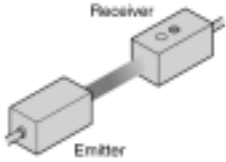


Photoelectric Sensors

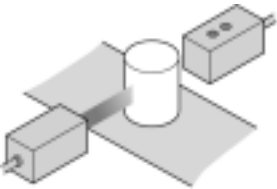
■ THROUGH-BEAM

Principle of operation

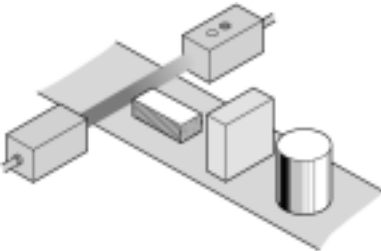
The through-beam sensor consists of two parts, an emitter (the light source) and a receiver (the detector). A beam of light links the two establishing a sensing area.



The target to be detected passes through the beam, breaking the link between emitter and receiver. When this occurs, the object has been sensed.

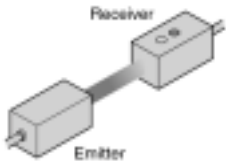


As the method of operation is by breaking the beam, the sensor is not affected by the target's color, texture or glossiness. However, the size of the object must be taken into consideration. Some through-beam sensors have sensitivity adjustment to allow different sizes to be detected.

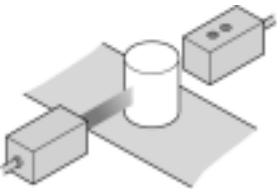


Operation mode

Light-ON: The output of the sensor operates when the beam is uninterrupted.

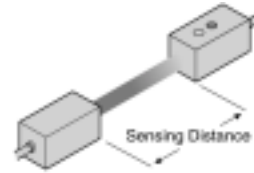


Dark-ON: The sensor output operates when the beam is interrupted.



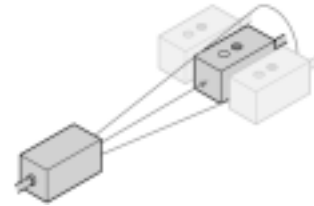
Sensing distance

The sensing distance shown in the catalog for through-beam sensors is the maximum distance between the emitter and receiver at which the sensor will operate stably. Depending on the sensor family used, the sensing range can be from millimeters up to 50 m.



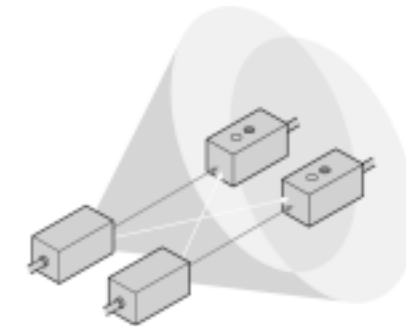
Alignment

Through-beam sensors operate precisely when the emitter and receiver are in line. This is because the light from the emitter spreads out very little, as the beam is focussed by a lens. This can be useful for positioning.

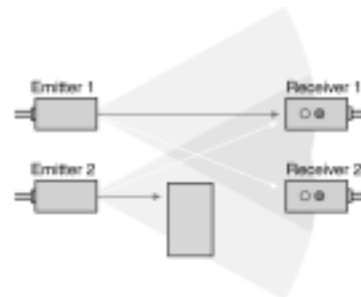


Mutual interference

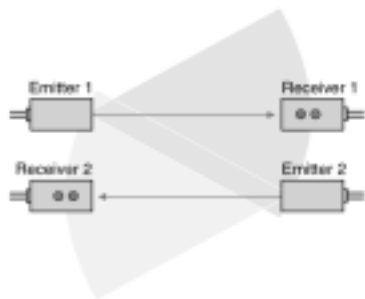
When using two pairs of through-beam sensors in close proximity, the spread of the beam can cover both receivers. This can cause sensing problems. (In these diagrams the spread of the beam of light has been exaggerated for clarity, in practice the beam spread is much smaller.)



If the target breaks the beam between emitter 2 and receiver 2, light is still received from emitter 1. Effectively the target has not been detected.



To overcome this, reposition the sensors in opposite pairs. "Opposite pair" arrangement enables the light of each emitter to only affect its respective paired receiver.

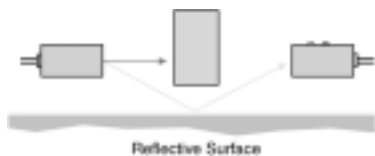


Glossy or reflective targets require extra care in setup. If the two sensors are too close a reflective target could cause triggering.

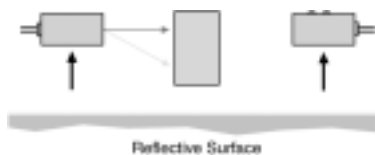


Mounting the sensor

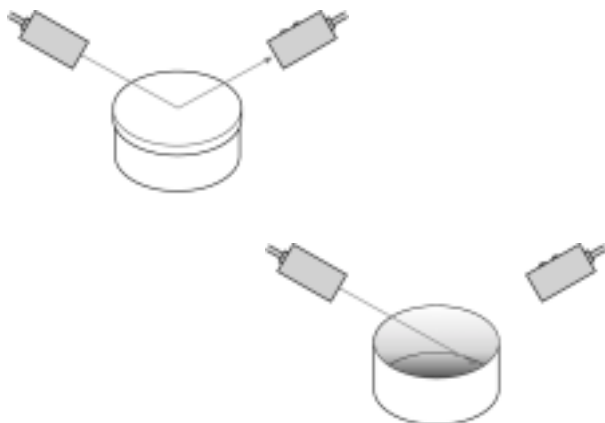
Shiny surfaces within the target area will likely reflect the light beam and as a result, false sensing may occur.



If this occurs, repositioning the sensor can overcome this. Alternatively, if possible, cover the reflective surface with a matte material.



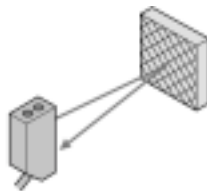
If, however, the product is shiny, take advantage of the reflection and position the sensor differently. In this case the lid's presence is detected by reflecting the beam off the lid. If the lid is not there, the beam is not detected by the receiver.



