Handbook of Photoelectric Sensing

Banner Engineering Corp.
Minneapolis, MN

Handbook of Photoelectric Sensing

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Introduction

Photoelectrics: The Past

Albert Einstein first gave momentum to photoelectric science when he published his Nobel Prize winning paper on quanta in 1905. His theory explained the *photoelectric effect*, which had been observed but not fully explained by scientists for many years. It was a bold proposition that light energy travels through space in concentrated bundles (now called *photons*). Photons that strike a material (especially a metal surface) liberate photoelectrons, and the energy from those photoelectrons may be used to create current flow. Careful experiments by R.A. Millikan in 1914 and 1916 confirmed Einstein's theory.

A growing understanding of the photoelectric effect over the next fifty years led to the development and evolution of various *opto-electronic devices.* The first applied photoelectric device was the photoemissive cell or *phototube*, whose primary application was in movie sound reproduction. The fragile nature of phototubes, however, limited their use in industrial sensing.

In the late 1940s, the photoconductive cell *(photocell)* was developed for use in light sensing circuits. Although it was originally manufactured in a fragile glass envelope, the photocell did have the advantage of being much smaller and simpler in function than the phototube.

From the beginning, photoelectric receivers took on the shape of small, round metal barrels, with a collimating lens on one end and a cable exiting the opposite end. The cable connected the photocell to a tube-type amplifier. Small incandescent bulbs, protected in matching metal barrels, were the opposing light source. These smaller and more rugged devices made *beam-break* (opposed) photoelectric sensing an attractive mode for many industrial applications, and were the forerunners of today's sensor designs.

The key to sensing success in the days of incandescent photoelectrics was to make the photocell "see" the light from its source without gathering any stray (ambient) light. This was usually not a problem deep inside machines or in elevator doors. However, ambient light rejection was a major requirement in almost all sensing situations. Lenses with long focal lengths were necessary to beam adequate light energy (to overcome the ambient light) from the light bulb to its photocell. Unfortunately, these long focal lengths made sensor alignment critical and difficult.

The *retroreflective* sensing mode was invented and first applied in the late 1950s. This mode took advantage of the *cube-corner* principle of light reflection and of 3M's mass production of

Photoelectric Sensors, old and new

Scotchlight® and Reflectolite® retroreflective materials, originally designed for highway signs and markers. Retroreflective sensors were easy to align to their retroreflective targets and gained instant popularity.

With the coming of the silicon transistor in the mid 1950s, photoelectric sensor manufacturers were quick to design them into new solid-state amplifiers for photocell receivers. This development had the obvious benefits of reduced heat, size, and cost, plus increased reliability. It also gave rise to the development of the first *self-contained photoelectric control*, which combined the optoelement(s) with the amplifier and output switch together in one housing.

The 1960s brought us solidly into the silicon era and produced *photojunction devices* including *photodiodes, phototransistors,* and *photodarlingtons.* The '60s also produced the *light emitting diode* solid-state light source, and the first offering of the LED emitter by photoelectric sensor manufacturers as an option to the standard incandescent source. LEDs were at first simply substituted for the bulb in existing emitter housings. LEDs eliminated the worries of filament sag, bulb burnout, and sensitivity to vibration. But there was a trade-off in limited sensing range: early LEDs produced only about 1% of the light intensity of an incandescent bulb of the same size.

Infrared LEDs are the most efficient light generators, and were the only type of LED offered until 1975. This "new" invisible light was not well-received by those who were accustomed to visually aligning and checking their visible incandescent emitters.

An infrared LED emitter was usually paired with a phototransistor receiver because of the phototransistor's good spectral response to infrared light.

The *phototransistor* has prevailed as the most widely used receiver optoelement in industrial photoelectric sensor design. Phototransistors offer the best trade-off between light sensitivity and speed of response as compared to photoresistive and other photojunction devices. *Photocells* are used whenever their greater sensitivity to visible wavelengths is required, as in color registration and ambient light detection applications. *Photodiodes* are generally reserved for applications requiring either very fast response or linear response over several magnitudes of light level change.

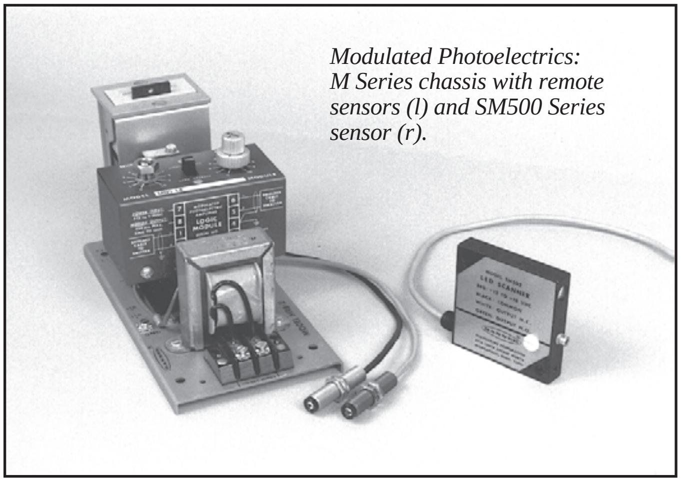
By 1970, photoelectric sensor designers recognized that the LED had a benefit much more profound than its long life. Unlike their incandescent counterparts, LEDs can be turned on and off at a high frequency, typically several kilohertz. This *modulating* of the LED meant that the amplifier of the phototransistor receiver could be *tuned* to the frequency of modulation, thus amplifying only light signals of that frequency.

This discovery caused a major revolution in photoelectric sensor design. Sensing ranges increased. Beam angles widened. Through the 1970s, users of modulated devices gradually began to place their trust in this invisible beam that they found so dependable and easy to align. Gone were the long focal length lenses, and alignment became simply a matter of line-of-sight positioning.

Retroreflective sensors only got better, with ranges typically reaching two to three times those of non-modulated equivalents. Also, modulation made direct-reflection sensing modes viable. Previously, non-modulated photoelectric sensors were sometimes used to sense an object by sensing the light reflected directly from the object's surface (photoelectric *proximity* mode). Sensing ranges of under two inches had been typical. Sensing ranges of the new modulated proximity sensors started out at several inches and have now grown to several feet.

A small number of engineers pioneered modulation methods and applied their schemes to industrial photoelectric controls. Among those engineers was Robert W. Fayfield of Banner Engineering Corp. In 1974, he introduced the SM500 Series of modulated *self-contained* sensors and the M Series of modulated *remote* sensors and amplifiers. The SM500 Series was first developed for retroreflective code reading, which explains its unique shape. Multiple SM502s were stacked on 1/2" centers for reading small retroreflective code plates in warehousing and identification systems. The shape of the SM502 became very popular, and a complete SM500 (aka "flat-pack") sensor family evolved in the same die-cast housing. The SM502A was also the first modulated photoelectric sensor to use a visible (red) LED for its light source.

The M Series placed a modulated amplifier plus a logic timer into the already-familiar aluminum octal base module "can" which had been used for years by Farmer Electric (and later by Banner) for their non-modulated amplifier modules. The remote sensors used by the M Series amplifiers are extremely rugged, and their performance set the standard for the modulated sensors that followed.



Modulated Photoelectrics: M Series chassis with remote sensors (l) and SM500 Series sensor (r).

The MULTI-BEAM®, introduced in 1978, revolutionized the photoelectric control industry by creating a new standard of performance for small, self-contained, modulated photoelectric sensors. It is a standard that still applies today. The MULTI-BEAM offered a number of "firsts", including the first compact ac self-contained sensor, the first PLC-compatible 2-wire sensor, the first limit-switch style photoelectric sensor, and the first built-in signal strength alignment indicator. The modular design of the MULTI-BEAM also offered a new approach to sensor customization. Over 5,000 different sensor models may be derived from the selection of the three component parts (scanner block, power block, and logic module). The MULTI-BEAM moved Banner toward its present status as the leader in the industrial photoelectric control field. Innovations in subsequent product families like the MINI-BEAM®, MAXI-BEAM®, OMNI-BEAM™, and MAXI-AMP™ have helped Banner earn a worldwide reputation as "the photoelectric specialist".

By 1980, the non-modulated photoelectric sensor was generally out of favor. In fact, many highly-automated processes could simply not tolerate the interruptions caused by bulb burnout. Exceptions included color sensing and applications requiring very high sensing response speed. Color registration sensors, like the model FO2BG, continued to use photocell receivers and incandescent lamps while sensor designers waited for more efficient visible LEDs to be developed.

For modulated sensors, sensing distance was the dominant design criterion. Modulated designs gave up speed of response in return for sensing distance. As a result, non-modulated sensors using phototransistors and either incandescent or LED emitters were sometimes still used to sense small parts or features moving at a high rate of speed.

One benefit of advancing solid-state technology was increased sensor ruggedness. As confidence in the reliability of modulated LEDs grew during the late 1970s, Banner began to epoxy encapsulate sensor circuitry. This enabled photoelectric sensors to reliably enter NEMA 4 (IP 65) environments for the first time. Further improvements in mechanical design have produced sensors with submersible NEMA 6P (IP 67) ratings.

Banner design engineers have been quick to take advantage of continuing advances in semiconductor technology through the 1980s and 1990s. As integrated circuits became more available, sensor electronics became smaller, more efficient, and less costly.

The design focus throughout the '70s and early '80s was on the miniaturization of self-contained modulated LED sensors. During the early 1980s, Banner design engineers began development of custom circuit components. They set about to develop digital modulation schemes for monolithic photoelectric amplifier ICs. In parallel with custom semiconductors, they took advantage of SMD technology. By 1985, self-contained photoelectric sensors had taken a quantum step in size reduction with the introduction of the VALU-BEAM® and MINI-BEAM® families. The next step down in sensor size was in 1992 with the Q19 and QØ8 Series families.

Photoelectrics: The Present

In addition to the advantage of small sensor size, present-day advances in semiconductor technology have made possible better sensor performance, more sensor features, and lower sensor cost. Improved amplifier design has produced longer sensing ranges, and longer sensing ranges have brought about good sensor performance at faster sensing response speeds.

Measurement of a sensor's *excess gain* quantifies the amount of optical sensing energy in a photoelectric sensing system in excess of the minimum light energy required in a clean environment. Excess gain is one of the specifications that is used to predict the success of applying a photoelectric sensor in a given sensing environment. Using today's opposed mode photoelectric sensors, excess gains of more than 100,000 are common is some situations. This is enough light energy to optically penetrate ("see through") cardboard and opaque plastic walls.

Higher available excess gain has enabled sensors to be used with smaller lenses or with small fiber optics to yield higher sensing resolution. Today, position sensing repeatability of less than .001 inch is routinely achieved with opposed or convergent mode modulated LED sensors.

New *digital* modulation designs have improved sensor noise immunity at a time when more and more sources of stray RF energy are working their way into sensing environments. Federal agencies have placed limits on allowable levels of RFI emission from computers, controllers, CRTs, etc. However, the collective level of RFI energy now present in the typical automated factory is often enough to saturate older analog modulated amplifier designs. Banner sensor designers have also focused attention in recent years on "bulletproofing" new and existing sensors against the effects of electromagnetic interference (EMI).

Improved sensor noise immunity has eliminated the need for expensive metal enclosures that were required for many years to shield high-gain photoelectric amplifiers from airborne and induced electrical "noise". Mechanically tough, corrosion-resistant engineering thermoplastics (such as VALOX®, see photo above) now dominate as sensor housing materials.

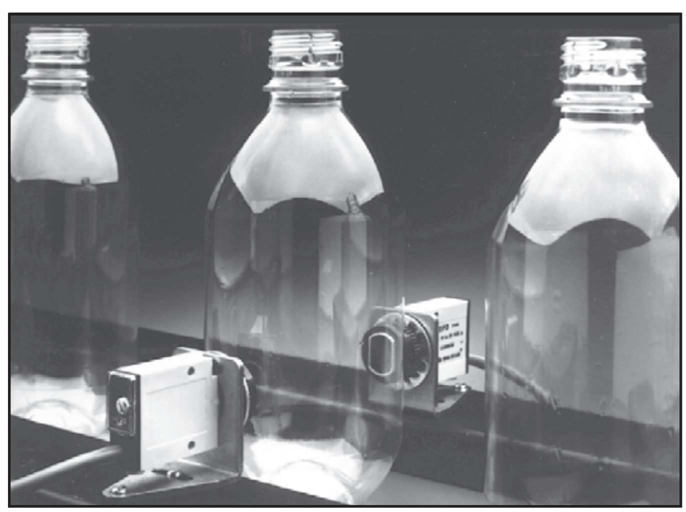
The custom integrated circuits used in Banner photoelectric sensor designs have brought with them some added sensor features. One example of a feature that has come (almost) "for free" is the intelligent alignment status indicator. Banner's Alignment Indicator Device (**AID**™) system actually tells the installer when the sensor is aligned, and also tells *how well* it is aligned. This indicator also serves as a maintenance warning when sensor signal strength becomes marginal. The **D.A.T.A.**™ (Display And Trouble Alert) system of the OMNI-BEAM sensor family displays excess gain, *plus* sensing contrast, and its dedicated alarm output warns of marginal sensing conditions.

Today's photoelectric sensors require much less power than comparable sensors of a decade ago. Specially-designed photoelectric sensors, such as the SMI912 Series, can now be rated *intrinsically safe* for use in hazardous areas. Today's sensors have much wider voltage ranges. DC sensors are protected against power supply polarity reversal. Many sensors may be powered by *either* ac or dc voltage, and solid-state sensor outputs are protected from overload and inductive transients.

In addition to its pioneering work with infrared sensors, Banner has engineered the "comeback" of the visible light source. Improvements in the output of visible LEDs, plus substantial improvements in amplifier design, have recently brought respectable performance to modulated visible LED sensors. Infrared LED sensors do remain the first choice for applications that require high levels of excess gain, but ease of sensor alignment (plus the comfort associated with being able to see the light from the emitter) has revived the popularity of the visible photoelectric light source.

The use of visible LEDs has solved some classic sensing problems. *Polarizing* the light from a visible LED emitter has all but eliminated the false return of light ("proxing") from shiny materials in a retroreflective beam. Polarized visible light is also used to reliably sense clear plastic materials (see photo, below).

VALOX® is a registered trademark of General Electric Company



Another important use of visible LEDs is with plastic fiber optics, which are poor conductors of infrared light. Plastic fiber optics are single strands of fiber material that can fit into extremely tight areas. Cut-to-length plastic fiber optics are fast becoming popular among machine designers, especially for multiple-point sensing applications. Typically, the photoelectric sensors are gang-mounted in a convenient location and plastic fibers are simply routed to the sensing points. Coiled plastic fiber optics solve the age-old problem of sensing reliably (without fiber breakage) on reciprocating mechanisms or robotic arms.

Glass fiber optics remain very popular for difficult or otherwise impossible sensing applications. Glass fiber optic assemblies are used to pipe light into and out of areas of high temperature, high shock and vibration, and extreme moisture and/or corrosiveness. Glass fiber optics may be quickly and economically designed and built to fit an exact physical space or sensing requirement. Banner was an innovator of LED fiber optic control, and remains the leader in their application. Over the years, Banner has built thousands of special glass fiber optic assemblies to fill *specific* application requirements. We always welcome your application requirements and encourage your design ideas.

Self-contained photoelectric sensors include an output switch to interface the sensor to an external circuit. The attention given to the design of the output configuration of Banner sensors has centered around interfaceability to programmable logic controllers (PLCs). The automated factory of the 1990s has adopted the PLC to integrate process control. Today's photoelectric sensor is more likely to be used to supply data to a computer or controller than to actually perform a control function. A sensor is now less likely to have a built-in delay timer or an electromechanical relay as its output device.

Another obvious and welcome trend has been toward lower cost. Circuit technology and manufacturing engineering have contributed heavily toward actually *reducing* sensor cost.

In 1987, Banner began manufacturing *ultrasonic* sensors. Ultrasonic sensors economically fill two photoelectric application voids. First, electrostatic-type ultrasonic sensors offer very long-range reflective sensing (up to 20 feet). Secondly, the output of analog ultrasonic proximity sensors, e.g. the analog ULTRA-BEAM™, may be made highly linear relative to sensing distance. Analog ultrasonic proximity sensors are often used for accurate distance measurement, as in fill-level and position control applications.

Photoelectrics: The Future

Banner design engineers continue to take full advantage of breakthroughs in semiconductor technology. In the future, photoelectric sensor size will be dictated more by lens size, cable size, or mounting scheme, and less by the volume required to accomodate the circuitry. Fewer components, plus advanced automated manufacturing techniques, will prompt further improvement in the performance-to-cost ratio of self-contained photoelectrics.

Advancing semiconductor technology will allow microcomputers to become an integral part of photoelectric devices. This added sensing intelligence will be used to analyze received light signals and to monitor sensor performance. It will become possible to configure output data into various formats for communication to a host computer.

As visible laser diodes follow the rapid development track of IR (infrared) laser diodes (as in the CD player), they will begin to replace the HeNe laser tubes now used in optical "scanners". When their cost drops, visible laser diodes will become a practical light source element for photoelectric sensors. Laser diodes will bring more precision to sensing repeatability, and will be used in a new group of industrial laser measuring and gauging sensors.

The sophistication and capabilities of new photoelectric sensor designs will begin to narrow the huge disparity that now exists between today's basic photoelectric presence sensors and high-end optoelectronic devices such as vision systems. Banner Engineering Corp. is committed to remaining the innovator in sensor design.

