel of 1mm in 98uS. Since the light source is modulated the light source may be on or off as the mark enters the sensor's field-of-view. Therefore, it is necessary that the sensor's response be fast enough to make a measurement before the mark leaves the sensor's field-of-view. Selecting a sensor with a response that is 4X faster than the time required for a mark to move the distance equal to its width will generally guarantee detection. In this example, a sensor with a maximum spot size of 0.5mm and a response time of 25uS or faster would be a suitable choice.

LUMINESCENCE SENSOR

Luminescence sensors respond to materials such as paints, greases, inks and adhesives that have luminescent tracers. The tracers emit light in the visible spectrum when stimulated by a UV light source. These sensors are very useful in many applications where the presence of these materials needs to be accurately verified. The technique of applying a luminescent marking is often useful in applications where there is significant variation in the background that needs to be ignored, such as text and graphics printed on labels. A luminescent mark can be printed using an invisible ink anywhere on a label without affecting the aesthetics of the label, while allowing a luminescence sensor to detect the mark to verify presence, orientation and positioning of the label.

Use of luminescent marks allow for reliable detection without affecting product aesthetics and visual feedback, such as a display, makes set-up easy

Often, clear films such as those used in tamper-evident seals contain optical brighteners that cause them to luminescence in the presence of a UV light source.

Many commonly used packaging and production materials use luminescent tracers as a means of providing presence verification. Among these materials are adhesives, gums, films, inks and greases. Since many of these materials are clear or nearly clear, other types of sensors are not suitable for reliable verification.

SENSOR SELECTION CONSIDERATIONS

Generally, selection of the proper sensor involves a careful assessment of the target characteristic(s) and the determination of what constitutes the acceptance criteria.

First and the most important consideration is the characteristic that is to be detected?

The following table shows many common materials and the type of sensor typically used for detection:

SENSOR TYPE	CHARACTERIST TO BE DETECTED
Luminescence sensor	Luminescent tracer in: Adhesive Gum Grease Inks Crayon Chalk Thread
Color sensor	Color consistency, verification and sorting of: Painted products Automotive interior trim components Plastics Tinted films Stained wood Packaging materials Labels Printed products Carpet Textiles
Color mark sensor	Precise, high-speed color mark detection for: Printing processes Packaging applications Print-to-cut triangle for gluer-folder Color registration mark verification
Contrast sensor	Detects marks or contrast changes of: Registration marks Objects

SENSOR SELECTION CONSIDERATIONS

Is there one condition or multiple conditions that constitute acceptance of the part?

With the exception of the color sensor, all of the other sensor types detect a single characteristic or condition that causes the reflected light signal to be above or below the threshold. Multiple characteristics can be often be differentiated using a color sensor or several contrast sensors.

Is it a glossy or matte surface?

Glossy, highly reflective surfaces generally require mounting the sensor on a slight angle relative to the target surface, e.g. 15˚ from perpendicular. When the glossy characteristic is what needs to be detected, then perpendicular mounting of the sensor is necessary. Matte surfaces diffuse light in a relatively uniform manner, improving detection consistency.

What is the size of the feature?

The mark or object should be larger than the sensor spot size for reliable operation. The size of the feature must be considered with the speed of the target in all but static or slow moving processes. Reliable detection requires that the target be present in the sensor light spot long enough to be acknowledged by the sensor.

How fast is the target moving?

Reliable detection is a function of the sensor's response time, sampling rate, size of the target and the speed of the target as it moves through the sensor's light spot. Simply put, the target needs to be present in the sensor's light spot long enough for the sensor to respond. Sensors that have response times faster than 100uS are generally suitable for all but the highest speed/small target applications.

What is the distance, minimum and maximum from the sensor mounting position to the target?

While some sensors operate at distances >100mm, most do not. Greater distance operation requires the use of higher sensitivity sensors. Some color sensors, contrast sensors and luminescence sensors provide large light spots allowing use at greater distances. Generally, it is best to select a sensor that will provide reliable detection and place it at the optimum distance rather than fix a distance requirement and try to find a sensor that will work.

Is the sensor-to-target distance fixed or does it vary?

Variation in sensor-to-target distance, typically referred to as "flutter" is a factor in successful detection. Since all photoelectric sensors measure differences in light that is collected by the sensor optics, changes in distance will cause changes in the light incident on the collection lens. Whether or not this results in a problem with detection reliability depends on the difference between presence and absence levels, the greater the difference, the greater the allowable distance variation.

CONCLUSION

While each application is sufficiently different from one another, applying the guidelines discussed in this paper will help to make the sensor selection process a bit easier. Photoelectric sensors are powerful tools that, when properly applied, can produce highly reliable solutions to some tough automation challenges.