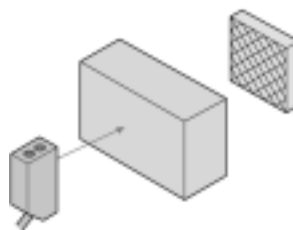
RETROREFLECTIVE

Principle of operation

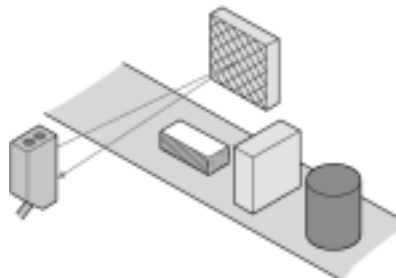
Unlike the through-beam sensors, the retro-reflective sensor has the emitter and receiver in one body. The light beam is established by the use of a reflector, returning the light from the transmitter back to the receiver.



Like the through-beam sensor, the object is detected by breaking the path of the beam. The retro-reflective sensor has the advantage over the through-beam type in that the sensor only has to be wired in one place.

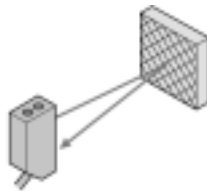


Since the target is detected by breaking the beam, the operation is not affected by the object color or shape.

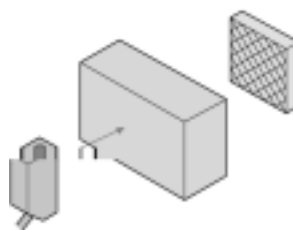


Operation mode

Light-ON: The sensor output operates when the beam is reflected back to the receiver.



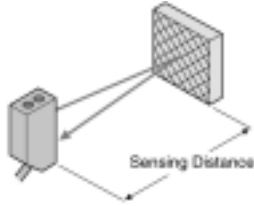
Dark-ON: The sensor output operates when the beam is interrupted.



■ RETROREFLECTIVE continued

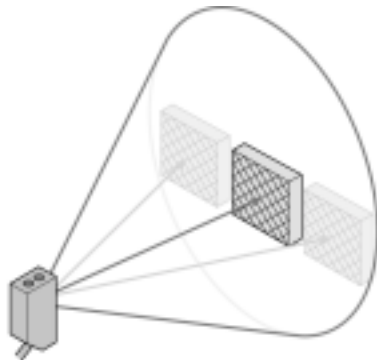
Sensing distance

The sensing distance shown in the catalog is based on the maximum distance between the sensor and reflector at which the sensor will stably detect the target.

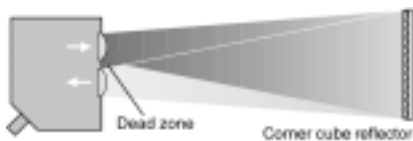


Alignment

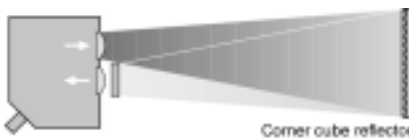
Since the reflector returns the light in the direction from which it came, alignment between the sensor and the reflector is easy (here the beam spread is exaggerated).



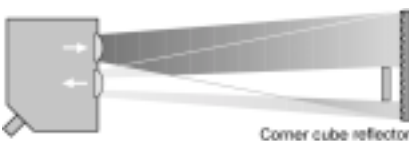
The sensing range of the retro-reflective sensor is slightly less than the overall distance, as a "dead band" occurs just in front of the sensor. This is due to physical separation of the emitter and receiver and the angle at which the light is reflected back from the reflector. When using the retro-reflective sensors, the target position (in relation to the reflector) can influence the operation of the sensor.



In this position, near the sensor, the target is obscuring all the light reflected.

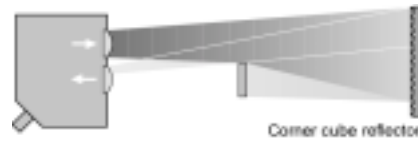


In contrast, the target is now directly in front of the reflector, the sensor is still receiving approximately 75% of the light emitted.



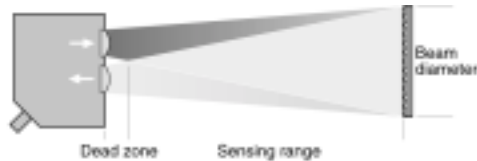
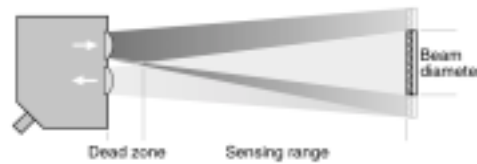
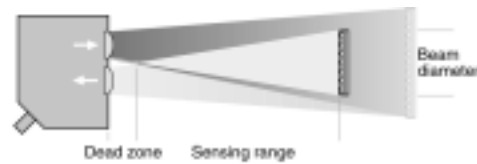
With the target halfway, 50% of the emitted light is obscured from the reflector.

Most retro-reflective sensors have a sensitivity adjustment so that the threshold point of switching for the sensor can be adjusted.



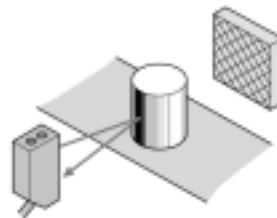
Reflector size and position

The size of the reflector also can be used to influence the sensing position and also the sensing range. With a smaller reflector the beam width is reduced, purely because this is determined by the size of the reflector. If the small reflector is moved further away, the dead zone extends slightly due to the angle narrowing. Due to the area of the reflector being smaller, the sensing range is shortened as less light is reflected.

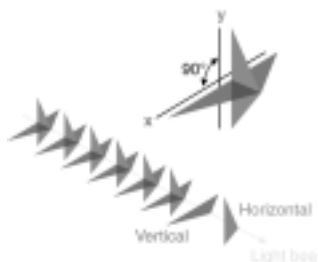


Polarized light sensors

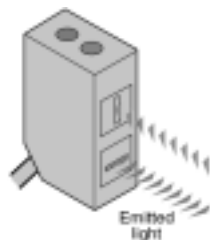
If, however, a shiny or glossy object passes in front of the sensor, this object can act as a reflector itself. When the light is reflected by the target object, the beam has effectively not been broken and the object has not detected. To overcome this problem we can choose sensors with polarized light sources and receivers.



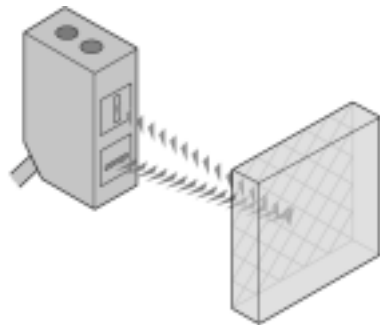
Instead of thinking of light as one uniform beam, simplified it can be split into two components that make up the beam. These components are horizontal light waves and vertical light waves. (This is shown in a simplified form in the illustration). These are at 90° to each other. This is called polarized light.