Banner is dedicated to producing the most reliable sensing products in the world. The most modern manufacturing facilities, combined with highly-automated subassembly, typify this committment to quality. Each individual product is repeatedly tested during the manufacturing process. The dependability of Banner sensing products is backed at the point of sale by highly-trained field application engineers who can often solve application challenges that others have "written off" as impossible.

This manual is designed to help readers who have had little or no experience with photoelectric or ultrasonic sensors become comfortable with sensing and control terminology, and to relate guidelines for making informed choices of sensing system components. The chapters that follow are structured as a ready-reference for both new and experienced controls persons. Selection tables located throughout the book help to define proper sensor use at a glance.

Selection of photoelectric or ultrasonic sensors requires that attention be given to the details of each sensing situation. System variables or constraints often make the sensor selection process seem complex. This book will help to eliminate the guesswork that so often results in marginal sensing system performance.

Thank you, and we sincerely hope that you find innovative solutions to all of your future sensing applications!

BANNER®
the photoelectric specialist

Robert H. Garwood,
Director of Publications

Section A: Sensing Theory

Definitions of Sensing Terms

Like nearly any other technology, photoelectric and ultrasonic sensing have their own sets of "buzzwords". This section introduces the most important terms. Some are not universal, and a few definitions have developed several names. Most of this synonymy is the result of inconsistent use of sensing terminology by various sensor manufacturers. Since it is unlikely that these terms will become standardized in the near future, it is best to be familiar with all of them and to become comfortable with using the synonyms interchangeably.

If you are already familiar with sensing terms, this section can serve as a quick checklist or refresher for sensing jargon. There is also an alphabetically-arranged glossary of sensing terms at the back of this manual for quick reference.

Figure A.1. Early photoelectric sensors used an incandescent bulb light source.

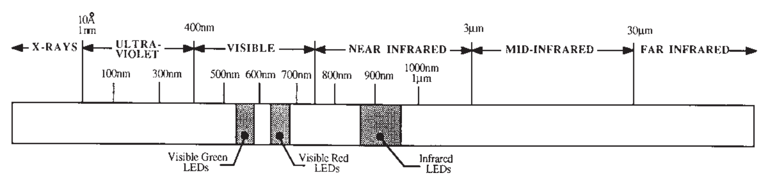
Photoelectric Sensor

A ***photoelectric sensor*** is an electrical device that responds to a change in the intensity of the light falling upon it. The first photoelectric devices used for industrial presence and absence sensing applications took the shape of small metal barrels, with a collimating lens on one end and a cable exiting the opposite end (Figure A.1). The cable connected a photoresistive device to an external vacuum tube type amplifier. A small incandescent bulb, protected inside a matching metal barrel, was the opposing light source. These small, rugged incandescent sensors were the forerunners of today's industrial photoelectric sensors.

LED (Light Emitting Diode)

The 1960s saw the introduction of ***light emitting diodes*** or ***LEDs*** which are now part of our daily lives as status indicators on most contemporary electrical and electronic appliances. An LED is a solid-state semiconductor, similar electrically to a diode, except that it emits a small amount of light when current flows through it in the forward direction. LEDs can be built to emit green, yellow, red, or infrared light. (Infrared light is invisible to the human eye; see Figure A.2.) Also, blue LEDs are now beginning to appear.

Figure A.2. The light spectrum.



Because LEDs are solid-state, they will last for the entire useful life of a sensor. LED sensors can be totally encapsulated and sealed, making them smaller yet more reliable than their incandescent counterparts. Unlike incandescent light sources, LEDs are not easily damaged by vibration and shock, and worry about filament sag is also eliminated. There is a tradeoff, however, in the area of light intensity: LEDs produce only a small percentage of the light generated by an incandescent bulb of the same size.

Infrared types are the most efficient LED light generators, and were the only type of LED offered in photoelectric sensors until 1975. However, this invisible infrared light, though ideal for security detection and film processing applications, was initially not well received by those accustomed to visually aligning and checking incandescent emitters.

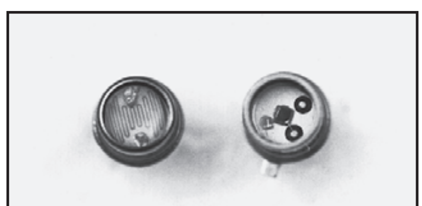


Figure A.3. Typical photocell (left) and phototransistor (right).

Phototransistor

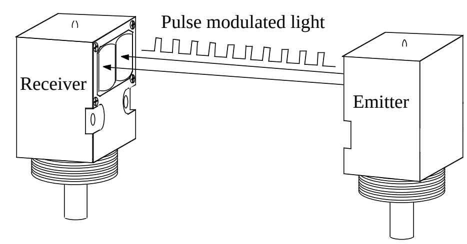
The 1960s brought us solidly into the silicon era, and produced photojunction devices including photodiodes, phototransistors, and photodarlingtons. Of these, the phototransistor has prevailed as the most widely used receiver optoelement in industrial photoelectric sensor design (Fig. A.3). ***Phototransistors*** offer the best tradeoff between light sensitivity and response speed compared to photoresistive and other photojunction devices.

Photocells are used whenever greater sensitivity to visible wavelengths is required, as in some color registration and ambient light detection applications. ***Photodiodes*** are generally reserved for applications requiring either extremely fast response time or linear response over several magnitudes of light level change.

Modulated LED Sensors

By 1970, photoelectric sensor designers had recognized that LEDs had a benefit much more profound than long life. Unlike their incandescent equivalents, LEDs can be turned "on" and "off" (or ***modulated***) at a high rate of speed, typically at a frequency of several kilohertz (Figure A.4). This modulating of the LED means that the amplifier of the phototransistor receiver can be "tuned" to the frequency of modulation, and amplify *only* light signals pulsing at that frequency.

Figure A.4. A modulated (pulsed) light source.



This is analogous to the transmission and reception of a radio wave of a particular frequency. A radio receiver tuned to one station ignores other radio signals that may be present in the room. The modulated LED light source of a photoelectric sensor is usually called the transmitter (or ***emitter***), and the tuned photodevice is called the ***receiver***.

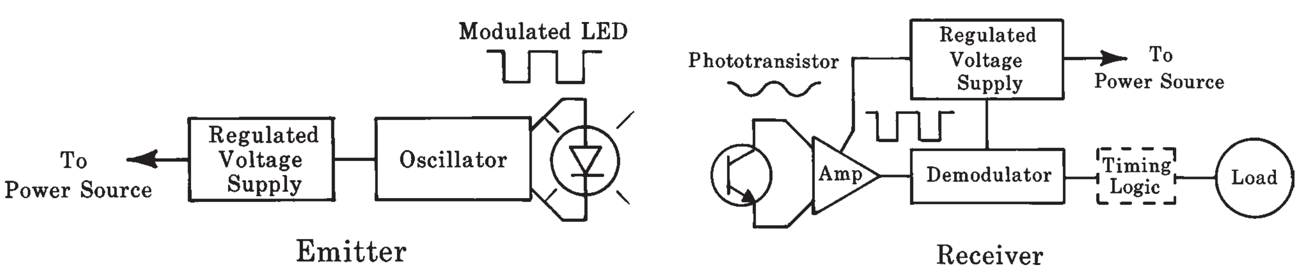
There is a common misconception that because an infrared LED system is invisible, it must therefore be powerful. The apparent high level of optical energy in a modulated photoelectric sensing system has, in itself, little to do with the wavelength of the LED. Remember that an LED emits only a fraction of the light energy of an incandescent bulb of the same size. *It is the modulation of an LED sensing system that accounts for its power.*

The gain of a non-modulated amplifier is limited to the point at which the receiver recognizes ambient light. A non-modulated sensor may be powerful only if its receiver can be made to "see" only the light from its emitter. This requires the use of lenses with very long focal lengths and/or mechanical shielding of the receiver lens from ambient light. In contrast, a modulated receiver ignores ambient light and responds only to its modulated light source. As a result, the gain of a modulated receiver may be turned up to a very high level. See Figure A.5.

There is, however, a limit to a modulated sensor's immunity to ambient light. Extremely bright ambient light sources may sometimes present problems. No modulated photoelectric receiver will function normally if it is pointed directly into the sunlight. If you have ever focused sunlight through a magnifying glass onto a piece of paper, you know that you can easily focus enough energy to start the paper on fire. Replace the magnifying glass with a sensor lens, and the paper with a phototransistor, and it is easy to understand why the receiver shuts down when the sensor is pointed directly into the sun. This is called *ambient light saturation.*

The concept of the modulated LED caused a major revolution in photoelectric sensor design. Sensing ranges increased, and beam angles widened. Throughout the 1970s, users of modulated devices gradually began to place more trust in this light beam that they found so dependable and easy to align. By 1980, the non-modulated photoelectric sensor was nearly just a memory. The newer, highly automated processes could not tolerate the interruptions caused by the incandescent bulb burnout common in non-modulated systems.

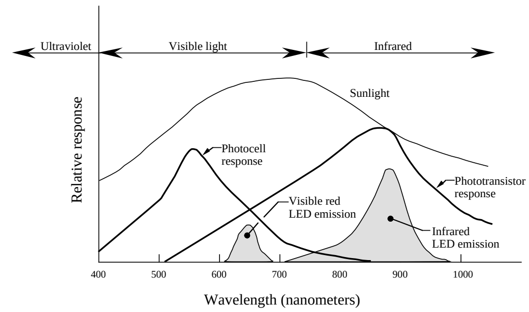
Figure A.5. A modulated photoelectric control.



Infrared LEDs were found to be the most efficient types, and were also the best spectral match to phototransistors (Figure A.6). However, photoelectric sensors used to detect *color differences* (as in color registration sensing applications) require a *visible* light source. As a result, color sensors continued to use photocell receivers and incandescent lamps while sensor designers awaited the development of more efficient visible LEDs. Today, with improved visible LEDs, most color registration sensors are modulated and utilize colored LEDs as emitters.

Modulated sensor designs usually trade off speed of response for sensing distance. Because distance is most often the dominant sensing system design criteria, non-modulated sensors using phototransistors and either incandescent or LED emitters continued to be used where response speed was important, as in sensing small parts or object features moving at a high rate of speed. But since the performance of modulated sensor designs steadily improved through the 1980's, there are now very high speed modulated designs that offer respectable sensing ranges *and* satisfy nearly all response requirements.

Figure A.6. Comparison of spectral response: photocell vs. phototransistor.

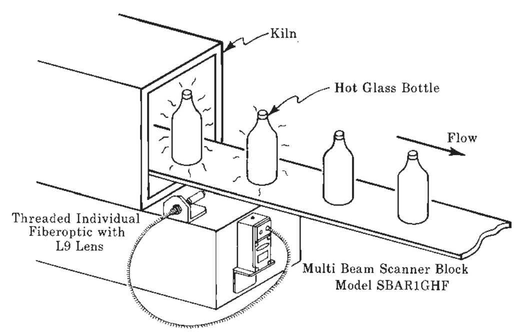


Ambient Light Receiver

One type of non-modulated photoelectric device still found in frequent use is the ***ambient light receiver***. Products like red-hot metal or glass emit large amounts of infrared light. As long as these materials emit more light than the surrounding light level, they may be reliably detected by an ambient light receiver (Figure A.7).

An ambient receiver might also be used beneath a conveyor, looking up between the rollers toward conventional factory lighting. Any objects passing over the sensor are detected by the shadows they cast upon the receiver. Ambient light receivers are also commonly used for outdoor lighting control.

Figure A.7. An ambient light receiver senses infrared energy radiated from red-hot glass or metal.

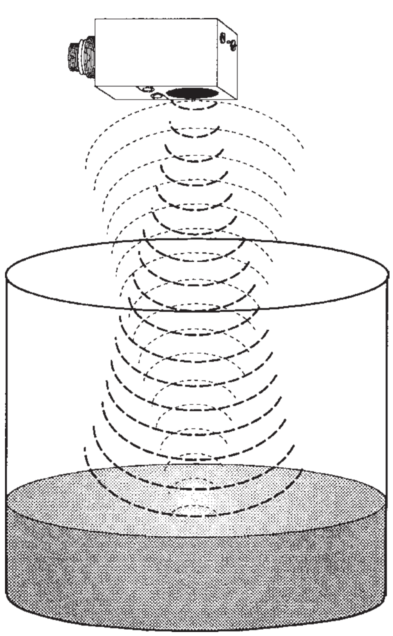


Counting bottles during the manufacturing process by detecting infrared (heat) radiation with an ambient light receiver.

Ultrasonic Sensors

Ultrasonic sensors emit and receive sound energy at frequencies above the range of human hearing (above about 20kHz). Ultrasonic sensors are categorized by transducer type: either ***electrostatic*** or ***piezoelectric***. Electrostatic types can sense objects up to several feet away by reflection of ultrasound waves from the object's surface. Piezoelectric types are generally used for sensing at shorter ranges. See Figure A.8.

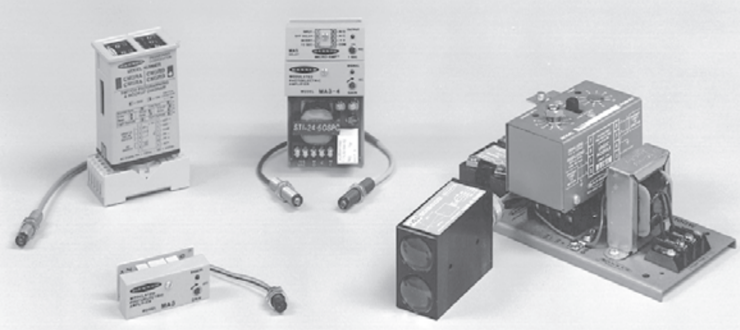
Figure A.8. Detection of ultrasonic sound energy.



Remote Photoelectric Sensors

Photoelectric sensors are divided into two basic package styles: *remote* and *self-contained*. ***Remote photoelectric sensors*** contain only the optical

Figure A.9. Remote sensors of a component sensing system.



components of the sensing system. The circuitry for system power, amplification, and output switching are all at another location, typically in a control panel. Consequently, remote sensors are generally smaller and more tolerant of hostile sensing environments than are self-contained sensors. Examples of remote sensors (see Figure A.9) include those designed for use with the Banner MAXI-AMP and MICRO-AMP family modules. These sensing systems, which have the optical elements at one location and the electrical components at another, are called ***component systems***.

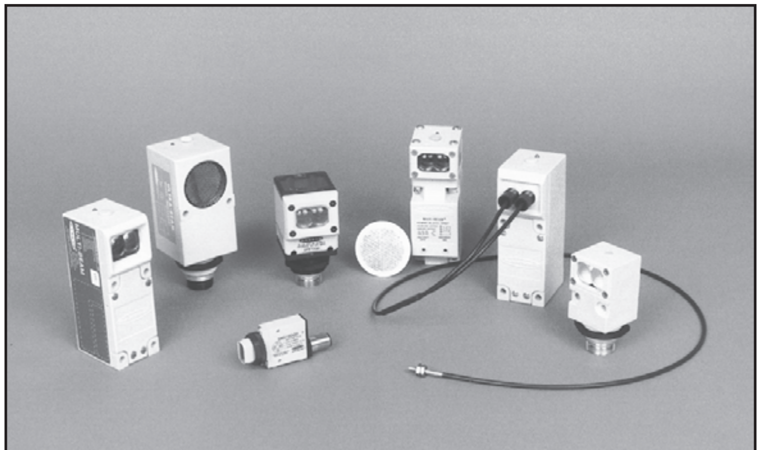


Figure A.10. Self-contained sensors.

Self-contained Photoelectric Sensors

Self-contained photoelectric sensors contain the optics along with all of the electronics. Their only requirement is a source of voltage for power. The sensor itself does all of the work, which includes modulation, demodulation, amplification, and output switching. Some self-contained sensors provide options such as built-in control timers or totalizing counters. Banner's OMNI-BEAM, MULTI-BEAM, MAXI-BEAM, VALU-BEAM, MINI-BEAM, ECONO-BEAM, QØ8, Q19, Q85, S18, ULTRA-BEAM, and SM512 Series sensors are examples of self-contained sensors (Figure A.10).

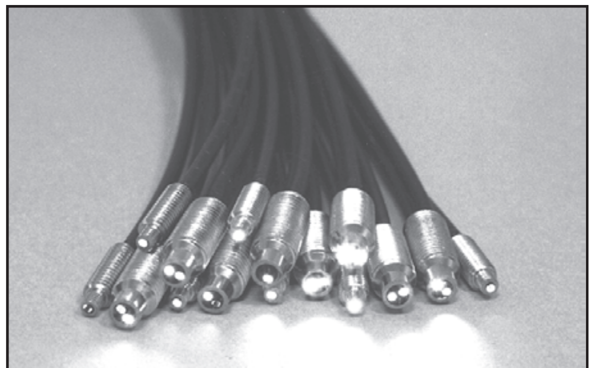


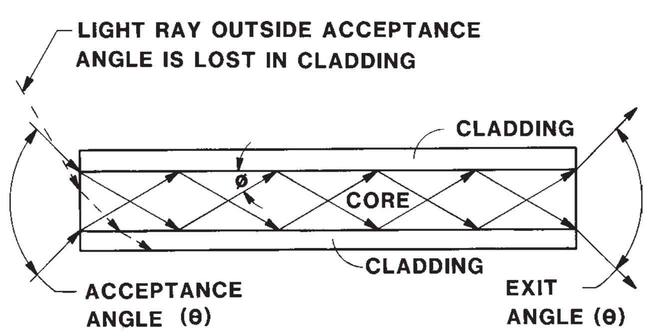
Figure A.11. Fiber optic "light pipes".