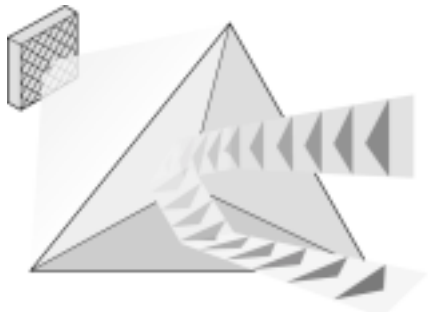
Using a polarizing filter, we can emit the light in one way only (in this case horizontally, as shown by the arrows).



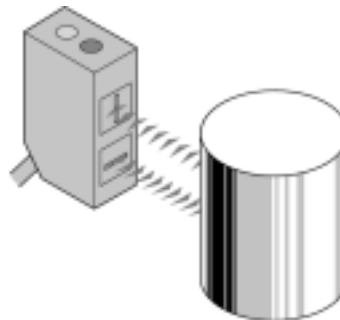
The light source is then transmitted in the usual way to be reflected back to the receiver. As can be seen, the light coming back to the sensor is in a different plane, it is now vertical. Only light that is in this plane will pass through the vertical filter. When the correct type of light is received back, the sensor recognizes that the beam path is established.



The light has actually been turned through the 90° by the corner cube reflector. This consists of many miniature reflectors. Each of these reflectors is actually three mirrored faces which the light reflects off. By reflecting the light three times it is turned 90°.



Using polarization, a shiny object passing between the sensor and reflector returns the beam in the same plane, i.e. horizontal. As the sensor is expecting to receive the light vertically, but does not, it knows that the beam has been broken and an object is present.



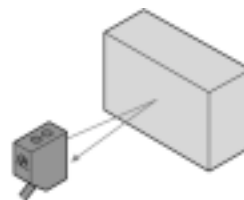
■ DIFFUSE

Principle of operation

The diffuse sensor incorporates the emitter and receiver in the same body, much like the retro-reflective sensors.

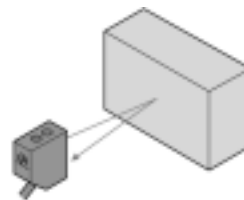


Unlike the retro-reflective sensors, there is no separate reflector to return the beam to the receiver. Instead the target itself reflects the light back to the sensor, and the target object is detected. This principle has the advantage to the user of only requiring wiring and fitting in one place, and for those applications where there is only access to one side.



Operation mode

Light-ON: The sensor output operates when the target reflects the beam back to the receiver.



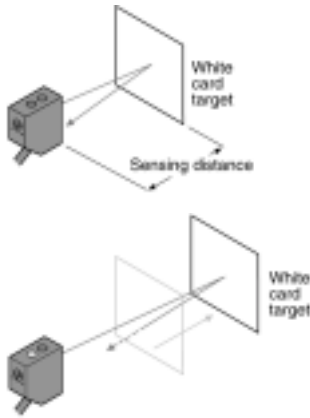
Dark-ON: The sensor output operates when no light is reflected to the receiver.



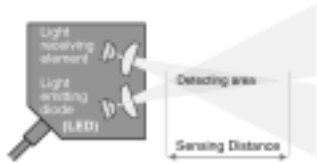
■ DIFFUSE continued

Sensing distance

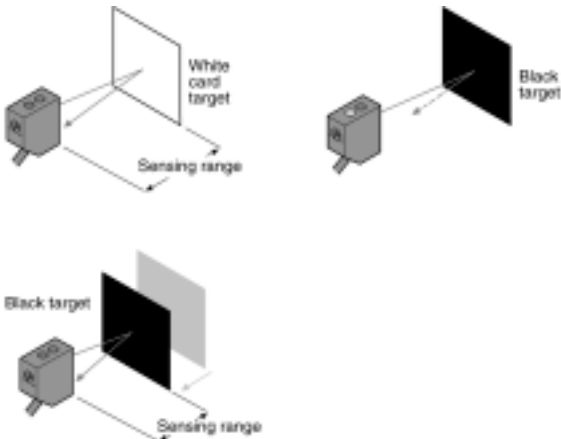
The sensing distances shown in the catalog for diffuse sensors are based on the maximum distance at which the sensor will stably detect a standard Kodak 90% reflectance white target. The closer the target is to the sensor, the more light is reflected. If the target is moved further away, less light is returned to the sensor. Eventually the target will reach a distance where it doesn't reflect enough light back and the target will not be detected.



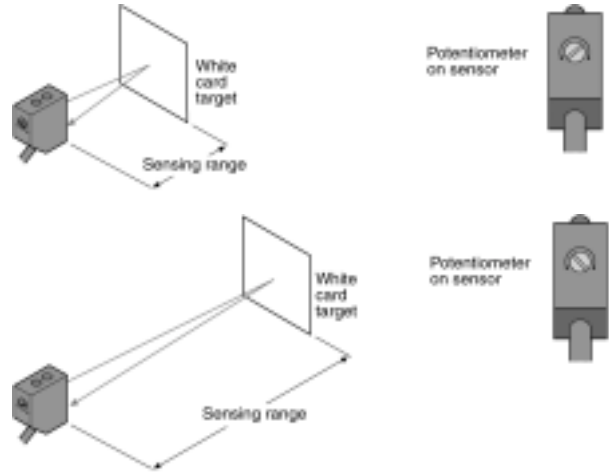
In the real world, however, the target is likely to be any color and this has to be taken into consideration when using a diffuse sensor. With a black target at the maximum sensing range, a standard diffuse sensor would be unable to detect it. This is because black absorbs light.



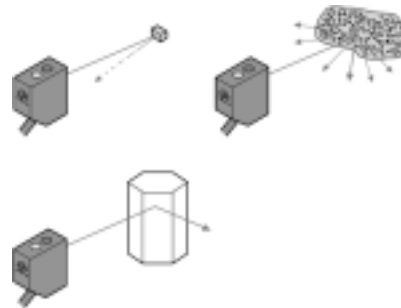
To sense the black target, shorten the distance between the sensor and the target. Doing this ensures enough light is reflected, enabling the sensor to operate. As diffuse sensors are affected by the color of the target they incorporate sensitivity adjustment into their design. Adjust the sensitivity to make allowances for color and distance from the sensor.



If the sensitivity is adjusted, the point at which the sensor operates can be controlled. When the potentiometer is turned fully clockwise the sensitivity is at a maximum, and objects can be detected at the greatest distance. By turning the adjustor counter-clockwise the sensor needs to receive more light to operate. By moving the target closer, more light is reflected to the receiver and the sensor operates.

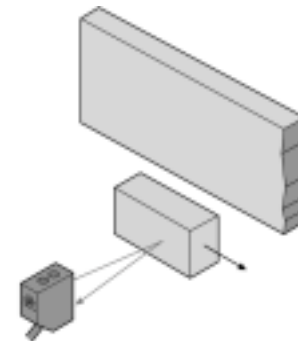


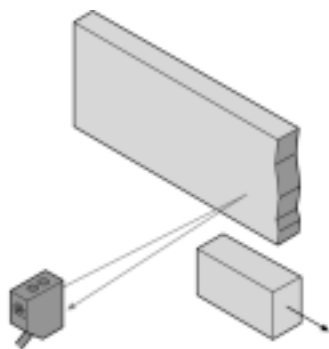
Along with color affecting the diffuse sensor, it is also influenced by the material, size and shape of the object. These factors affect the amount (intensity) of light reflected back to the sensor. The smaller the target, the less area there is to reflect light. Also, the material of the target will affect the amount of light. If the surface is uneven, light is reflected away from the target rather than back to the sensor. The same can occur with the shape of the target.



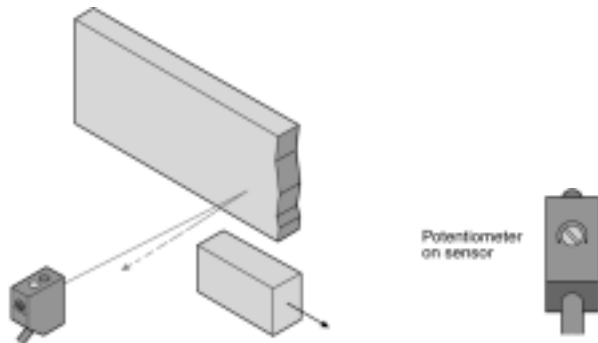
Background suppression

In some diffuse sensing applications the background area behind the target can influence the sensor's operation by reflecting the beam.

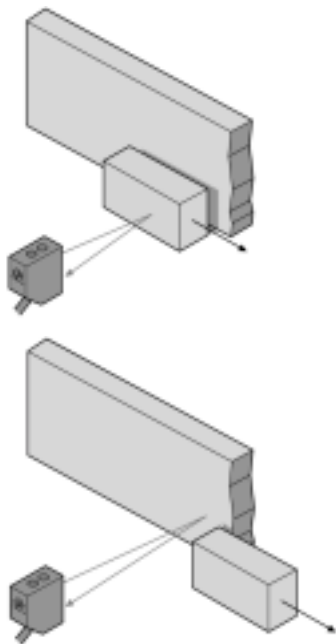




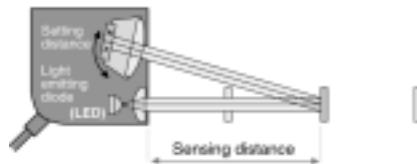
If the distance between the target and background is reasonable, then the use of the sensitivity adjustment will normally prevent "false" operations.



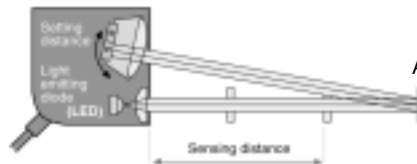
Sometimes, however, the difference in distance between the target and background is too small, and a standard diffuse sensor cannot be tuned to differentiate between the two. To overcome this problem, we use a refinement of the diffuse sensor. Background suppression sensors use a combination of mechanical and electrical principles to eliminate the influence of the background.



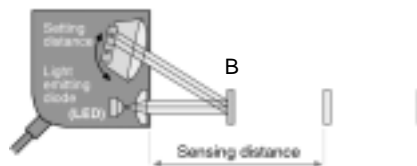
The sensor now consists of a light receiving element which can be moved along with the standard LED light source. The basis of the detection is by a trigonometrical range finding system. When the sensor is adjusted to detect the target at the correct distance, the light is reflected equally on elements N and F. By measuring how the light falls on the detector and comparing it to a reference, we can say the object has been detected.



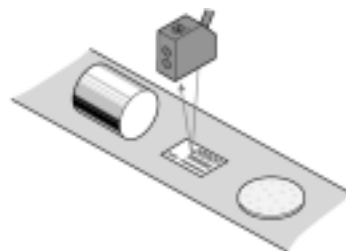
If there is a background, or the target moves away from the sensor, for example position A, then the light received falls on a different area of the detector. Since the light is received at F and none at N, the sensor is able to determine that the target is not at the correct position, and in effect that no target is present. This methodology eliminates the influence of the background. This form of operation is generally known as "Background suppression".



When the target moves toward the sensor, for example position B, then the light falls on N and none on F. In this case the sensor determines that a target is present, and as a result, operates as it is within the sensing range.

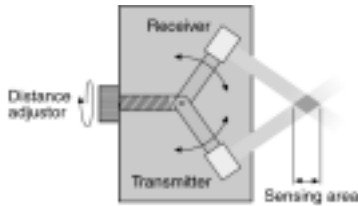


The principle of operation uses the position of the light detected, not its intensity. This gives the advantages of stable detection regardless of color, material or the size of the target.

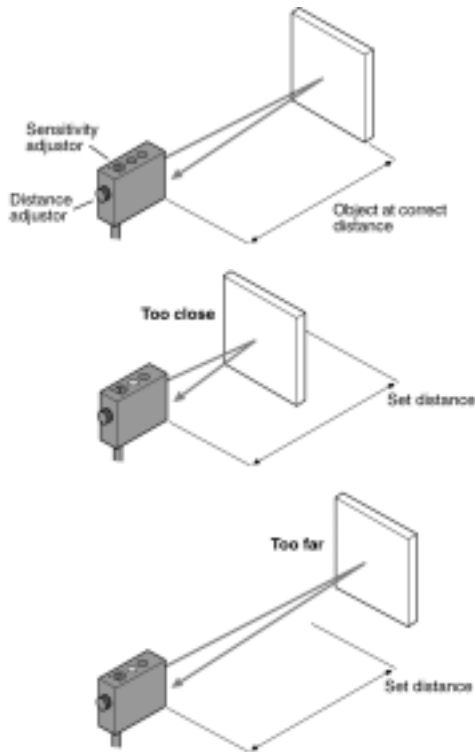


■ BACKGROUND/FOREGROUND SUPPRESSION (BGS/FGS)

This sensor (E3S-LS10) uses a slightly different method of operation to look for target objects. It is able to operate without influence of the background, and it will also ignore the presence of objects too close to it. The method uses mechanics to set the distance at which it operates, as is shown in the diagram.