Fiber Optics

There are many sensing situations where space is too restricted or the environment too hostile even for remote sensors (component systems). For such applications, photoelectric sensing technology offers fiber optics as a third alternative in sensor "packaging". ***Fiber optics*** are transparent strands of glass or plastic that are used to conduct light energy into and out of such areas.

Fiber optic "light pipes", used *along with* either remote or self-contained sensors, are purely passive, mechanical components of the sensing system (Figure 11). Since fiber optics contain no electrical circuitry and have no moving parts, they can safely pipe light into and out of hazardous sensing locations and withstand hostile environmental conditions. Moreover, fiber optics are completely immune to all forms of electrical "noise", and may be used to isolate the electronics of a sensing system from known sources of electrical interference.

Figure A.12. Acceptance angle and exit angle of a single fiber.



An optical fiber consists of a glass or plastic core surrounded by a layer of cladding material. The cladding material is less dense than the core material, and consequently has a lower index of refraction. The optical principle of *total internal reflection* says that any ray of light that hits the boundary between two materials with different densities (in this case, the core and the cladding) will be totally reflected, provided that the angle of incidence is less than a certain critical value (ø).

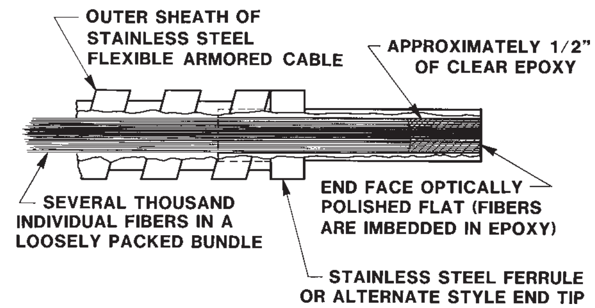
Figure A.12 illustrates two light rays (inside the angle of acceptance) that are repeatedly reflected along the length of the fiber. The light rays exit the opposite end at approximately the entry angle. Another light ray (outside the angle of acceptance) is lost into the cladding. Note that the acceptance angle is slightly larger than twice ø. This is because the rays are bent slightly as they pass from the air into the more dense fiber material.

The principle of total internal reflection works regardless of whether the fiber is straight or bent (within a defined minimum bend radius). Most fiber optic assemblies are flexible and allow easy routing through tight areas to the sensing location.

Glass Fiber optics

Glass fiber optics used for photoelectric light pipes are made up of a bundle of very small (usually about .002 inch diameter) glass fiber strands. A typical glass fiber optic assembly consists of several thousand cladded glass fibers protected by a sheathing material, usually a flexible armored cable. The cable terminates in an end tip that is partially filled with rigid clear epoxy. The sensing face is optically polished so that the end of each fiber is perfectly flat. The degree of care taken in the polishing process dramatically affects the light coupling efficiency of the fiber bundle (see Figure A.13).

Figure A.13. Construction of a typical glass fiber bundle.



There are two types of glass fiber optic bundles. One type, the ***coherent bundle,*** is used in medical instruments and in borescopes. Coherent fiber optic assemblies have each fiber carefully lined up from one end to the other in such a way that an image at one end may be viewed at the opposite end. Coherent bundles are expensive to manufacture. Because the production of a clear image is irrelevant in most fiber optic sensing applications, almost all glass fiber optic assemblies use the much less costly ***randomized bundles***, in which no special care is taken to line up corresponding fiber ends.

It is relatively easy, fast, and inexpensive to create a glass fiber optic assembly to fit a specific space or sensing environment. These are called ***special fiber optic assemblies.*** The bundle may even be shaped at the sensing end to create a beam to "match" the profile of the object to be sensed (Figure A.14).

Figure A.14. In special fiber optic assemblies, the bundle may be shaped on the sensing end to match the profile of the object to be sensed.

The outer sheath of a glass fiber optic assembly is usually stainless steel flexible conduit, but may be PVC or some other type of flexible plastic tubing. Even when a non-armored outer covering is used, a protective steel coil is usually retained beneath the sheath to protect the fiber bundle.

Most glass fiber optic assemblies are very rugged and perform reliably in extreme temperatures. The most common problem experienced with glass fibers is breakage of the individual strands resulting from sharp bending or continued flexing, as occurs on reciprocating mechanisms.

Plastic Fiber optics

Plastic fiber optics (Figure A.15) are *single* strands of fiber optic material (typically .01 to .06 inch in diameter). They can be routed into extremely tight areas.

Most plastic fiber optic assemblies are terminated on the sensing end with a probe and/or a threaded mounting tip. The control (sensor) end of a plastic fiber optic assembly is left unterminated so that it may be easily cut by the user to the proper length. Every Banner plastic fiber assembly is supplied with a cutting device for this purpose.

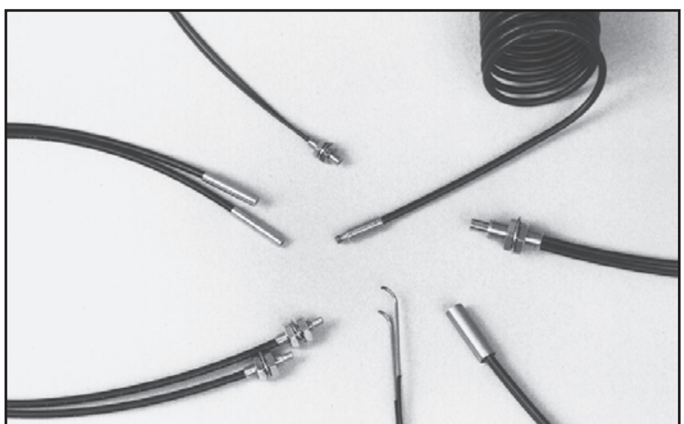


Figure A.15. Plastic fiber optic assemblies.

Unlike glass fiber optics, plastic fibers survive well under repeated flexing. In fact, pre-coiled plastic fiber optics are available for sensing applications on reciprocating mechanisms.

Plastic, however, does absorb certain bands of light wavelengths, including the light from most infrared LEDs (see Figure A.16). Consequently, plastic fiber optics require a *visible* light source, such as a visible red LED, for effective sensing. Plastic fiber optics also are less tolerant of temperature extremes, and are sensitive to many chemicals and solvents.

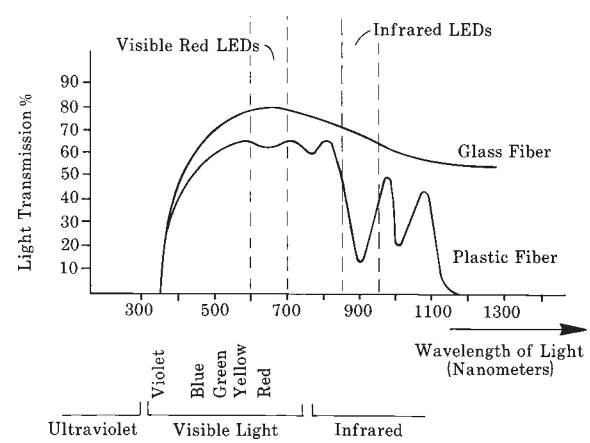
Individual and Bifurcated Fiber Optics

Both glass and plastic fiber optic assemblies are manufactured in two styles. ***Individual*** fiber optics (Figure A.17) simply guide light from an emitter to a sensing location, or from the sensing location back to a receiver.

Bifurcated fiber optics (Figure A.18) conduct the emitted light together with the received light (via two branches consisting of different fibers) within one fiber optic assembly. This allows a single sensor to both illuminate and view an object through the same fiber optic assembly. If an object appears in front of the sensing end of a bifurcated fiber optic, light from one branch will be reflected off the object and back to the receiver through the other branch.

A bifurcated *glass* fiber optic assembly usually randomly mixes the emitter and receiver fibers together in the sensing end tip. Bifurcated *plastic* fiber strands are joined side-by-side along the length of the cable, and so may be thought of as two individual fibers joined together at the sensing end.

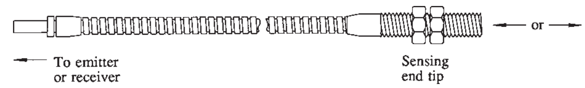
Figure A.16. Spectral transmission efficiency in glass vs. plastic fiber optics.



Sensing Modes

The optical system of any photoelectric sensor is designed for one of three basic sensing modes: *opposed*, *retroreflective*, or *proximity*. The photoelectric proximity mode is further divided into four submodes: *diffuse proximity*, *divergent-beam proximity*, *convergent-beam proximity*, and *fixed-field proximity*. Ultrasonic sensors are designed for either opposed or proximity mode sensing. Following is a description of each sensing mode.

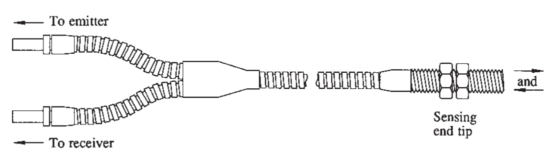
Figure A.17. Individual fiber optic assembly.



Opposed mode

Opposed mode sensing is often referred to as "direct scanning", and is sometimes called the "beam-break" mode. In the opposed mode, the emitter and receiver are positioned opposite each other so that the sensing energy from the emitter is aimed directly at the receiver. An object is detected when it interrupts the sensing path established between the two sensing components. See Figure A.19.

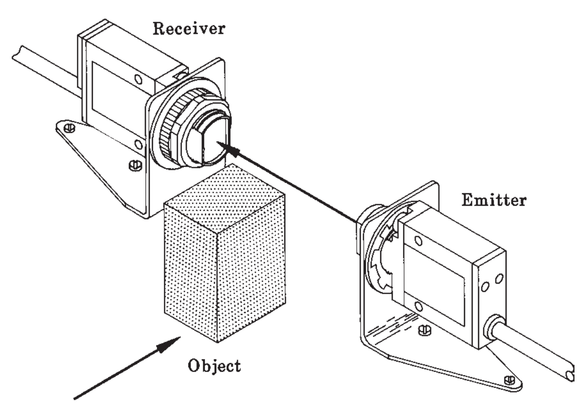
Figure A.18. Bifurcated fiber optic assembly.



Opposed sensing was historically the first photoelectric sensing mode. In the early days of non-modulated photoelectrics, problems of difficult emitter-receiver alignment gave the opposed mode a bad reputation that still exists to some extent. With today's high-powered modulated designs, however, it is extremely easy to align most opposed mode photoelectric sensors.

Alignment of a sensor means positioning the sensor(s) so that the maximum amount of emitted energy reaches the receive sensing element. In opposed sensing, this means that the emitter and the receiver are positioned relative to each other so that the radiated energy from the emitter is centered on the field of view of the receiver.

Figure A.19. Opposed sensing mode.



Sensing range is specified for all sensors. For opposed sensors, range is the maximum operating distance between the emitter and the receiver. A sensor's ***effective beam*** is the "working" part of the beam: it is the portion of the beam that must be completely interrupted in order for an object to be reliably sensed. The effective beam of an opposed mode sensor pair may be pictured as a rod that connects the emitter lens (or ultrasonic transducer) to the receiver lens (or transducer). See Figure A.20. This rod will be tapered if the two lenses (or transducers) are of different sizes. The effective beam should not be confused with the actual radiation pattern of the emitter, or with the field of view of the receiver.

The effective beam size of a standard opposed mode photoelectric sensor pair may be too large to detect small parts or inspect small profiles, or for very accurate position sensing. In such cases, opposed mode photoelectric sensor lenses can usually be ***apertured*** to reduce the size of the effective beam (Figure A.21). Some sensors, like the LR400/PT400, SP12, SM30, and MINI-BEAM opposed mode sensors, have optional aperture assemblies that mechanically attach to the sensor lens. Creating an aperture can be as easy as drilling a hole or milling a slot in a thin metal plate and locating the plate directly in front of the lens, with the opening on the lens centerline. When selecting an aperture material, it is important to remember that the powerful beam of modulated opposed mode photoelectric sensors can actually penetrate many non-metallic materials to varying degrees.

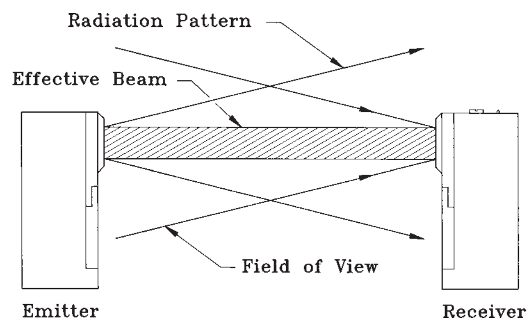
Apertures reduce the amount of light energy that can pass through a lens by an amount equal to the lens area reduction. For example, if a one inch diameter lens is apertured down to 1/4-inch diameter, the amount of optical energy passing through the apertured lens is equal to $(1/4)^2 = 1/16$th the amount of energy through the one-inch lens. *This energy loss is doubled if apertures are used on both the emitter and the receiver.*

A rectangular aperture of any given width covers much less light gathering lens area as does a round aperture of the same width (diameter). For this reason, rectangular apertures (also called "slit apertures") should be used whenever possible. Rectangular apertures are reliable whenever an object travels into the beam with a predictable orientation to the effective beam (as in edge detection, for example). Whenever objects with small profiles move through the beam with random orientation, round apertures are required.

If the object to be detected will always pass very close to either the emitter or the receiver, an aperture may be required on only one side of the process. In this case, the size of the effective beam is equal to the size of the aperture on the apertured side and uniformly expands to the size of the lens on the unapertured side. The effective beam is therefore "cone-shaped". See Figure A.22.

The goal in any application requiring the detection of small parts in an opposed beam is to size and shape the effective beam to be smaller than the smallest profile that will ever need to be detected, while retaining as much lens area as possible. Often the easiest way to size and shape an effective beam to match a part profile is to use a glass fiber optic assembly that has its sensing end terminated in the desired shape. See Figure A-14.

Figure A.20. Effective beam.



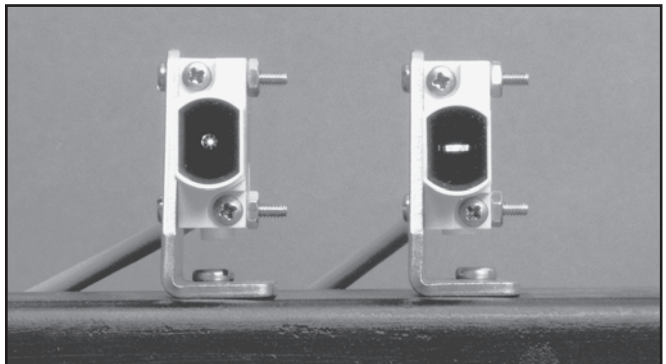
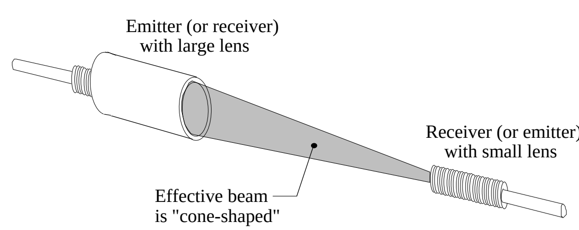


Figure A.21. Sensors with apertures attached.

Figure A.22. Effective beam with unequal lens diameters.



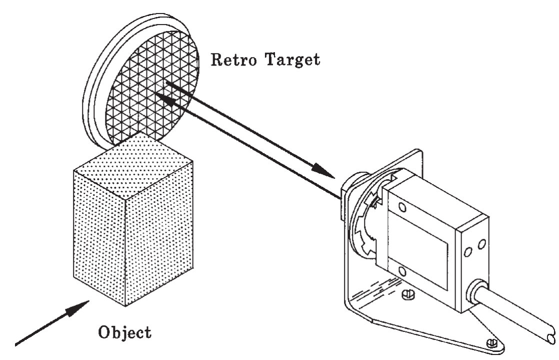
The very high power of some modulated LED opposed sensor pairs (especially when used at close range) can create a "flooding" effect of light energy around an object that is equal to or even slightly larger than the effective beam. This is another reason to ensure that the size of the effective beam is always smaller than the profile of the object to be detected.

It is possible to shape an opposed *ultrasonic* beam by using ***waveguides***. Waveguides attach to the transducer of the ultrasonic receiver (and sometimes to the emitter). With waveguides attached, the receiver is less likely to respond to sound echoes that approach from the side. This makes for more reliable detection of small objects that interrupt the ultrasonic beam.

Retroreflective mode

The photoelectric ***retroreflective sensing mode*** is also called the "reflex" mode, or simply the "retro" mode (Figure A.23). A retroreflective sensor contains both emitter and receiver circuitry. A light beam is established between the emitter, the retroreflective target, and the receiver. Just as in opposed mode sensing, an object is sensed when it interrupts the beam.

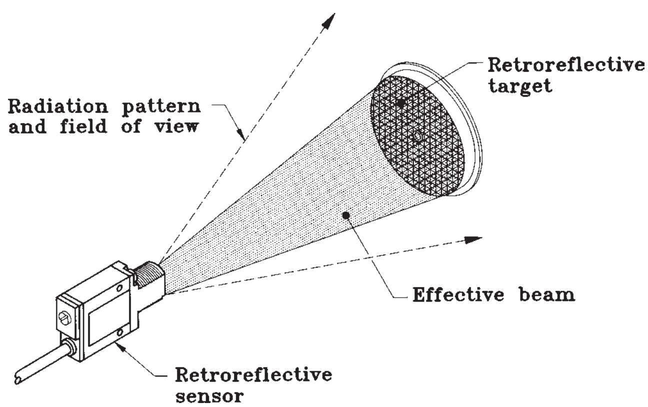
Figure A.23. Retroreflective sensing mode.