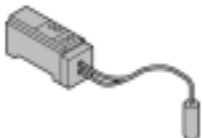
By moving both the transmitter and receiver together, the beam converges at different distances. In combination with this mechanical adjustment, a sensitivity adjuster is used to set the point at which the target is detected.



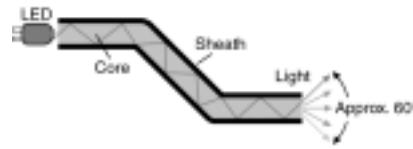
■ FIBER OPTICS

Principle of operation

Fiber optic photoelectric sensors consists of two parts, the amplifier and the sensing head. The amplifier contains the emitter (the light source) and the receiver (detector) along with their associated electronics. The fiber optic cable is the means used to transfer the light to the sensing head.



The light source (an LED) transmits the light beam down the fiber optic cable by repeatedly reflecting the light off the boundary between the fiber core and its sheath. When it reaches the end of the fiber the light is dispersed at the end.

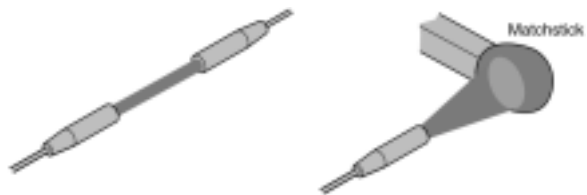


When the light is dispersed it spreads out and forms a beam much like that of other sensors, but on a smaller scale. With smaller light source and lens area the sensing range is on the whole much shorter.



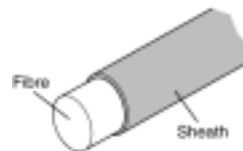
Types of fiber

Fiber optic heads mainly split into two types, through-beam and diffuse (although there are a few retro-reflective types). The principle of operation of both types is exactly that of standard photoelectric sensors.

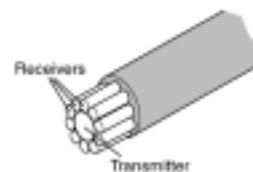


There are several types of fiber construction:

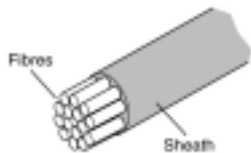
Standard fiber: Most fiber optic sensing heads use this configuration of fiber (i.e. a single fiber covered by a protective sheath). The fibers are usually plastic, 0.5 to 1 mm in diameter and covered in a plastic protective sheath.



Concentric fiber: This gives greater accuracy. The core is used as the transmitter and the surrounding fibers are bundled together to form the receiver. This provides better accuracy, allowing the target to enter the detecting area from any direction.



Multicore: These consist of large numbers of small fibers. This results in a more flexible cable (E32-R types) which can literally be tied in a knot without loss of light intensity. With a 1 mm minimum bending radius, these fibers can follow robot contours.

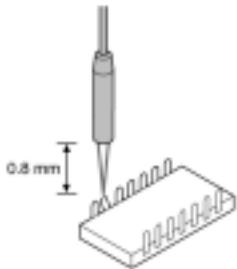


Using fiber optic sensors

The main advantage of fiber optics is their small package. They can be mounted in places where other sensors can't fit. Some fibers are as small as 0.8 mm in diameter at the sensing head. However, being of a smaller construction, they are less mechanically robust.

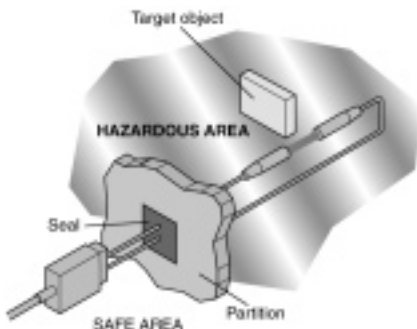


Since the sensor heads are extremely compact, they are ideal for the stable detection of small objects. As a result of less light that is emitted they generally have a smaller range than conventional photoelectric sensors.

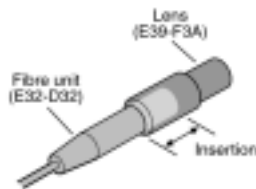


Fiber optic sensor heads can be used in areas that standard sensors are unable to go, for instance hazardous areas. This is because no electric current flows through them. This also means they are totally unaffected by electrical noise (provided the amplifier is suitably positioned).

By using glass fibers instead of plastic they can be used in areas of up to 300°C.



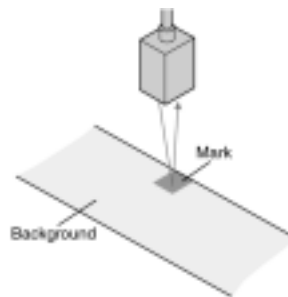
Extremely small objects can be detected with a diffuse sensor and additional lens. Using diffuse fiber sensors, objects as small as 0.5 mm can be detected.



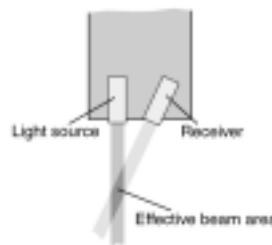
■ COLOR MARK AND RGB SENSORS

Mark sensors

Mark sensors are a type of diffuse sensor, designed to detect a mark by the contrast between the mark and the background.

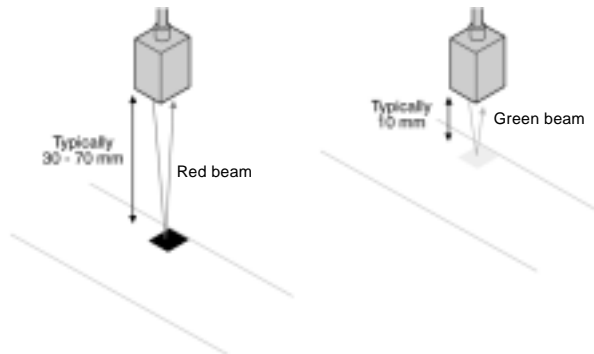


The lens arrangement of the sensors is slightly different to a standard diffuse type in that they are focused. The amplifier also differs in that it is more sensitive to changes of color.