Retroreflective range is defined as the distance from the sensor to its retroreflective target. The effective beam is usually cone-shaped and connects the periphery of the retro sensor lens (or lens pair) to that of the retroreflective target. See Figure A.24. The exception to this is at close range, where the size of the retro beam has not expanded enough to at least fill the target.

Retroreflective targets are also called "retroreflectors" or "retro targets". Most retroreflective targets are made up of many small corner-cube prisms, each of which has three mutually perpendicular surfaces and a hypotenuse face. A light beam that enters a corner-cube prism through its hypotenuse face is reflected from the three surfaces and emerges back through the hypotenuse face parallel to the entering beam (Figure A.25). In this way, the retroreflective target returns the light beam to its source.

Figure A.24. Effective beam for retroreflective mode sensor.



Most corner-cube retroreflectors are molded using clear acrylic plastic, and are manufactured in various sizes, shapes, and colors. Corner-cube plastic retroreflectors are commonly used for highway markers and vehicle safety reflectors. Retroreflectors appear brightly illuminated to a driver whenever light from a vehicle's headlamps is returned by the array of corner cubes. Highway markers are often wrapped in retroreflective tape, which has a covering of either many microscopic molded corner-cube reflectors or microscopic glass beads. A clear glass sphere also has the ability to return a light beam back to its source, but a coating of glass beads is not as efficient a reflector as is a molded array of corner-cubes.

A single mirrored surface may also be used with a retroreflective sensor. Light striking a flat mirror surface, however, is reflected at an angle that is equal and opposite to the angle of incidence (Figure A.26). This is called ***specular reflection.*** In order for a retroreflective sensor to "see" its light reflected from a flat mirrored surface, it must be positioned so that its emitted beam strikes the mirror exactly perpendicular to its surface. A retroreflector, on the other hand, has the ability to forgivingly return incident light back to its source at angles up to about 20 degrees from the perpendicular. This property makes retroreflective sensors easy to align to their retro targets.

Figure A.25.
A corner-cube prism.

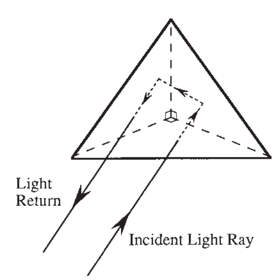
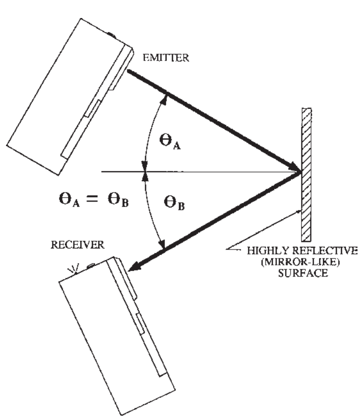


Figure A.26. Specular sensing mode senses the difference between shiny and dull surfaces.



A good retroreflector returns about 3,000 times as much light to its sensor as does a piece of white typing paper. This is why it is easy for a retroreflective sensor to recognize only the light returned from its retroreflector. If the object that is to interrupt a retroreflective beam is *itself* highly reflective, however, it is possible for the object to slip through the retroreflective beam without being detected. This retroreflective sensing problem is called ***proxing***, and relatively simple methods exist to deal with it.

Figure A.27. Use of skew angle to control "proxing".

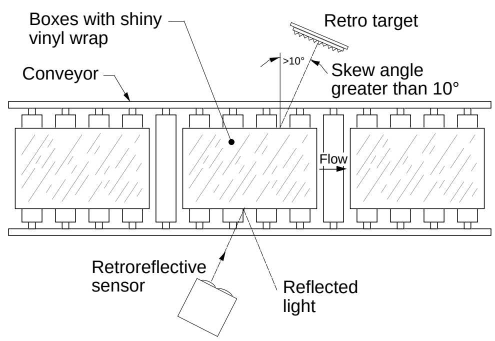
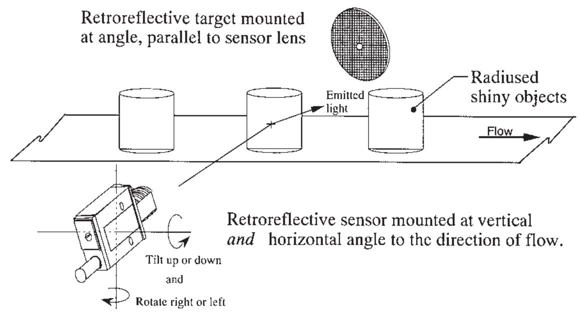
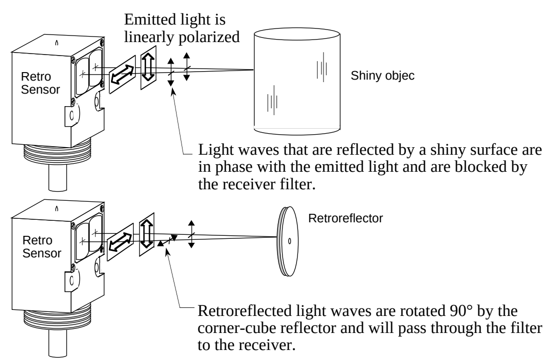


Figure A.28. Retroreflective sensing of radiused shiny objects requires both vertical and horizontal skew angles.



If a shiny object has flat sides and passes through a retroreflective beam with a predictable orientation, the cure for proxing is to orient the beam so that the object's specular surface reflects the beam away from the sensor. This is called scanning at a ***skew angle*** to the object's surface (Figure A.27). The skew angle usually need be only 10 to 15 degrees (or more) to be effective. This solution to proxing may, however, be complicated if the shiny object has a rounded (radiused) surface or if the object presents itself to the beam at an unpredictable angle. In these cases, the best mounting scheme, although less convenient, has the beam striking the object at *both* a vertical and a horizontal skew angle (Figure A.28).

Figure A.29. Polarized light.



With recent improvements in LED technology, the use of *visible light* LEDs as photoelectric emitters has increased. When equipped with a visible emitter, a retro sensor may be aimed like a flashlight at its retroreflective target. When the reflection of the beam is seen on the retroreflector, correct alignment is assured. This principle is also of benefit when a visible emitter is used in an opposed mode photoelectric system. A retro target is placed directly in front of the lens of the receiver, and the emitter is aligned by sighting the visible beam on the target. The retro target is then removed, and the emitter and receiver orientations are "fine-tuned" for optimum alignment.

Polarizing filters are readily available for use with visible emitters. When used on visible retroreflective sensors, polarizing filters (sometimes called anti-glare filters) can significantly reduce the potential for proxing. A polarizing filter is placed in front of both the emitter lens and the receiver lens. The two filters are oriented so that the planes of polarization are at 90 degrees to one another. When the light is emitted, it is polarized "vertically" (Figure A.29). When the light reflects from a corner-cube retro target, its plane of polarization is rotated 90 degrees, and only the polarized target-reflected light is allowed to pass through the polarized receiver filter and into the receiver. When the polarized emitted light strikes the shiny surface of the object being detected, its plane of polarization is *not* rotated, and the returned non-polarized beam is blocked from entering the receiver.

This scheme is very effective for elimination of proxing. Polarizing filters, however, like a good pair of sunglasses, reduce the amount of optical power available in a retro beam by more than 50%. This is an important consideration whenever the environment is very dirty or where the sensing range is long. Also, polarized retro sensors work only with corner-cube type retroreflective materials.

Often, the best insurance against proxing is the skew angle approach. When this is not possible, opposed mode sensors should be considered.

Proximity mode

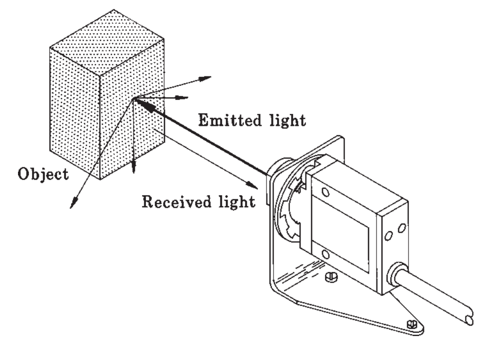
Proximity mode sensing involves detecting an object that is directly in front of a sensor by detecting the sensor's own transmitted energy reflected back from the object's surface (Figure A.30). For example, an object is sensed when its surface reflects a sound wave back to an ultrasonic proximity sensor. Both the emitter and receiver are on the same side of the object, usually together in the same housing. In proximity sensing modes, an object, when present, actually "makes" (establishes) a beam, rather than interrupts the beam. Photoelectric proximity sensors have several different optical arrangements. They are described under the following headings: diffuse, divergent, convergent beam, and fixed-field.

Diffuse —

Diffuse mode sensors are the most commonly used type of photoelectric proximity sensor. In the diffuse sensing mode, the emitted light strikes the surface of an object at some arbitrary angle. The light is then diffused from that surface at many angles. The receiver can be at some other arbitrary angle, and some small portion of the diffused light will reach it.

Generally speaking, the diffuse sensing mode is an inefficient mode, since the receiver looks for a relatively small amount light that is bounced back from a surface. Also, the diffuse mode, like the other proximity sensing modes, is dramatically influenced by the reflectivity of the surface being sensed. A bright white surface will be sensed at a greater range than a dull black surface.

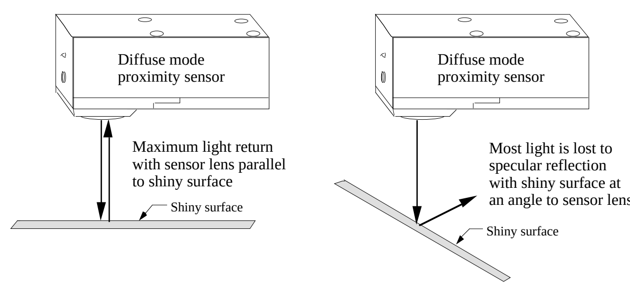
Figure A.30. Diffuse sensing mode.



Most diffuse mode sensors use lenses to ***collimate*** (make parallel) the emitted light rays and to gather in more received light. While lenses help a great deal to extend the range of diffuse sensors, they also increase the criticality of the sensing angle to a shiny or glossy surface. Because all such surfaces are mirror-like to some degree, the reflection is more specular than diffuse.

Most diffuse sensors can guarantee a return light signal only if the shiny surface of the material presents itself perfectly parallel to the sensor lens (Figure A.31). This is usually not possible with radiused parts like bottles or shiny cans. It is also a concern when detecting webs of metal foil or poly film where there is any amount of web "flutter".

Figure A.31. In diffuse sensing of a shiny surface, the sensor lens must remain parallel to the shiny surface for reliable detection.



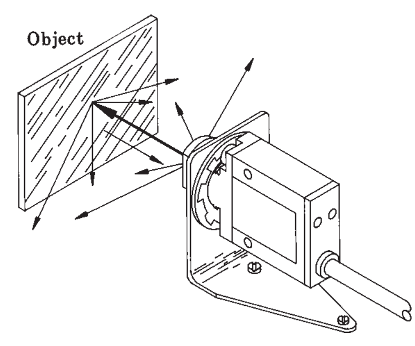
Divergent —

To avoid the effects of signal loss from shiny objects, special short-range, unlensed ***divergent mode*** sensors should be considered. By eliminating collimating lenses, the sensing range is shortened, but the sensor is also made much less dependent upon the angle of incidence of its light to a shiny surface that falls within its range. See Figure A.32.

The range of any proximity mode sensor also may be affected by the size and profile of the object to be detected. A large object that fills the sensor's beam area will return more energy to the receiver than a small object that only partially fills the beam.

A divergent sensor responds better to objects within about one inch of its sensing elements than does a diffuse mode sensor. As a result, divergent mode sensors can successfully sense objects with very small profiles, like yarn or wire. Remote sensor model LP400WB is a good example of this type of sensor.

Figure A.32. Divergent proximity sensing mode.



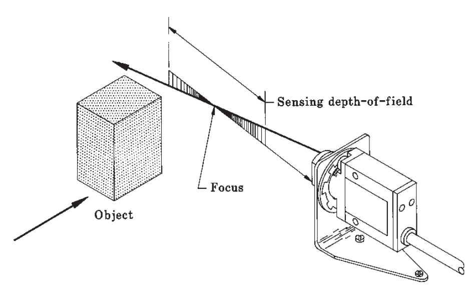
Convergent Beam —

Another proximity mode that is effective for sensing small objects is the ***convergent beam mode***. Most convergent beam sensors use a lens system that focuses the emitted light to an exact point in front of the sensor, and focuses the receiver element at the same point. This design produces a small, intense, and well-defined sensing area at a fixed distance from the sensor lens (Figure A.33).

This is a very efficient use of reflective sensing energy. Objects with small profiles are reliably sensed. Also, materials of very low reflectivity that cannot be sensed with diffuse or divergent mode sensors can often be sensed reliably using the convergent beam mode.

The range of a convergent beam sensor is defined as its ***focus point***, which is fixed. This means that the distance from a convergent beam device to the surface to be sensed must be more or less closely controlled. Every convergent beam sensor will detect an object of a given reflectivity at its focus point, plus and minus some distance. This sensing area, centered on the focus point, is called

Figure A.33. Convergent beam sensing mode.

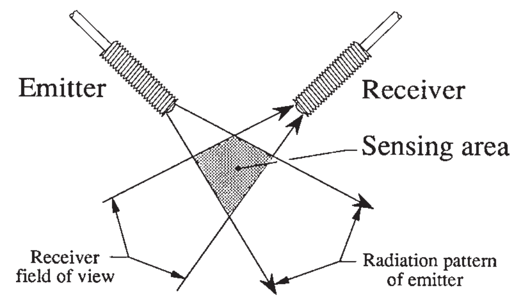


the sensor's ***depth of field***. The size of the depth of field depends upon the sensor design and the reflectivity of the object to be sensed.

The depth of field of ***precise focus convergent beam sensors*** is very small. Such sensors, like remote sensor model LP510CV, may be used for precise position sensing or profile inspection.

The depth of field of ***mechanical convergent beam sensors*** is relatively large. As the name suggests, mechanical convergent beam sensors direct a lensed emitter and a separate lensed receiver toward a common point ahead of the sensor. Remote sensor model SP100C is a good example of this type. With the proper bracketing, any opposed mode sensor pair may be configured for the mechanical convergent beam mode (Figure A.34).

Figure A.34. Mechanical convergent mode: emitter and receiver are angled toward a common point ahead of the sensor.



One specialized use of mechanical convergence is for the sensing of specular reflections (see Figure A.26). This involves positioning a lensed emitter and receiver at equal and opposite angles (from the perpendicular) to a glossy or mirror-like surface. *The distance from the shiny surface to the sensors must remain constant.* Specular reflection is useful for sensing the difference between a shiny and a dull surface. It is particularly useful for detecting the presence of materials that do not offer enough height differential from their background to be recognized by a convergent beam or fixed-field sensor. For example, the specular mode may be used to sense the presence of cloth material of any color (a "diffuse material") on a steel sewing machine work surface (a "shiny surface").

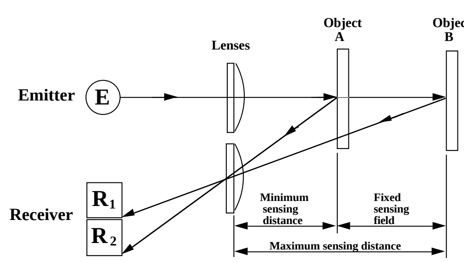
It is often necessary to detect objects that pass the sensor within a specified range, while ignoring other stationary or moving objects in the background. One advantage of convergent beam sensors is that objects beyond the far limit of the depth of field are ignored. It is important to remember, however, that the near and far limits of a convergent beam sensor's depth of field are dependent upon the reflectivity of the object in the scan path. Background objects of high reflectivity will be sensed at a greater distance than objects of low reflectivity.

Fixed-field—

There is a photoelectric proximity mode that has a definite limit to its sensing range. ***Fixed-field sensors*** (Figure A.35) ignore objects that lie beyond their sensing range, regardless of object surface reflectivity.

Fixed-field sensors compare the amount of reflected light that is seen by *two* differently-aimed receiver optoelements. A target is recognized as long as the amount of light reaching receiver R2 is equal to or greater than the amount "seen" by R1. The sensor's output is cancelled as soon as the amount of light at R1 becomes greater than the amount of light at R2. Banner S18 Series self-contained barrel sensors with the "FF" model number suffix and remote sensor model SP100FF are good examples of fixed-field sensors.

Figure A.35. Fixed-field proximity sensing mode.



Object is sensed if the amount of light at R2 is equal to or greater than the amount of light at R1.

Ultrasonic proximity —

Ultrasonic transducers vibrate with the application of ac voltage. This vibration alternately compresses and expands air molecules to send "waves" of ultrasonic sound outward from the face of the transducer. The transducer of an ***ultrasonic proximity sensor*** also receives "echoes" of ultrasonic waves that are located within its response pattern.

Ultrasonic sensors are categorized by transducer type, either "electrostatic" or "piezoelectric" (Figure A.36). ***Electrostatic*** types fill requirements for very long range proximity detection. A proximity range of up to 20 feet is common. These long-range sensors are the solution to applications that require level monitoring in large bins or tanks. ***Piezoelectric*** types usually have a much shorter proximity range, typically up to 3 feet, but can be sealed for protection against harsher operating conditions.

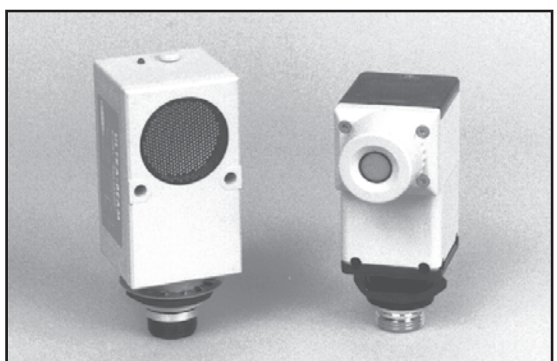


Figure A.36. Ultrasonic sensors: electrostatic (left) and piezoelectric (right).

Generally, ultrasonic proximity sensors are affected less by target surface characteristics than are diffuse mode photoelectrics. They do, however, require that the transducer face be within 3 degrees of parallel to smooth, flat target objects. This angle is much less critical when sensing the sound-scattering target surfaces of irregular or aggregate material. Sound-absorbing materials such as fibers and foam make poor target objects for ultrasonic proximity sensors. Also, minimum target size is an important specification in sensor selection.

Ultrasonic proximity sensors offer excellent sensing repeatability in the direction of sensing (i.e., for objects moving perpendicularly to the sensing face). Consequently, they are used frequently for distance measurement applications. Many sensors have multiple distance set points or analog outputs. Analog outputs can be highly linear.

Beam Patterns

A ***beam pattern*** is included as part of the description for each photoelectric sensor. It includes information that may be useful for predicting the performance of the sensor. All beam patterns are drawn in two dimensions; symmetry of each pattern around the optical axis is assumed, and the shape of the pattern is assumed to be the same in all sensing planes. (However, note that this is not *always* an accurate assumption.) Beam patterns are drawn for perfectly clean sensing conditions, optimum angular sensor alignment, and the proper sensor sensitivity (gain) setting for the specified range. Maximum light energy occurs along the sensor's optical axis, and light energy decreases with movement toward the beam pattern boundaries. Beam pattern dimensions are typical for the sensor being described, and should not be considered exact. Also, beam pattern information is different for each sensing mode.

Opposed Mode Beam Patterns

Beam patterns for opposed sensors represent the area within which the receiver will effectively "see" the emitted light beam. The horizontal scale is the separation distance between the emitter and receiver. The vertical scale is the width of the active beam, measured on either side of the optical axis of the emitter or receiver lens.

It is assumed that there is no angular misalignment between the emitter and the receiver. In other words, the optical axis of the emitter lens is kept exactly parallel to the optical axis of the receiver lens while plotting the pattern. Even small amounts of angular misalignment will significantly affect the size of the sensing area of most opposed sensor pairs, except at close range.

Opposed beam patterns predict how closely adjacent to one another parallel opposed sensor pairs may be placed without generating optical crosstalk from one pair to the next. A typical beam pattern for an opposed mode sensor pair is shown in Figure A.37. This pattern predicts that, at an opposed sensing distance of four feet, a receiver that is kept perfectly parallel to its emitter will "see" enough light for operation at up to just over eight inches in any direction from the optical axis of the emitter. This means that adjacent emitter/receiver pairs may be safely placed parallel to each other as close as about ten inches apart (i.e. safely more than eight inches apart) without optical crosstalk from an emitter to the wrong receiver (Figure A.38).

Figure A.39 shows how parallel beam spacing may be cut in half by *alternating* emitter - receiver - emitter - receiver - etc. on each side of the sensing area. Whenever *only two* opposed beams are involved in the sensing scheme, they may be placed in this manner as closely together as the dimensions of the sensors permit without causing direct optical crosstalk. However, whenever emitters and receivers that are on the same side of the sensing area get very close together (typically two inches or less) the potential for reflective crosstalk (i.e. "proxing") increases. Since the receivers in opposed mode sensing are "looking" for dark (i.e. beam blocked) for object detection, the light detected by a receiver due to reflective crosstalk may cause an object in the sensing area to slip past undetected.

Figure A.37.
Typical opposed mode beam pattern.

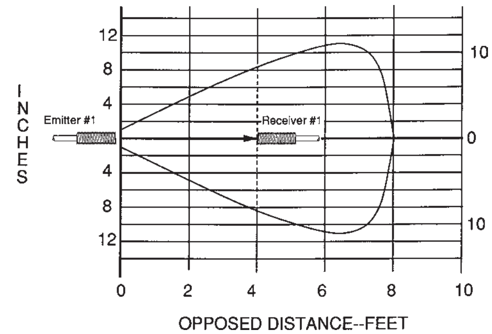


Figure A.38. Spacing for three opposed pairs. A beam pattern indicates the minimum separation required to avoid crosstalk between adjacent opposed mode sensor pairs.

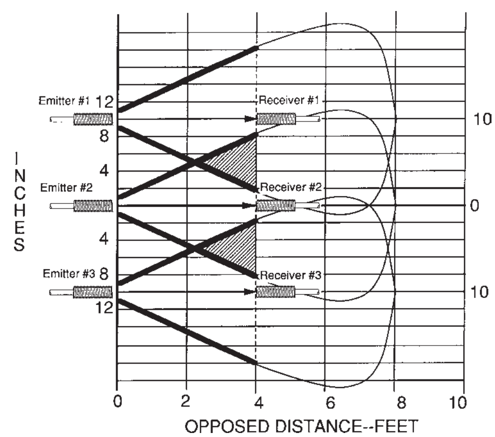


Figure A.39. Spacing for three opposed sensor pairs (staggered). The minimum spacing between adjacent opposed sensor pairs is cut in half if emitters and receivers are alternated on each side.

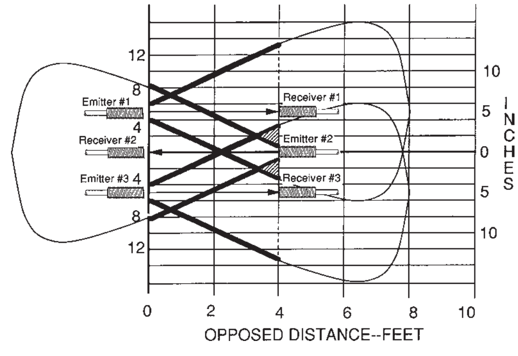
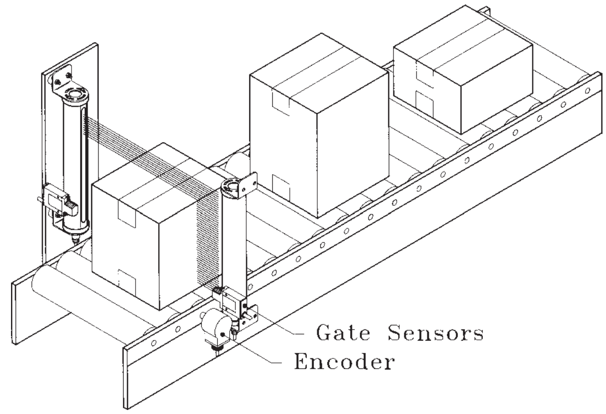


Figure A.40.
BEAM-ARRAY multiplexed light curtain.



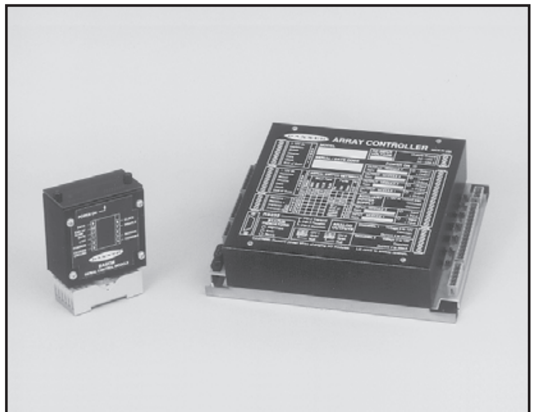


Figure A.41. Model BC1T Serial Control Module and model BC2A/BC2B Controller, for use in BEAM-ARRAY Systems.

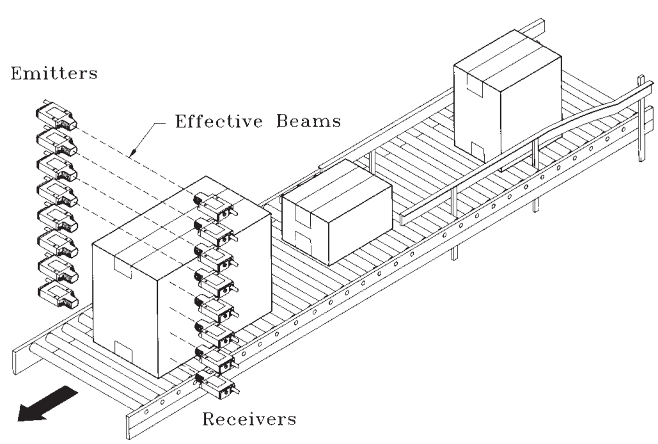
Another common way to minimize optical crosstalk between adjacent opposed sensor pairs is to include a slight angle in the emitter or receiver mounting to intentionally misalign the outermost beams of the array. For example, in Figure A.38, Emitter #1 could be rotated to direct its beam slightly "up" and away from the view of Receiver #2. Similarly, Emitter #3 could be rotated slightly "down" and away from Receiver #2.

Yet another way to minimize optical crosstalk is to separate adjacent emitter/receiver pairs both hoizontally *and* vertically. The diagonal separation between adjacent beams is determined by the beam pattern. In this way, adjacent beams may be placed on closer centers in one dimension. This is possible whenever the object that is to be sensed is large in crossection and when available space permits this approach to sensor mounting.

When adjacent opposed beams are placed on very close centers, optical crosstalk can be eliminated by *multiplexing* the sensors in the array. ***Multiplexing*** is a scheme in which an electronic control circuit interrogates each sensor in the array in sequence. True photoelectric multiplexing enables ("turns on") each modulated emitter only during the time that it samples the output of its associated receiver. The chance of false response of any receiver to the wrong light source is eliminated. The BEAM-ARRAY (Fig. A.40) is an example of a multiplexed "light curtain" used for on-the-fly parts measurement.

The BC1T Serial Control Module and BC2A/BC2B Controllers (Figure A.41) add sophisticated data acquisition and scan configuration capabilities to the basic BEAM-ARRAY System. The BC1T enables the system to output continuous, gated, or on-demand scan data in binary format (via an RS232C interface) to a host computer or PLC. BC2A/BC2B Controllers make possible several user-defined scanning response configurations, and provide output options (both switched and analog) to suit nearly any application. The Controller communicates with a host computer or PLC via built-in RS232C, RS422, and RS485 interfaces. Typical uses are: product profiling, loop tensioning control, edge-guiding, and a wide variety of inspection applications.

Figure A.42. Example of a multiple-sensor array using MP-8 Multiplexer module: product profile measurement.



Another example, model MP-8, is a photoelectric multiplexer that is used to control up to eight pairs of self-contained emitter/receiver pairs (Fig. A.42). Sensors used with the MP-8 may each be mechanically configured exactly as required for the application.

Opposed mode beam pattern information is also useful for predicting the area within which an emitter and receiver will align when one is moving relative to the other, as with automatic vehicle guidance systems. The beam pattern represents the largest typical sensing area when sensor sensitivity is adjusted to match range specifications. The boundary of the beam pattern will shrink with decreased sensitivity setting, and may expand with increased sensitivity.

Retroreflective Mode Beam Patterns

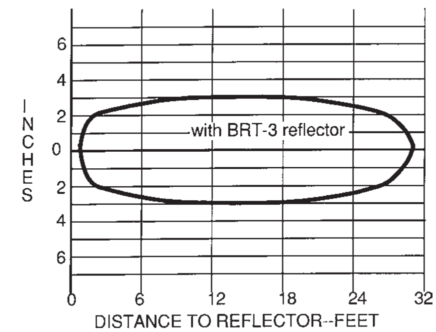
Beam patterns for retroreflective sensors are plotted using a model BRT-3 three inch diameter plastic corner-cube type retroreflector. The beam pattern represents the boundary within which the sensor will respond to a BRT-3 target (Figure A.43). The retroreflective target is kept perpendicular to the sensor's optical axis when plotting the pattern.

The horizontal scale is the distance from the retro sensor to the BRT-3 retroreflector. The vertical scale is the farthest distance on either side of the sensor's optical axis where a BRT-3 reflector can establish a retroreflective beam with the sensor.

A "retro" beam pattern indicates how *one* BRT-3 target will interact with multiple parallel retroreflective sensors that are mounted on close centers. The beam pattern also predicts whether a 3-inch reflector will be detected if it is traveling past the sensor parallel to the sensor face, or vice versa.

Most important, a retroreflective beam pattern is an accurate depiction of the size of the active beam area at distances of a few feet or more from the sensor. It is always good practice, if possible, to capture the entire emitted beam with retroreflective target area. The beam pattern indicates how much reflector area is needed at any distance where the beam size is greater than 3 inches wide.

Figure A.43. Typical beam pattern for retroreflective sensors.



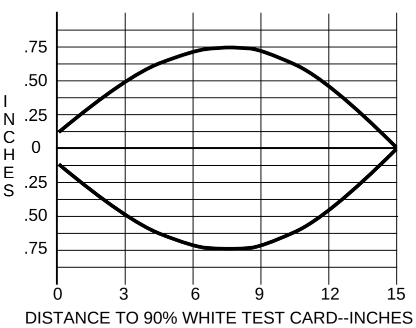
Proximity Mode Beam Patterns

The beam pattern for any proximity mode photoelectric sensor represents the boundary within which the edge of a light-colored diffuse surface will be detected as it moves past the sensor. Beam patterns for diffuse, convergent, divergent, and fixed-field mode sensors are developed using a Kodak 90% reflectance white test card, which is about 10% more reflective than most white copy paper. The beam pattern will be smaller for materials that are less reflective, and may be larger for surfaces of greater reflectivity.

The test card used to plot the pattern measures 8 by 10 inches. Objects that are substantially smaller may decrease the size of the beam pattern at long ranges. Also, the angle of incidence of the beam to a *shiny* surface has a pronounced effect on the size and the shape of a diffuse mode beam pattern.

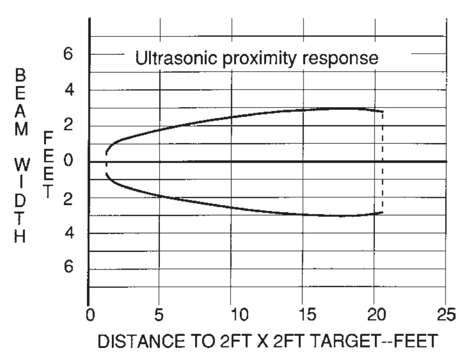
The horizontal scale is the distance from the sensor to the reflective surface. The vertical scale is the width of the active beam measured on either side of the optical axis (Figure A.44). *The beam pattern for any diffuse, convergent, divergent, or fixed-field sensor is equivalent to the sensor's effective beam.*

Figure A.44. Typical beam pattern for diffuse proximity mode sensors.



The beam pattern (more commonly called the ***response pattern***) for an ultrasonic proximity sensor is drawn for a square, solid, flat surface (Figure A.45). The size of the target is specified for each type of sensor. The size of an ultrasonic proximity response pattern is affected by the size, shape, texture, and density of the material being sensed.

Figure A.45. Typical ultrasonic proximity mode response pattern.



Excess Gain

Excess gain is a measurement that may be used to predict the reliability of any sensing system. As its name suggests, excess gain is a measurement of the sensing energy falling on the receiver element of a sensing system *over and above* the minimum amount required to just operate the sensor's amplifier.

Once a signal is established between the emitter and the receiver of any sensor or sensing system, there may be attenuation (reduction) of that signal resulting from dirt, dust, smoke, moisture, or other contaminants in the sensing environment. The excess gain of a sensing system may be seen as the extra sensing energy that is available to overcome this attenuation.

Excess gain is usually clearly specified for photoelectric sensors. In equation form:

$$\text{Excess Gain (E.G.)} = \frac{\text{Light energy falling on receiver element}}{\text{Sensor's amplifier threshold}}$$

The ***threshold*** is the level of sensing energy required by the sensor's amplifier to cause its output to change state (i.e., to switch "on" or "off"). In a modulated photoelectric system, excess gain is measured as a voltage (typically at millivolt levels), usually at the first stage of receiver amplification. This measured voltage is compared to the amplifier's threshold voltage level to determine the excess gain. There is an excess gain of one (usually expressed as "1x" or "one times") when the measured voltage is at the amplifier threshold level.

If 50% of the original light energy becomes attenuated, then a minimum of 2x ("two times") excess gain is required to overcome the light loss. Similarly, if 80% of a sensor's light is lost to attenuation (i.e. only 20% left), then an available excess gain of at least 5x is required.

If the general conditions in the sensing area are known, the excess gain levels listed in Table A-1 may be used as guidelines for assuring that the sensor's light energy will not be entirely lost to attenuation.

TABLE A-1.
Guidelines for Excess Gain Values

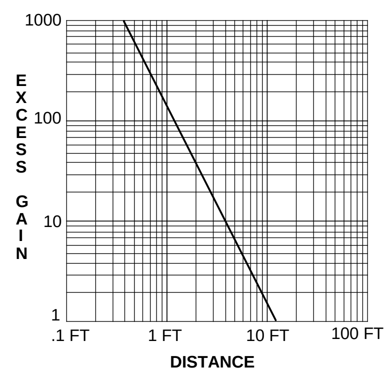
Minimum Excess Gain Required	Operating Environment
1.5x	***Clean air:*** no dirt buildup on lenses or reflectors.
5x	***Slightly dirty:*** slight buildup of dust, dirt, oil, moisture, etc. on lenses or reflectors. Lenses are cleaned on a regular schedule.
10x	***Moderately dirty:*** obvious contamination of lenses or reflectors (but not obscured). Lenses cleaned occasionally or when necessary.
50x	***Very dirty:*** heavy contamination of lenses. Heavy fog, mist, dust, smoke, or oil film. Minimal cleaning of lenses.