The sensitivity of mark sensors is also influenced by the light source used. A red light source (which is the normal light source for most diffuse sensors) provides reasonable sensing distances, but is more limited in its response to color combinations, and in particular red on white as the red content is reflected.

For a green or blue light LED, a smaller sensing distance can be used. It is much more sensitive across the color range and is better for like colors (i.e. less of a contrast between mark and background).

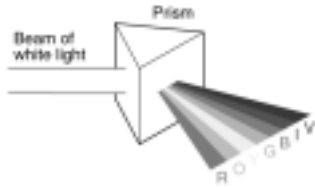


■ COLOR MARK AND RGB SENSORS continued

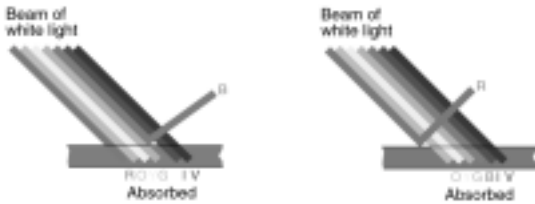
RGB color sensor

The sensing capabilities of the diffuse sensors mentioned up to this point are based on the amount of light that is received by their detectors. Light is actually made up of many different parts, visible light only being a small part of the composition of light.

A prism can show that white light is in fact made up of a number of mixed colors. By shining the light through the prism, it is split into seven colours: Red, Orange, Yellow, Green, Blue, Indigo, Violet (R O Y G B I V).



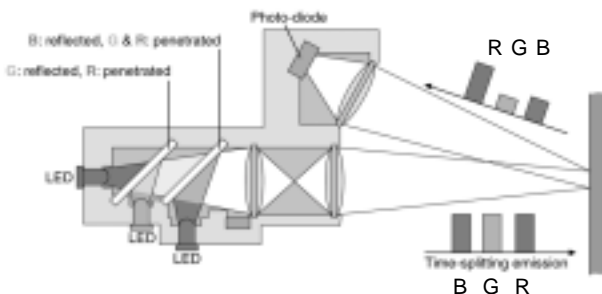
When we look at a color, what we actually see is the effect the color has on the light shining on it. If we are looking at what we perceive to be a blue object, what we are seeing is the object reflecting the blue part of the light back and absorbing the remaining colors. The same applies for other colors. When different amounts of these seven colors are absorbed and reflected, we are able to see millions of colors.



We can actually make any color from three constituents, Red, Green and Blue. If these are mixed they appear white. We can simulate this by spinning a disk with the three colors on it at a high speed.

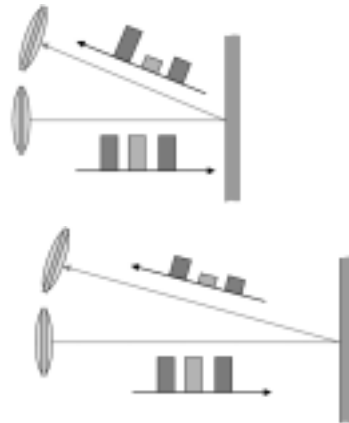


To detect colors accurately we can analyze the contents of the light that is reflected. Firstly, however, we need to know the exact nature of the light that is transmitted. The E3MC sensor has three light sources, Red, Green and Blue LEDs. They emit light via the same lens and this is reflected from the target object. Depending on the color of the target object, different quantities of light are absorbed and reflected.



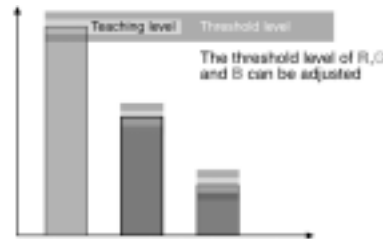
C mode

The reflected light is detected by a photodiode and is then analyzed by the sensor for the content of R (red), G (green) and B (blue). The operation of the sensor is then dependent upon which of the two operation modes the user has selected. If C mode has been used the ratio between R, G and B is analyzed. Regardless of the sensing distance the color ratio of the light will not change, although the intensity will. This gives the advantage of stable detection if the target is mechanically fluctuating.

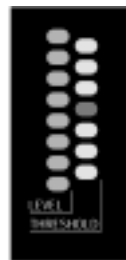


I mode

In I mode the detection of minute color differences is possible. This mode uses the intensity of the RGB reflected light. Using this method, the detection of minute color differences is achieved, but the sensor is influenced by the mechanical position of the target, unlike the C mode.



Whichever method is applied, the sensor is easy to use. A teach function is used to teach the target color required. The light received is indicated by a bar graph and the threshold level can be set to determine the operation point.



■ LASER SAFETY GUIDELINES

Laser Safety Standards and Hazard Classifications

Laser safety standards classify lasers by their hazard potential based upon their optical emission. Based upon the hazard the laser presents, and for each classification, a standard set of control measures applies. In this manner, unnecessary restrictions are not placed on the use of many lasers which are engineered to assure safety.

This philosophy has given rise to a number of specific classification schemes such as the one employed in the American National Standards Institute's (ANSI) Z136.1 Safe Use of Lasers (1993) standard. This standard was developed by the accredited standards committee Z136, and the Laser Institute of America is the secretariat. This standard has been used as a source by many organizations including the Occupational Health and Safety Agency (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) in developing their laser safety guidelines.

The ANSI scheme has four hazard classifications. The classification is based upon the beam output power or energy from the laser (emission) if it is used by itself. If the laser is a component within a laser system where the raw beam does not leave the enclosure, but instead a modified beam is emitted, the modified beam is normally used for classification. The classification scheme is used to describe the capability of the laser or laser system to produce injury to personnel. The higher the classification number, the greater the potential hazard. Brief descriptions of each class are as follows:

Class 1

This denotes lasers or laser systems that do not, under normal operating conditions, pose a hazard.

Class 2

This denotes low-power visible lasers or laser systems which, because of the normal human aversion response (i.e., blinking, eye movement, etc.), do not normally present a hazard, but may present some potential for hazard if viewed directly for extended periods of time (like conventional light sources).

Class 2a

This denotes low-power visible lasers or laser systems that are not intended for prolonged viewing, and under normal operating conditions will not produce a hazard if the beam is viewed directly for periods not exceeding 1000 seconds.