Table A-1 lists an excess gain of 1.5x (i.e. 50% more energy than the minimum for operation) for a perfectly clean environment. This amount includes a safety factor for subtle sensing variables such as gradual sensor misalignment and small changes in the sensing environment. At excess gains above 50x, sensors will begin to ***burn through*** (i.e. "see" through) paper and other materials with similar optical density.

The excess gain that is available from any sensor or sensing system may be plotted as a function of distance (Figure A.46). ***Excess gain curves*** are plotted for conditions of perfectly clean air and maximum receiver gain, and are an important part of every photoelectric sensor specification. The excess gain curve for any Banner sensor represents the lowest *guaranteed* excess gain available from that model. Most sensors are factory calibrated to the excess gain curve. Sensors that have a gain adjustment (also called "sensitivity control") can usually be field-adjusted to exceed the excess gain specifications; however, this is never guaranteed.

The excess gain curve in Figure A.46 suggests that operation of this opposed sensor pair is possible in a perfectly clean environment (excess gain ≥ 1.5x) at distances up to 10 feet apart, and in a moderately dirty area (excess gain ≥ 10x) up to 4 feet apart. At distances inside 1 foot, these sensors will operate in nearly any environment.

Figure A.46. Typical excess gain curve for an opposed mode sensor pair.



Excess Gain - Opposed Mode Sensing

The relationship between excess gain and sensing distance is different for each photoelectric sensing mode. For example, the excess gain of an opposed mode sensor pair is directly related to sensing distance by the inverse square law. If the sensing distance is doubled, the excess gain is reduced by a factor of $(1/2)^2$ = one-fourth. Similarly, if the sensing distance is tripled, the excess gain is reduced by a factor of $(1/3)^2$ = one-ninth, and so on. As a result, the excess gain curve for opposed mode sensors is always a straight line when plotted on a log-log scale.

Since the light from the emitter goes directly to the receiver, opposed mode sensing makes the most efficient use of sensing energy. Therefore, the excess gain that is available from opposed mode sensors is much greater than from any other photoelectric sensing mode.

Excess Gain - Retroreflective Mode Sensing

The shape of excess gain curves for the other sensing modes are not as predictable. Retroreflective excess gain curves are plotted using a model BRT-3 three-inch diameter retroreflector, except where noted. The shape of retroreflective excess gain curves is affected by the size of the retroreflective target. Several BRT-3 targets, used together in a cluster, will usually result in longer sensing range and a higher maximum excess gain (Figure A.48, next page). A smaller corner-cube reflector, like the one-inch diameter model BRT-1, yields a smaller curve.

Figure A.47. Typical excess gain curve for a retroreflective mode sensor.

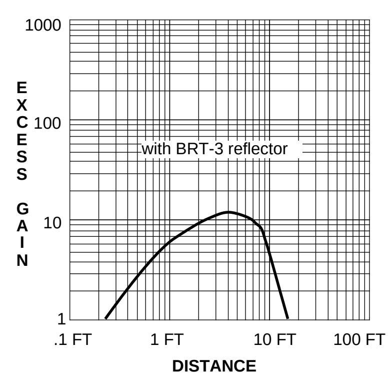
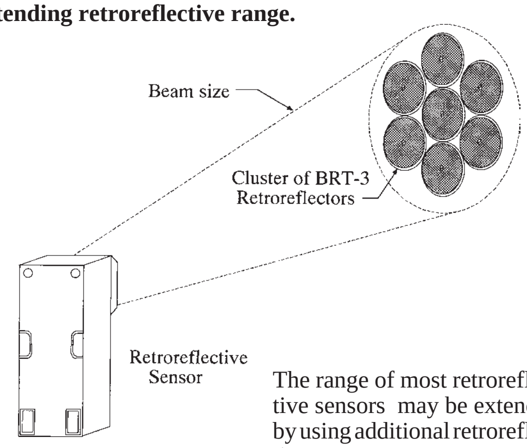
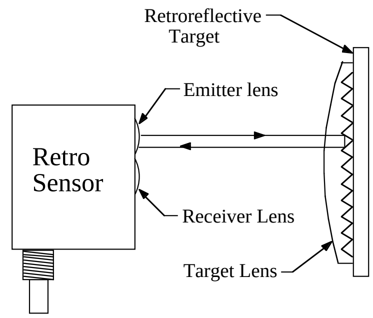


Figure A.48.
Extending retroreflective range.



The range of most retroreflective sensors may be extended by using additional retroreflective target area.

Figure A.49. Retroreflective "blind spot".
Most retroreflective sensors with separate emitter and receiver lenses have a "blind spot" at very close range.



The type of retroreflective target material used also affects excess gain. The Banner product catalog lists a "Reflectivity Factor" for each type of retro material. This factor compares each retroreflective material to the reflectivity of target model BRT-3. Any point on an excess gain curve may be multiplied by this factor to approximate the excess gain for an equivalent amount of reflective area of the retro target material in question.

Most retroreflective sensors are designed for long-range performance, and use separate lenses for the emitter and the receiver. A good retroreflector has the property of returning most of the incoming light directly back to the sensor. At close ranges, the retroreflector sends most of the incoming light directly back into the *emitter* lens (see Figure A.49). As a result, many two-lens retroreflective sensors suffer a ***blind spot*** at close-in ranges, which is evident on excess gain curves and may be seen in Figure A.47.

Special single-lens retroreflective sensors are available for close-in sensing of retro material. This design typically uses a beam splitter device located directly behind the lens. Model SM502A is a good example of a single-lens retro design. It can even sense retro material that is actually in contact with the lens itself.

Figure A.49 illustrates an important consideration to make, especially when using retroreflective sensors in dirty locations. The light energy must pass through *two* surfaces (lens surfaces) on each end of the sensing path, so it is necessary to account for double attenuation on both ends. This is equivalent to saying that the actual excess gain drops off twice as fast in a retroreflective system as in an opposed system, in any sensing environment.

Excess Gain - Proximity Mode Sensing

Generally speaking, photoelectric proximity modes are inefficient sensing modes. The receiver must "look" for a relatively small amount of light that is bounced back directly from the surface of an object. As a result, the excess gain available from a proximity mode sensor is usually lower than that of the other photoelectric sensing modes.

The curves for diffuse, convergent, divergent, and fixed-field sensors are plotted using a Kodak 90% reflectance white test card

TABLE A-2
Relative Reflectivity Chart

Material	Reflectivity (%)	Excess Gain Required
Kodak white test card	90%	1
White paper	80%	1.1
Newspaper (with print)	55%	1.6
Tissue paper: 2 ply	47%	1.9
1 ply	35%	2.6
Masking tape	75%	1.2
Kraft paper, cardboard	70%	1.3
Dimension lumber (pine, dry, clean)	75%	1.2
Rough wood pallet (clean)	20%	4.5
Beer foam	70%	1.3
Clear plastic bottle*	40%	2.3
Translucent brown plastic bottle*	60%	1.5
Opaque white plastic*	87%	1.0
Opaque black plastic (nylon)*	14%	6.4
Black neoprene	4%	22.5
Black foam carpet backing	2%	45
Black rubber tire wall	1.5%	60
Natural aluminum, unfinished*	140%	0.6
Natural aluminum, straightlined*	105%	0.9
Black anodized aluminum, unfinished*	115%	0.8
Black anodized aluminum, straightlined*	50%	1.8
Stainless steel, microfinish*	400%	0.2
Stainless steel, brushed*	120%	0.8

*For materials with shiny or glossy surfaces, the reflectivity figure represents the maximum light return, with the sensor beam exactly perpendicular to the material surface.

as the reference material. The excess gain of diffuse sensors is dramatically influenced by the reflectivity of the surface to be sensed. Any material surface may be ranked for its reflectivity as compared to the Kodak 90% reflectance white reference card (Table A-2).

In Table A-2, the numbers in the "Excess Gain Required" column indicate the *minimum* excess gain that is required to sense the material. For example, if the material to be sensed is opaque black plastic (excess gain required = 6.4), then the diffuse sensor with the excess gain curve of Figure A.50 will "see" the material from 0 (zero) to 10 inches. This assumes perfect sensing conditions.

To get the actual required excess gain for diffuse sensing of any material, multiply the material's ***reflectivity factor*** by the excess gain level that is required for the sensing conditions (from Table A-1). For example, to sense black opaque plastic in a slightly dirty environment, the minimum required excess gain is:

$$\text{Excess gain required} = 6.4_{\text{(reflectivity factor)}} \times 5_{\text{(minimum E.G. required)}} = 32.$$

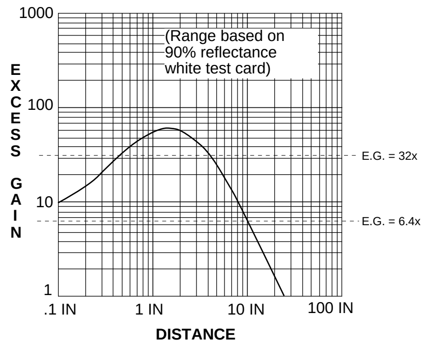
Under these conditions, the diffuse sensor of Figure A.50 will reliably sense the black plastic from 1/2 to 4 inches, even after there is a slight build-up of dirt on the lens.

The excess gain of diffuse mode sensors is also affected by the size and the profile of the object to be detected. The excess gain curves assume a white test card that fills the entire area of the diffuse sensor's effective beam. If the object to be detected only fills a portion of the sensor's effective beam, there will be proportionately less light energy returned to the receiver.

Like the diffuse mode, the excess gain of divergent mode sensors is affected by the reflectivity and size of the object to be sensed. However, the effect of these variables is less noticeable in divergent sensing, simply because divergent mode sensors loose their sensing ability within such a short range.

Since most of the energy of a convergent beam sensor is concentrated at its focus, the maximum available excess gain is much higher than for any of the other proximity modes. This relatively high excess gain allows the detection of materials of very low reflectivity, where diffuse, divergent, and fixed-field mode sensors would fail. The effect of an object's relative reflectivity is most noticeable in the size of the resultant depth of field. Also, because the effective beam of a convergent beam sensor is so small, even objects with narrow profiles can return a relatively high percentage of the incident light.

Figure A.50. Typical excess gain curve for a diffuse proximity mode sensor.



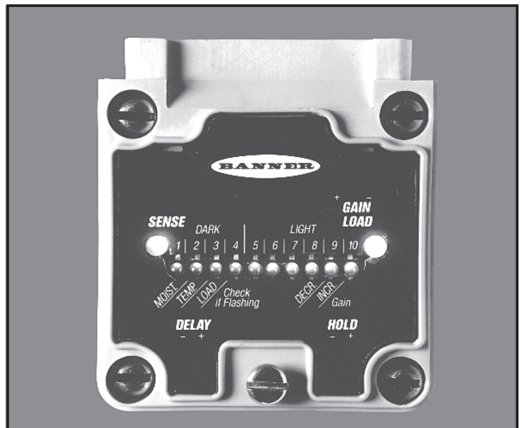


Figure A.51. The D.A.T.A. system array of OMNI-BEAM sensors.

Excess Gain and Sensor Alignment

The most common mistake made when installing infrared (invisible light) LED sensors is failing to center the light beam on its receiver or target. An installer often will simply adjust a sensor's position until the alignment indicator LED lights or until the output load switches. It is likely that this sensor has been only marginally aligned, with very little excess gain available to overcome dirt build-up and other sensing variables. Most photoelectric sensor lenses have accurately-placed optical axes. However, it is seldom absolutely safe to assume that perfect mechanical sensor alignment is *exactly* equivalent to the best optical alignment.

Excess gain measurement is the easiest and best way to assure optimal sensor alignment and to monitor sensor performance. Banner offers two excess gain measurement schemes. The OMNI-BEAM sensor family features the **D.A.T.A.**™ light system. The **D.A.T.A.** system (Figure A.51) displays relative received signal strength on a built-in ten element LED array. As more light is received, more LEDs in the array are lighted. Table A-3 shows the direct relationship between the number of lighted LEDs and the excess gain.

TABLE A-3. Relationship between Excess Gain and D.A.T.A. System Lights

D.A.T.A. light LED number	Excess Gain
#1	0.25x excess gain
#2	0.35x
#3	0.5x
#4	0.7x
#5	1.0x
#6	1.3x
#7	1.7x
#8	2.2x
#9	2.9x
#10	3.7x (or more)

Other self-contained sensor models in the MULTI-BEAM, MAXI-BEAM, VALU-BEAM, and MINI-BEAM families, plus component systems using modulated amplifiers in the MAXI-AMP or MICRO-AMP families, offer the **AID**™ (Alignment Indicating Device) feature. The **AID** feature allows measurement and monitoring of relative excess gain.

When alignment is first established, the alignment indicator on the sensor (or amplifier module) will come "on" at full brightness. After one or two seconds, the **AID** circuitry will superimpose a pulse rate, oscillating between full and half brightness. The pulse (or flash) rate in beats-per-second is directly proportional to the excess gain of the sensing system. Alignment simply involves adjusting the sensor's position to yield maximum flash rate.

It is difficult to judge relative pulse rates beyond about ten beats per second. The **D.A.T.A.** light system lights all ten LEDs at an excess gain of about 4x (Table A-3). In many sensing situations, the available excess gain can or must be much higher. In such situations, which include most opposed and retroreflective sensing applications, more accurate alignment can be accomplished using one of two simple methods.

If the sensor has a sensitivity (gain) control, the receiver gain can be temporarily adjusted downward so that fine increments of alignment again register an easily discernible difference on the **AID** or **D.A.T.A.** signal strength display.

If the sensor has no sensitivity control, the signal strength may be temporarily attenuated by masking the lens(es). This may be done by affixing layers of paper tape to the lens(es). A piece of thin paper held or taped over the lens(es) will serve the same purpose. If total coverage of the lens yields too much attenuation, then the lens may be masked so that only a portion of the lens center is exposed. In retroreflective sensing, the retro target may be masked so that only a small amount of the center area is exposed. Lens masking may be used in conjunction with temporary sensitivity reduction for accurate alignment in situations like short-range opposed sensing where excess gain is very high.

Signal strength indicators also serve the important function of system monitoring. A slow pulse rate of the **AID** indicator or a short string of LEDs on the **D.A.T.A.** display is a visual indication of marginal signal strength. (Additionally, the **D.A.T.A.** display flashes a warning LED and energizes an alarm output signal whenever excess gain approaches 1x.)

The concept of excess gain is not intended to be an exact science, but rather is a guideline for the sensor selection process. Knowing values from an excess gain curve can be valuable information for predicting the success of a particular sensor in a given sensing environment. *In most sensing situations, high excess gain relates directly to sensing reliability.*

Contrast

All photoelectric sensing applications involve differentiating between two received light levels. ***Contrast*** is the ratio of the amount of light falling on the receiver in the "light" state as compared to the "dark" state. Contrast is also referred to as the "light-to-dark ratio", as represented by the following equation:

$$\text{Contrast} = \frac{\text{Light level at the receiver in the light condition}}{\text{Light level at the receiver in the dark condition}}$$

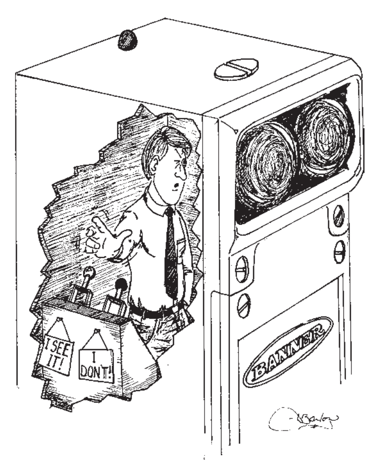
It is always important to choose the sensor or lensing option that will optimize contrast in any photoelectric sensing situation. Many situations, like a cardboard box breaking a retroreflective beam, are applications with infinitely high contrast ratios. In this type of high-contrast application, sensor selection simply involves verifying that there will be enough available excess gain for reliable operation in the sensing environment.

Many of today's industrial photoelectric sensing applications are not so straight-forward. Most problems with contrast in opposed and retroreflective applications occur when:

1) the beam must be blocked by a material that is not opaque, or
2) less than 100% of the effective beam is blocked.

When proximity mode sensors are used, most low contrast problems occur where there is a close-in background object directly in the scanning path. This problem is compounded when the background object's reflectivity is greater than the reflectivity of the object to be detected. Fixed-field or ultrasonic proximity mode sensors can often deal successfully with this problem.

Figure A.52. Contrast: all photoelectric sensing applications involve differentiating between two received light levels.



*As a general rule, a contrast of **3** is the minimum for any sensing situation.* This is usually just enough to overcome the effect of subtle variables that cause light level changes, such as small amounts of dirt build-up on the lenses or inconsistencies in the product being sensed. Table A-4 (right) gives suggested guidelines for contrast values.

TABLE A-4. Contrast Values and Corresponding Guidelines

Contrast	Recommendation
1.2 or less	***Unreliable:*** evaluate alternative sensing schemes.
1.2 to 2	***Poor contrast:*** consider sensors with ac-coupled amplification.
2 to 3	***Low contrast:*** sensing environment must remain clean and all other sensing variables must remain stable.
3 to 10	***Good contrast:*** minor sensing system variables will not affect sensing reliability.
10 or greater	***Excellent contrast:*** sensing should remain reliable as long as the sensing system has enough excess gain for operation.

Close Differential Sensing

Some applications offer a contrast of less than 3, regardless of the sensing method used. These low contrast situations fall into the category of ***close differential sensing*** applications. Most color registration applications qualify as close differential sensing. Another common close differential situation involves breaking a relatively large effective beam with a small part, as in ejected small part detection or thread break detection.

Whenever a close differential sensing application is encountered, use of an ***ac-coupled amplifier*** should be considered. Most sensing systems, and self-contained sensors, use dc-coupled amplifiers. A dc-coupled amplifier is one that amplifies all received signal levels. AC-coupled amplifiers may sometimes be used more reliably in close differential sensing, since they *amplify only ac (changing) signals*, while completely ignoring dc (steady) signals. This means that very small changes in received light level can be highly amplified.

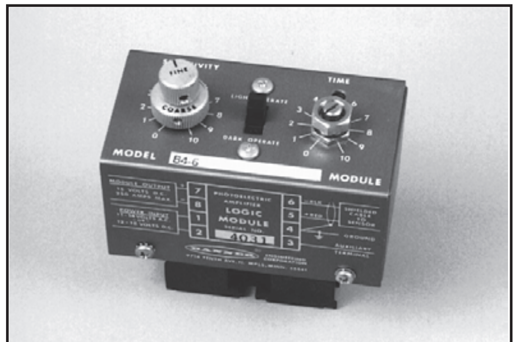


Figure A.53. A typical ac-coupled amplifier, model B4-6.

An example of an ac-coupled amplifier is model B4-6 (Figure A.53). It has a sensitivity adjustment that is typically set to respond to the smallest signal change to be sensed. It is important to set the sensitivity well below the point where the amplifier will unwantedly respond to light level changes due to environmental conditions. The output of all ac-coupled amplifiers is a timed pulse, since the amplifier cannot amplify steady-state conditions. The B4-6 has an adjustable time setting for this output pulse. Model B4-1500A is similar to model B4-6, except that its response time is five times faster (0.2 milliseconds). Model B4-6L is similar to model B4-6, except that its output latches "on" and is reset via a second input.

AC-coupled amplifiers are most often used to amplify the *analog* output of a non-modulated remote receiver, like model PT200B, PT250B, PT400B, PC400, or PT410. They are also used for color registration sensing with model FO2BG fiber optic interface (Figure A.54). The FO2BG contains a focused incandescent (white) light source and a blue/green-enhanced photocell. The combination of bifurcated glass fiber optic assembly, ac-coupled amplifier, and FO2BG interface forms a versatile and reliable color registration sensing system.

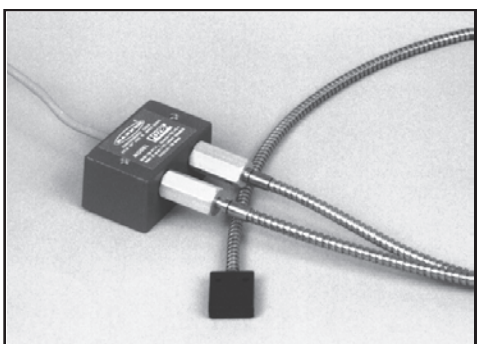


Figure A.54. The model FO2BG fiber optic interface contains an incandescent (white) light source and a photocell for color registration sensing

Figure A.55. Models SM53E and SM53R, a modulated opposed mode emitter and receiver pair, are useable with ac-coupled amplifiers.

Model SM53R, a modulated receiver, has a specially-conditioned analog output that is compatible with ac-coupled amplifiers (Figure A.55). Models SM53E and SM53R form an opposed mode pair that may be fitted with lenses, apertures, or fiberoptic adaptors for a variety of close-differential sensing applications such as yarn break, wire break, and web flaw detection. The power of this modulated LED opposed sensor pair, plus the sensitivity of an ac-coupled amplifier, offers a solution to many otherwise impossible sensing applications. Also, the OMNI-BEAM modulated self-contained sensor family offers special-purpose model sensor heads that have a *built-in* ac-coupled amplifier.

As useful as they are, ac-coupled amplifiers should be avoided whenever the contrast is high enough for a dc-coupled device. Because they are so sensitive to very small signal changes, ac-coupled amplifiers may unwantedly respond to conditions like electrical "noise" or sensor vibration. Also, ac-coupled amplifiers require a sensing event to occur at a minimum rate of change. As a general guideline, a target must move into the sensing beam at a minimum speed of one inch per second.

In the contrast range of 2 to 3, consider a dc-coupled device as a first choice. However, in order for a dc-coupled sensor to be reliable in this low contrast range, sensing variables like dirt build-up on lenses, reflectivity or translucency of the part being sensed, and the mechanics of the sensing system *must* remain constant. If it is known that these variables might gradually change over time, ac-coupled amplification should be considered.

Measuring Contrast

Contrast may be calculated if excess gain values are known for both the light and the dark conditions:

$$\text{Contrast} = \frac{\text{Excess gain (light condition)}}{\text{Excess gain (dark condition)}}$$

The **D.A.T.A.** light system of the OMNI-BEAM provides an easy way to determine sensing contrast. Both the light and the dark sensing condition (e.g. "part present" and "part absent") are presented to the OMNI-BEAM, and the signal level for each condition is read from the **D.A.T.A.** display. The ratio of the two numbers (from Table A-3) that correspond to the highest **D.A.T.A.** light numbers registered for the light and the dark conditions determines the sensing contrast.

Figure A.56. Dark condition example: the D.A.T.A. system display lights two LEDs.

For example, if **D.A.T.A.** system LEDs #1 through #8 come "on" in the light condition and LEDs #1 and #2 come "on" on the dark condition (as shown in photos A.56 and A.57), the contrast (referring to Table A-3) is calculated as follows:

$$\text{Contrast} = \frac{2.2x}{0.35x} = 6$$

Figure A.57. Light condition example: the D.A.T.A. system display lights eight LEDs.

The sensor's position and/or the sensor's gain control may require adjustment in order for the **D.A.T.A.** display to register a difference between the light and the dark conditions. If the gain is too high, the display may show all LEDs lighted for both conditions. If the gain is too low, the display may show fewer than five LEDs lighted for both conditions. The best adjustment places the #5 LED midway between the light and the dark levels.

The most reliable sensor adjustment will cause all ten **D.A.T.A.** LEDs to come "on" for the light condition, and will cause *no* LEDs to come "on" in the dark condition. In this condition (such as an application in which an opaque box breaks the beam of an opposed mode emitter and receiver):

$$\text{(from table A-3)} \quad \text{Contrast is } \textit{greater than } \frac{3.7x}{0.25x} = 15$$

In such high contrast situations, it is important to use the maximum amount of available excess gain. Increase the gain (clockwise rotation of the control) until the the dark condition begins to register (one LED) on the **D.A.T.A.** display. The best sensing situation will allow the gain to be adjusted to its maximum setting while resulting in no **D.A.T.A.** system LED response for the dark condition.

OMNI-BEAM sensor heads and CM Series MAXI-AMP amplifier modules are programmable for ***hysteresis***. Switching hysteresis is an electronic design parameter that requires the signal level (i.e. the amount of received light) at the operate (turn-on) point of an amplifier to be different from the signal level at the release point. This differential prevents the output of a sensor from "buzzing" or "chattering" when the received signal is at or near the amplifier threshold.

TABLE A-5. The relationship between Scale Factor and D.A.T.A. System Lights

D.A.T.A. light LED number	STANDARD scale factor	FINE scale factor
#1	0.25x E.G.	0.5x E.G.
#2	0.35x	0.7x
#3	0.5x	0.8x
#4	0.7x	0.9x
#5	1.0x	1.0x
#6	1.3x	1.1x
#7	1.7x	1.2x
#8	2.2x	1.3x
#9	2.9x	1.7x
#10	3.7x (or more)	2.2x (or more)

NOTE: The scale factor is selected by programming switch #4 inside the sensor head. "OFF" = STANDARD; "ON" = FINE. Use the FINE scale only for setup and monitoring of close-differential sensing applications where LOW hysteresis is required.

Most sensing is done using the NORMAL hysteresis setting. The LOW hysteresis setting allows the sensing system to be used without an ac-coupled amplifier for some poor contrast (1.2 to 2) sensing applications. The OMNI-BEAM's **D.A.T.A.** display should be programmed for FINE scale factor whenever the LOW hysteresis setting is used. This scale factor expands the display to indicate smaller differences in excess gain (Table A-5) and can, therefore, be used to register smaller contrast ratios. All sensing conditions must remain perfectly stable for such small contrasts to be reliably sensed.

The **D.A.T.A.** system of the OMNI-BEAM includes an alarm that warns of low contrast. In the low hysteresis mode, the alarm output energizes whenever sensing contrast drops below 1.2, and alerts the operator to readjust the sensing parameters. Also, an alarm output will energize if the sensing gain drifts downward (e.g. as dirt builds up on the lenses), or if the gain drifts upward (e.g. as the object changes in reflectivity or translucency). Flashing LEDs on the **D.A.T.A.** array tell the operator whether gain is too high or too low, or if the contrast is too low.

When using a sensor or sensing system with the **AID** feature, contrast cannot be measured exactly, but it can be estimated. First, present the light condition and align the sensor for the fastest pulse rate of the alignment indicator. If the maximum attainable pulse rate is less than about 10 per second, estimate the maximum rate and fix the sensor in that position. If the pulse rate is greater than about 10 per second, adjust the gain control downward (counterclockwise adjustment) until the pulse rate is roughly 10 per second.

Next, present the dark condition and estimate the number of pulses per second. If the alignment indicator turns "off", then assume a pulse rate of one per second (usually, this assumption is conservative). The ratio of the estimated pulse rates for the light and dark conditions is a rough approximation of the sensing contrast. This procedure cannot produce an accurate *measurement* of contrast; however, it will identify a low contrast situation.

When using sensors or component amplifiers not having a signal strength indication system, a simple procedure using the sensitivity control and alignment indicator (or output indicator) can be used to determine whether the contrast ratio is more than or less than 3. First, turn the sensitivity to minimum (fully counterclockwise) and program the output, where applicable, for "light operate". Next, present the light condition to the sensor and increase the sensitivity until the alignment indicator (or output indicator) just turns "on" (this is the threshold, where the excess gain is 1x). Then, present the dark condition and further increase the sensitivity until the indicator, again, just turns "on".

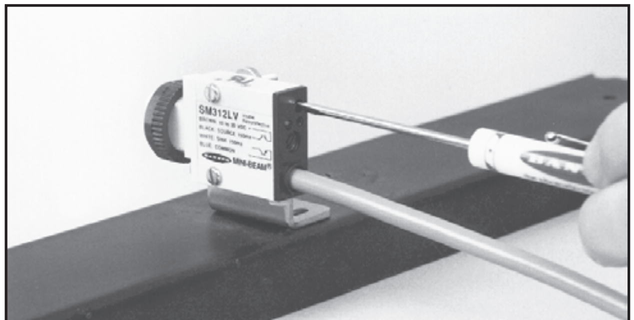


Figure A.58. Verifying contrast. Marginal contrast may be verified by noting the differential between sensitivity settings for the light and dark thresholds.

The difference between these two set points (thresholds) should represent at least one-third of the full range of the sensitivity adjustment control. (Note that most multi-turn potentiometers have 15 turns from minimum to maximum gain.) Thirty percent of the full sensitivity adjustment relates to a contrast of about 3. The ideal operating sensitivity setting is midway between these two thresholds. If the indicator LED does not come "on" in the dark condition when the gain is adjusted to maximum, the operating sensitivity setting should be left at or near the fully clockwise position in order to take advantage of the full amount of available excess gain. See Figure A.58.

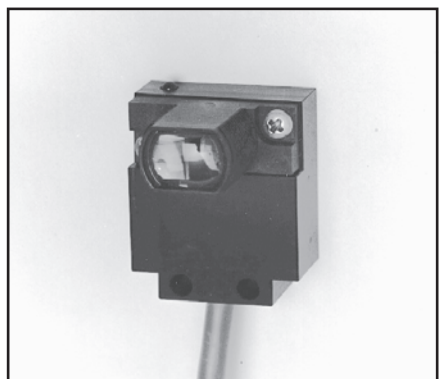


Figure A.59. Sensors without sensitivity controls: these should be used only in high-contrast applications.

If the two thresholds occur within the bottom 20 percent of the sensitivity adjustment, there is *too much excess gain* for the dark condition. There may actually be a contrast of 3 or more, but it becomes impossible to find a stable setting near the bottom end of a sensitivity range. A common example is a paper web detection application. Although opposed sensors usually offer the best sensing contrast, they may offer so much excess gain (10,000x, or more!) that they "see" right through the paper. In cases like this, it may be necessary to mechanically attentuate the light energy by intentional misalignment of the sensors or by adding apertures in front of the sensor lenses. *It is always best to attenuate the light energy so that the operating sensitivity setting ends up near the midpoint of the gain adjustment range.*

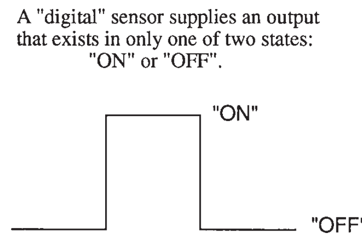
Sensors *without* sensitivity controls, such as ECONO-BEAM, THIN-PAK, and S18 Series sensors, are popular for OEM use. These sensors should be used only in applications that offer contrast values of 10 or higher, and when it is known that the sensors offer enough excess gain to easily survive the operating conditions.

Contrast should always be considered when choosing a sensor, and should always be maximized by alignment and gain adjustment during sensor installation. *Optimizing the difference in the amount of received light between the light and dark conditions of any photoelectric sensing application will always increase the reliability of the sensing system.*

Sensor Outputs

The output of a self-contained sensor or of the remote amplifier of a component sensing system is either digital or analog. A ***digital output*** (Figure A.60) is more commonly called a *switched* output. A switched output has only two states: "on" and "off". "On" and "off" commonly refer to the status of the ***load*** that the sensor output is controlling. The load might be an indicator light, an audible alarm, a clutch or brake mechanism, a solenoid valve or actuator, or a switching relay. The load might also be the input circuit to a timer, counter, programmable logic controller, or computer.

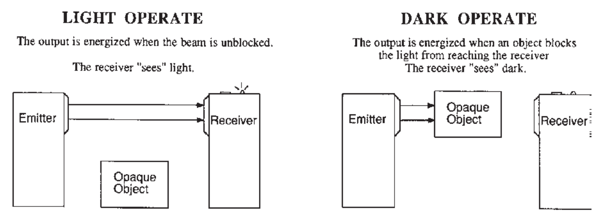
Figure A.60. Digital sensor output.



In photoelectrics, the sensing event (input) and the switched output state are characterized together by one of two sensing terms. ***Light operate*** describes a sensing system that will energize its output when the receiver "sees" more than a set amount of light. ***Dark operate*** means that the sensor's output will energize when its receiver is sufficiently dark.

In an opposed mode sensing system (Figure A.61), "dark operate" means that the output energizes its load when an object is present (breaking the beam). The light condition occurs when the object is absent.

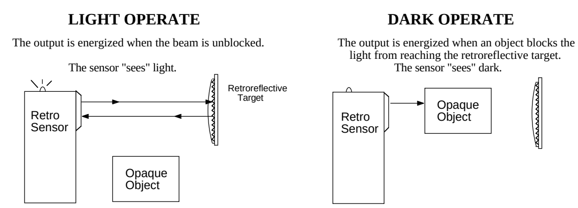
Figure A.61. LIGHT operate vs. DARK operate for an opposed mode system.



In a retroreflective sensing system (Figure A.62), the conditions are the same. The dark condition occurs when the object is present, and the receiver sees light when the object is absent.

These conditions are reversed in all proximity sensing modes (Figure A.63). The light condition occurs when the object is present, "making" (establishing) the beam. When the object is absent, no light is returned to the receiver.

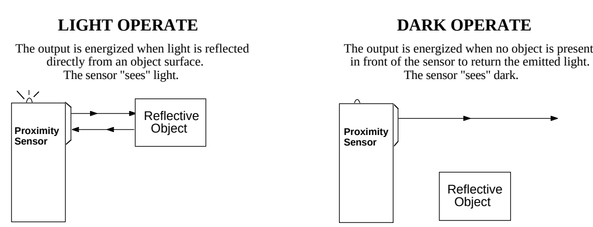
Figure A.62. LIGHT operate vs. DARK operate for a retroreflective mode sensor.



An ***analog output*** (Figure A.64) is one that varies over a range of voltage (or current) and is proportional to some sensing parameter. The output of an analog photoelectric sensor is proportional to the strength of the received light signal (e.g. OMNI-BEAM analog sensors).

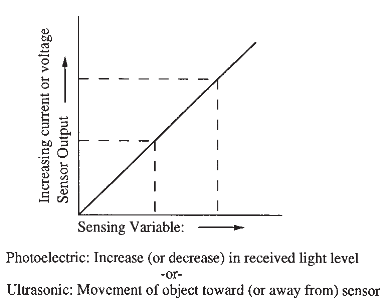
The output of an analog ultrasonic proximity sensor is proportional to the distance between the sensor and the object that is returning the sound echo (e.g. ULTRA-BEAM 923 Series sensors). The output is proportional to the time required for the echo to return to the sensor.

Figure A.63. LIGHT operate vs. DARK Operate for a proximity mode sensor (diffuse, divergent, convergent, and background suppression modes).



Sensors with analog outputs are useful in many process control applications where it is necessary to monitor an object's position or size or translucency, and to provide a continuously variable control signal for another analog device, like a motor speed control. Specific types of switched (digital) and analog outputs are detailed in Section C.

Figure A.64.
Analog sensor output: output varies over a range of voltage or current and is proportional to a sensing parameter.