Class 3a

This denotes lasers or laser systems having a CAUTION label that normally would not injure the eye if viewed for only momentary periods with the unaided eye, but may present greater hazard if viewed using collecting optics. Another group of Class 3a lasers have DANGER labels and are capable of exceeding permissible exposure levels for the eye in 0.25 s but they pose a low risk of injury.

Class 3b

This denotes lasers or laser systems that can produce a hazard if viewed directly. This includes intrabeam viewing of specular reflections. Normally, Class 3b lasers will not produce a hazardous diffuse reflection.

Class 4

This denotes lasers or laser systems that produce a hazard not only from direct or specular reflections, but may also produce hazardous diffuse reflections. Such lasers may produce significant skin hazards as well as fire hazards.

Safety Procedures for Each Laser Classification

The hazard controls necessary for laser radiation vary with:

1. the laser classification;
2. the environment where the laser is used; and
3. the people operating or within the vicinity of the laser.

The ANSI standard lists safety procedures by laser classification. Users can determine which rules are relevant to their particular environment by considering the environment where people are potentially exposed to the optical radiation from the laser. In all cases, the safest user is the informed user, and some form of laser safety education program is recommended for all laser users (such as reading this section).

Safety Rules for Class 1 Lasers

"Eye Safe" lasers are by definition devices which cannot be considered hazardous even if all of the laser output were directed into the eye's pupil or focused into a 3.5 mm spot on the skin for the classification duration (e.g. 3×10^4 seconds), therefore there are no safety requirements.

The Federal product performance standard and the ANSI Z136.1 (1993) laser safety standard definitions of a Class 1 laser product include the concept of embedded lasers of higher power. Both standards require that a warning sign should be located at an access panel to alert a user that more hazardous laser radiation is contained therein. Another panel covering the warning sign and access panel is permitted.

Safety Rules for Class 2 Lasers

"Low-Power" lasers are by definition incapable of causing eye injury within the duration of the blink, or aversion response (0.25 s), and must be visible (400 to 700 nm). Therefore, an ocular hazard can only exist if an individual overcomes their natural aversion to bright light and stares directly into the laser beam. The product requirements for these lasers are two: to have a CAUTION label and to have an indicator light to indicate laser emission.

The two operational safety rules are:

- Do not permit a person to stare at the laser from within the beam.
- Do not point the laser at a person's eye at close range.

Safety Rules for Class 3 Lasers

Although these "medium-power" lasers usually present a serious potential for eye injury resulting from intrabeam viewing, they generally do not represent a diffuse reflection hazard, a skin hazard for momentary exposure, or a fire hazard. To eliminate the possibility of intrabeam viewing, follow these control measures:

- Never aim the laser at a person's eye.
- Use proper safety eyewear if there is a chance that the beam or a hazardous specular reflection will expose the eyes.

Safety Procedures continued

- Permit only experienced personnel to operate the laser and do not leave an operable laser unattended if there is a chance that an unauthorized user may attempt to operate the laser. A key switch should be used if untrained persons may gain access to the laser. A warning light or buzzer may be used to indicate when the laser is operating.
- Enclose as much of the beam's path as practicable.
- Avoid placement of the unprotected eye along or near the beam axis as attempted in some alignment procedures. The chance of hazardous specular reflections is greatest in this area.
- Terminate the primary and secondary beams, if possible, at the end of their useful paths.
- Use beam shutters and laser output filters to reduce the beam power to less hazardous levels when the full output power is not required.
- Assure that any spectators are not potentially exposed to hazardous conditions.
- Keep laser beam paths above or below eye level for either sitting or standing position.
- Operate the laser only in a well-controlled area. For example, within a closed room with covered or filtered windows and controlled access.
- Label lasers with appropriate Class 3 danger statements and placard hazardous areas with danger signs if personnel can be exposed.
- Mount the laser on a firm support to assure that the beam travels along the intended path.
- Do not look directly into a laser beam with optical instruments unless an adequate protective filter is present within the optical train.
- Eliminate unnecessary specular (mirror-like) surfaces from the vicinity of the laser beam path, or avoid aiming at such surfaces.

Safety Rules for Class 4 Lasers

These "high-power" lasers present the most serious of all laser hazards. Fortunately, these lasers are seldom found outside research laboratories and hospital operating rooms, and are not part of the Omron sensor line.

PHOTOELECTRIC SENSORS TECHNICAL INFORMATION

ENGINEERING CONTROL MEASURES

| Control measure | 1 | 2a | 2 | 3a | 3b | 4 |
|----------------------------------|-------|-------|-------|-------|-------|-------|
| Protective housing | X | X | X | X | X | X |
| Without protective housing | ■ | ■ | ■ | ■ | ■ | ■ |
| Interlocks on protective housing | ▲ | ▲ | ▲ | ▲ | X | X |
| Service access panel | ▲ | ▲ | ▲ | ▲ | X | X |
| Key control | — | — | — | — | • | X |
| Viewing portals | — | — | MPE | MPE | MPE | MPE |
| Collecting optics | MPE | — | MPE | MPE | MPE | MPE |
| Totally open beam path | — | — | — | — | X NHZ | X NHZ |
| Limited open beam path | — | — | — | — | X NHZ | X NHZ |
| Enclosed beam path | ■ | ■ | ■ | ■ | ■ | ■ |
| Remote interlock connector | — | — | — | — | • | X |
| Beam stop or attenuator | — | — | — | — | • | X |
| Activation warning system | — | — | — | — | • | X |
| Emission delay | — | — | — | — | — | X |
| Indoor laser controlled area | — | — | — | — | X NHZ | X NHZ |
| Class 3b laser controlled area | — | — | — | — | X | — |
| Class 4 laser controlled area | — | — | — | — | — | X |
| Laser outdoor controls | — | — | — | — | X NHZ | X NHZ |
| Laser in navigable airspace | — | — | — | • | • | • |
| Temporary laser controlled area | ▲ MPE | ▲ MPE | ▲ MPE | ▲ MPE | — | — |
| Remote firing and monitoring | — | — | — | — | — | • |
| Labels | X | X | X | X | X | X |
| Area posting | — | — | — | • | X NHZ | X NHZ |

Legend:

- X = Mandatory
- = Suggested
- = No requirement
- ▲ = Mandatory if enclosed Class 3b or Class 4
- MPE = Mandatory if Maximum Permissible Exposure is exceeded
- NHZ = Nominal Hazard Zone analysis required
- = Laser Safety Officer determination

ADMINISTRATIVE AND PROCEDURAL CONTROL MEASURES

| Control measure | 1 | 2a | 2 | 3a | 3b | 4 |
|-----------------------------------|-------|-------|-------|-------|-------|-------|
| Standard operating procedures | — | — | — | — | • | X |
| Output emission limitations | — | — | — | ■ | ■ | ■ |
| Education and training | — | — | • | • | X | X |
| Authorized personnel | — | — | — | — | X | X |
| Alignment procedures | — | — | X | X | X | X |
| Protective equipment | — | — | — | — | • | X |
| Spectator | — | — | — | — | • | X |
| Service personnel | ▲ MPE | ▲ MPE | ▲ MPE | ▲ MPE | X | X |
| Demonstration with general public | MPE | — | X | X | X | X |
| Laser optical fiber systems | MPE | MPE | MPE | MPE | X | X |
| Laser robotic installations | — | — | — | — | X NHZ | X NHZ |
| Eye protection | — | — | — | — | • MPE | X MPE |
| Protective windows | — | — | — | — | X NHZ | X NHZ |
| Protective barriers and curtains | — | — | — | — | • | • |
| Skin protection | — | — | — | — | X MPE | X MPE |
| Other protective equipment | ■ | ■ | ■ | ■ | ■ | ■ |
| Warning signs and labels | — | — | • | • | X NHZ | X NHZ |
| Service and repairs | ■ | ■ | ■ | ■ | ■ | ■ |
| Modification of laser systems | ■ | ■ | ■ | ■ | ■ | ■ |

Legend:

- X = Mandatory
- = Suggested
- = No requirement
- ▲ = Mandatory if enclosed Class 3b or Class 4
- MPE = Mandatory if Maximum Permissible Exposure is exceeded
- NHZ = Nominal Hazard Zone analysis required
- = Laser Safety Officer determination

Contents paraphrased from "Laser Safety Guide" with permission of the Laser Institute of America. To order a complete copy, write the Laser Institute of America, 12424 Research Parkway, Suite 125, Orlando, FL 32826.

PHOTOELECTRIC SENSORS TECHNICAL INFORMATION

■ NOMENCLATURE

Part Number
Key

E3 S□ - D S 2 0 □ E 4 □ □ - □
1 2 3 4 5 6 7 8 9 10 11 12

| Key | Subject | Character | Description |
|-----|------------------------------|--|--|
| 1 | Product family | E3 | Photoelectric sensor |
| 2 | Series | A to Z | For example, S, JU, V, X |
| 3 | Method of detection | Blank D G L M R V X | Separate type (through-beam type) Diffuse reflective Grooved head or slotted Convergent beam with definite sensing distance Color Retroreflective Mark sensor Uses fiber-optic cables |
| 4 | Unit of sensing distance | Blank S M | Meters Centimeters (precedes figure) Millimeters (precedes figure) |
| 5 | Sensing distance | Numbers | Sensing distance with standard object |
| 6 | Optical system | Blank X | Fixed optics Variable optical system |
| 7 | Light source | Blank G H R | Usually infrared LED, but other sources possible Green LED, usually in mark sensing Infrared LED Red LED, usually in mark sensing |
| 8 | Power source and output type | A B C E F H K M Y Z | Solid-state AC 4-wire, short-circuit protected Solid-state DC 3-wire, PNP open collector Solid-state DC 3-wire, NPN open collector Solid-state DC 3-wire, NPN with pull-up resistor Solid-state DC 3-wire, PNP with pull-down resistor Complementary DC, both NPN and PNP outputs Relay output Universal AC/DC supply with relay output Solid-state AC 2-wire Solid-state AC 3-wire |
| 9 | Operation mode | 1 2 3 4 | Light-ON operation Dark-ON operation Light-ON and Dark-ON for both outputs Selectable Light-ON/Dark-ON operation |
| 10 | Sensing direction | Blank 1 2 | Top sensing (in relation to mounting holes) Side sensing (lens on same surface as label) Side sensing (lens is 90° to right of label) |
| 11 | Extra functions | D S T | Built-in timer (single) Self-diagnostics Built-in timer (dual) |
| 12 | Special type code | Blank MN1 M1C or P1 5M 10M | Standard cable length, 2 m (6.56 ft) Mini-Change® style receptacle for connector Micro-Change® style receptacle for connector 5 m (16.4 ft) cable length 10 m (32.8 ft) cable length |

Micro-Change and Mini-Change are registered trademarks of Woodhead Industries, Inc.

■ WIRE GAUGE

| AWG | mm ² | Diameter (mm) | Diameter (in) |
|-----|-----------------|---------------|---------------|
| 27 | 0.099 | 0.361 | 0.014 |
| 26 | 0.129 | 0.405 | 0.016 |
| 25 | 0.163 | 0.455 | 0.018 |
| 24 | 0.203 | 0.511 | 0.020 |
| 23 | 0.291 | 0.573 | 0.024 |
| 22 | 0.317 | 0.644 | 0.025 |
| 21 | 0.397 | 0.723 | 0.028 |
| 20 | 0.519 | 0.812 | 0.032 |
| 19 | 0.657 | 0.912 | 0.036 |
| 18 | 0.811 | 1.024 | 0.040 |
| 17 | 1.025 | 1.15 | 0.045 |
| 16 | 1.32 | 1.29 | 0.051 |
| 15 | 1.65 | 1.45 | 0.057 |
| 14 | 2.08 | 1.63 | 0.064 |
| 13 | 2.63 | 1.83 | 0.072 |
| 12 | 3.32 | 2.05 | 0.081 |

■ WAVELENGTH

| Color | Wavelength |
|-------------|--------------|
| Ultraviolet | below 400 nm |
| Violet | 400-450 nm |
| Blue | 450-500 nm |
| Green | 500-570 nm |
| Yellow | 570-590 nm |
| Orange | 590-610 nm |
| Red | 610-700 nm |
| Infrared | above 700 nm |

■ CONVERSIONS

| | |
|---------------------------------------|--------------------------|
| Length | |
| 1 inch = 25.4 mm | 1 mm = 0.03937 inch |
| Torque | |
| 1 kgf•m = 86.796 lbf•in | 1 lbf•in = 0.01152 kgf•m |
| Weight | |
| 1 gram = 2.205 x 10 ⁻³ lbs | 1 lb = 453.6 grams |