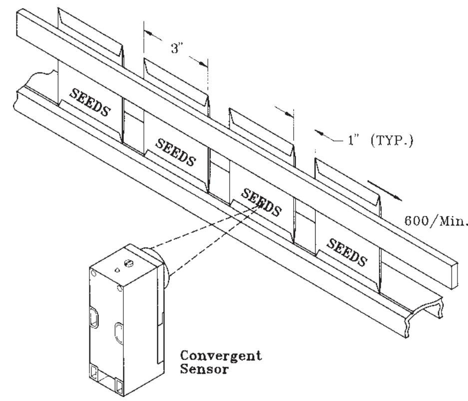
Response Time

Every sensor is specified for its response time. The ***response time*** of a sensor or sensing system is the maximum amount of time required to respond to a change in the input signal (e.g. a sensing event). It is the time between the leading edge (or trailing edge) of a sensing event and the change in the sensor's output. With a switched output, the response time is the time required for the output to switch from "off" to "on" or from "on" to "off". These two times are not always equal. With an analog output, the response time is the maximum time required for the output to swing from minimum to maximum or from maximum to minimum. Again, these two times are not necessarily equal.

The response time of a sensor is not *always* an important specification. For example, sensors that are used to detect boxes passing on a conveyor do not require fast response. In fact, time delays are sometimes added to extend sensing response to avoid nuisance trips or to add simple timing logic for flow control applications. All of the commonly used timing logic functions are detailed in Section D, "Sensing Logic".

Response time does become important when detecting high-speed events, and becomes quite critical when detecting small objects moving at high speed. Narrow gaps between objects or short times between sensing events must also be considered when verifying that a sensor's response is fast enough for the application.

Figure A.65. A convergent beam sensor counting seed packets on a conveyor.



Required Sensor Response Time

The required sensor response time may be calculated for a particular sensing application when the size, speed, and spacing of the objects to be detected are known:

$$\text{Required Sensor Response Time} = \frac{\text{Apparent width of object as it passes the sensor}}{\text{Speed (velocity) of the object as it passes the sensor}}$$

As an example, consider an application in which seed packets on a conveyor are counted by a convergent beam sensor (Figure A.65). The following information is known:

1) The seed packets are processed at a rate of 600 per minute.

2) The packets are 3 inches wide.

3) The packets are equally spaced with about a one inch separation between adjacent packets.

To compute the required sensor response time, the processing rate is first converted to packet speed:

600 packets/minute = 10 packets/second

Each packet accounts for 3 inch (packet width) + 1 inch (space) = 4 inches of linear travel.

Speed of the packets = 4 inches/packet x 10 packets/second = 40 inches/second.

The time during which a packet is "seen" by the convergent beam sensor is:

$$\text{Time of light condition} = \frac{\text{Object width}}{\text{Object speed}} = \frac{\text{3 inches}}{\text{40 in./sec.}} = .075 \text{ seconds} = 75 \text{ milliseconds.}$$

(Time of packet passing the sensor)

In this application, the time between adjacent packets is actually much less than the time during which the sensor "sees" a packet. As a result, it is the dark or "off" time between packets that is the most important to consider when specifying a sensor:

$$\text{Time of dark condition} = \frac{\text{Width of space}}{\text{Object speed}} = \frac{\text{1 inch}}{\text{40 in./sec.}} = .025 \text{ seconds} = 25 \text{ milliseconds.}$$

(Time of space between packets)

A sensor with a specified response time of less than 25 milliseconds will work in this counting application. It is always wise to include a safety factor, and to choose a sensor with a response time faster than required.

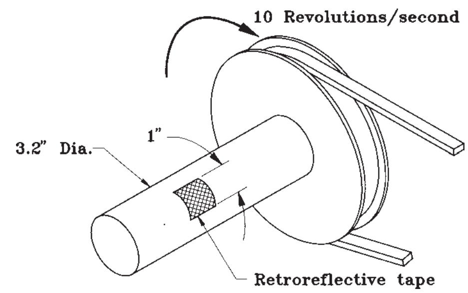
Response Requirements for Rotating Objects

When sensing a rotating object, the calculation for the required sensor response time is the same. The only additional calculation is conversion of rotational speed to linear speed. For example, calculate the required sensor response time for sensing a retroreflective target on a rotating shaft, given the following information:

1) The target is a 1 inch by 1 inch square piece of retroreflective tape on a 3-1/4 inch diameter shaft.

2) Maximum shaft speed is 600 revolutions per minute = 10 revolutions per second.

Figure A.66. Calculating response time for a rotating member.



To convert rotational speed to linear velocity:

Circumference of the shaft = π x diameter = π x 3.25 inches = 10 inches

Linear velocity on shaft circumference = 10 inches/revolution x 10 revolutions/second = 100 inches/second.

The required sensor response time is:

$$\text{Time of light condition} = \frac{\text{Target length}}{\text{Linear speed}} = \frac{1 \text{ inch}}{100 \text{ in./sec.}} = 0.01 \text{ second} = 10 \text{ milliseconds.}$$

(Time sensor "sees" retro tape)

Ten milliseconds is the fastest response requirement in this application, since the untaped portion of the circumference is 9 times longer. A retroreflective sensor with a small effective beam and a response time faster than 10 milliseconds, like a MINI-BEAM model, will reliably sense the tape at the maximum shaft speed. To ease the response time requirement in applications like these that simply require one pulse per revolution (or per cycle), a target should cover 50% of the shaft circumference so that half of the revolution is light time and the other half is dark time.

Response Time Requirements for Small Objects

A safe assumption to make when calculating the response time requirement for an object with a small cross section is that the object must fill 100 percent of the sensor's effective beam to be detected. Whenever the size of a small object begins to approach the size of the effective beam, the apparent size of the object as "seen" by the sensor becomes less than the actual width of the object. A safe assumption in these situations is to reduce the apparent size of the object by an amount equal to the diameter of the effective beam at the sensing location. As a result, the required response time decreases:

$$\text{Required response time} = \frac{\text{Width of object - Diameter of effective beam}}{\text{Speed of the object through the beam}}$$

To illustrate the effect of small objects on response time requirements, consider the following example of a small pin that breaks the beam of an opposed sensor pair (Figure A.67):

1) 1/4-inch diameter pins pass through the beam of an opposed LR400 emitter and PT400 receiver pair that has a 1/8-inch diameter effective beam.

2) The maximum speed of the pins is 10 inches per second.

Figure A.67. A 1/4-inch diameter pin is sensed in a 1/8-inch diameter effective beam.

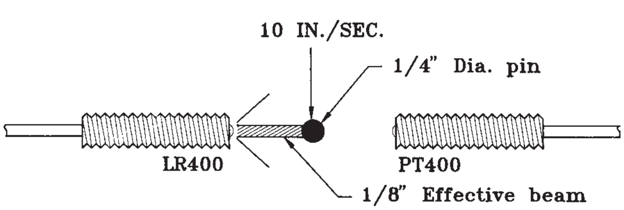
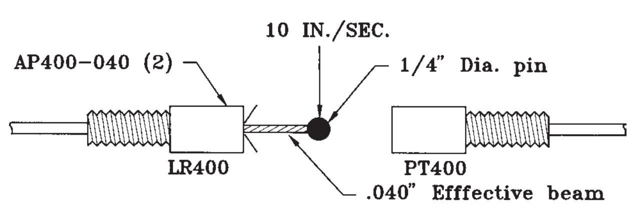


Figure A.68. Required sensor response time is eased by use of apertures.



Computing the required sensor response time:

$$\text{Time of dark condition} = \frac{\text{Pin diameter - Effective beam diameter}}{\text{Speed of the pin through the beam}} = \frac{\text{.25 inch - .125 inch}}{\text{10 inches/second}} =$$

$$= \frac{\text{.12 inch}}{\text{10 in./sec.}} = \text{.012 seconds} = \text{12 milliseconds}$$

The addition of apertures on the LR400 and the PT400 (Figure A.68) will ease the response time requirement because the pin will block the smaller effective beam for a longer time. If the standard AP400-040, .040 inch diameter apertures are used:

$$\text{Time of dark condition} = \frac{\text{.25 inch - .04 inch}}{\text{10 inches/second}} = \frac{\text{.21 inch}}{\text{10 in./sec.}} = \text{.021 seconds} = \text{21 milliseconds}$$

Due to resulting low excess gain, it is usually impractical to aperture an opposed beam to less than about .02 inch. Objects with cross sections smaller than about .03 inch are usually sensed most reliably using one of the proximity sensing modes. The wider the proximity beam, the longer a small part will be sensed. This eases the sensor response requirement. A divergent-beam sensor (e.g. model LP400WB) or a bifurcated fiberoptic sensor are preferred for sensing very small profiles.

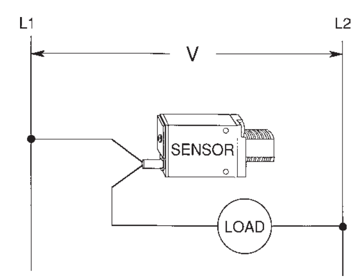
When sensing narrow gaps, opposed mode sensors should have a wide beam so that light is seen through the gap for a long time. Use of individual fiberoptics with a rectangular termination is one way to shape the effective beam and ease sensor response requirements. When sensing narrow gaps with a proximity sensor, the small effective beam of a convergent mode sensor is usually preferred.

Response Time of a Load

The ***response time of a load*** is the maximum time required to energize and/or de-energize a particular load, and is included in the load's specifications. In general, solid-state loads like counters and solid-state relays have faster response times than electromechanical devices like solenoids and contactors.

The response speed characteristics of any load to be controlled by a sensor's output should be checked to be sure that the duration of the output signal from the sensor and the time between adjacent outputs are both long enough to allow the load to react properly. In situations where the load is too slow to react, a delay timer may be required between the sensor output and the load to extend the duration of the sensor's output signal. An even better solution involves changing the sensing geometry, if possible, to equalize the durations of the light and the dark ("on" and "off") times.

Figure A.69. The response time of any load is included in its specifications.



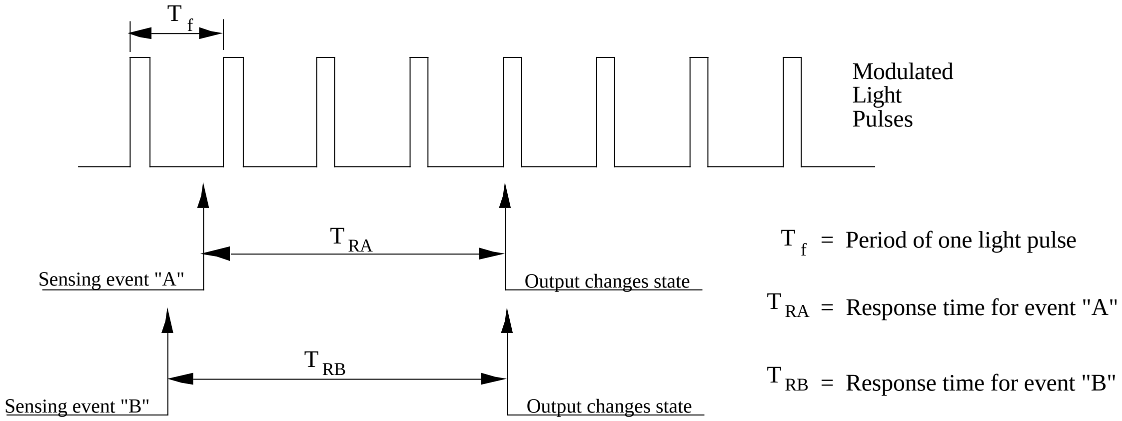
Repeatability of Response

Sensor repeatability is a concern whenever a sensing event triggers a resultant action. This is especially important in cyclical operations that take place at high speed. Application examples include sensors used to trigger glue striping (on box flaps, envelopes, etc.), ink-jet printing (imprinting of product date codes, etc.), and label registration. In each of these examples, repeatability of sensor response is important to ensure consistent product appearance.

Repeatability of response is easily defined for most modulated photoelectric sensors. Today's digital modulation schemes count a defined number of received light pulses before responding to any light signal. This helps the sensor to discriminate between its emitter's light and all other interfering signals.

The number of modulated light pulses counted before the sensor's output is allowed to switch is typically three or four. The "on" response time for a modulated sensor is equal to the total amount of time taken for the sensor to count (i.e. demodulate) the required number of pulses. The sensor output changes state as soon as the sensor counts enough light pulses of the correct frequency. However, since the sensing event can occur at any time during a modulation cycle (period), the actual time between the sensing event and the sensor's output change can vary by up to one modulation period (see Figure A.70). This variation in sensing response is specified as the sensor's *repeatability*.

Figure A.70. The repeatability of a modulated photoelectric sensor is equal to the period of one light pulse.



Sensor response varies by up to one pulse period ⟹ T_f = the sensor repeatability specification.

NOTE: In this example, the received light is demodulated in four pulses.

The sensor repeatability specification is multiplied by the velocity of the sensed object to define the mechanical repeatability (i.e. the amount of mechanical error) due to the sensor response. For example, while referring to Figure A.65, assume that the sensor shown is triggering an ink-jet printer to imprint a date code on the seed packets. The amount of variation in placement of the printing along the direction of travel is calculated as follows:

Velocity of seed packets = 40 inches/second
Sensor repeatability = 0.3 milliseconds = 0.0003 seconds (typical value)

Mechanical repeatability = 40 inches/second x 0.0003 seconds = 0.012 inch
(Due to sensor)

This amount of error in placement of the date code on each seed packet does not take the repeatability of the other control elements into account. Here, the control circuit for the ink-jet printer head and the control circuit for the printer mechansim itself each contribute to the total variation in the location of the imprint.

The sensor's repeatability specification is based on the transition from dark to light. Counting of modulated light pulses is not an issue to consider for each light-to-dark transition. Repeatability for dark-operated outputs is not specified; however, it is a much smaller amount of time than the repeatability specification given for dark-to-light (typically less than 10% of the specified "off" response time). The specified sensor repeatability time is a "worst case" value, which can be relied upon when evaluating applications that involve high speeds, where repeat accuracy is important.

Summary

Now, equipped with a general understanding of these sensing terms and concepts, you are well prepared to investigate the whys and wherefores of the sensor selection process discussed in Section B.

Additional sensing terms will be defined as they are presented.

Section B: Sensor Selection

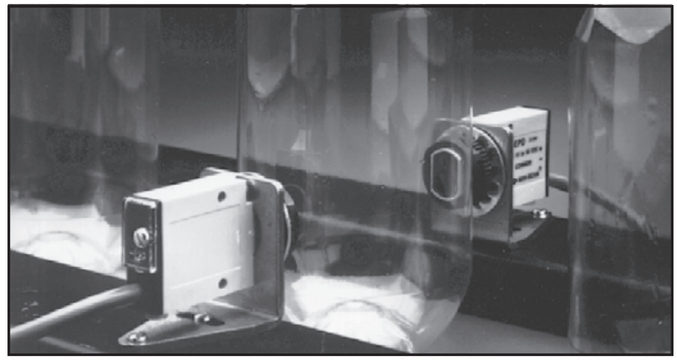
The selection of any photoelectric or ultrasonic sensor is based upon the requirements of the application in which the sensor is to be used. Special requirements for some applications may narrow the choice to within a single sensor family, or even dictate the exact sensor model. More often, though, sensor selection is a process of elimination involving careful evaluation of *several* sensing variables.

Some of the major requirements that might enter into a sensor selection process are *sensing mode* and various sensor characteristics including *cost, size and shape, ruggedness, chemical resistance, input voltage range, output configuration, response speed, (special) features or functions, and options.* These selection considerations are discussed in this section, which is organized as shown below. Note: Selection charts on the following pages list model numbers available for each category, plus relevant specifications. For *complete* specifications, see the Banner product catalog. Use the index at the end of the catalog to locate the desired model in the catalog.

Section B   Contents

Sensor Selection Category A: Sensing Mode

An important part of any sensor selection process involves determination of the best *sensing mode* for the application:



Photoelectric sensing modes:
- Opposed
- Retroreflective
- Proximity (four variations):
  - Diffuse
  - Divergent
  - Convergent
  - Fixed-field
- Fiberoptic modes

Ultrasonic proximity sensing mode

The **best** sensing mode is the mode that yields the greatest amount of sensing signal differential between the conditions of target present and target absent (i.e. the most sensing *contrast*), while maintaining enough sensing signal (i.e. enough *excess gain*) to comfortably overcome any attenuation caused by conditions in the sensing environment.

The concepts of *sensing contrast* and *excess gain* are explained in Section A. These measurements actually apply only to **photoelectric** sensing modes. Selection of an **ultrasonic** sensor is based upon application requirements that are best handled only by that mode.

TABLE B-1.
Guidelines for Excess Gain Values

Minimum Excess Gain Required	Operating Environment
1.5x	***Clean air:*** no dirt buildup on lenses or reflectors.
5x	***Slightly dirty:*** slight buildup of dust, dirt, oil, moisture, etc. on lenses or reflectors. Lenses are cleaned on a regular schedule.
10x	***Moderately dirty:*** obvious contamination of lenses or reflectors (but not obscured). Lenses cleaned occasionally or when necessary.
50x	***Very dirty:*** heavy contamination of lenses. Heavy fog, mist, dust, smoke, or oil film. Minimal cleaning of lenses.

For example, linear analog reflective position sensing or very long range (several feet) proximity presence sensing are application requirements that are reliably filled only by ultrasonic proximity sensors.

To determine which mode will yield the highest sensing contrast, you must evaluate the properties of the target to be sensed, including: *part size/profile, optical opacity, and optical or acoustical surface reflectivity*. The geometry of the application should be analyzed to determine whether sensing of the target will be at a repeatable point or if the target, instead, will pass at random distances and/or with random orientations to the sensor. It may also be necessary to evaluate the properties of other objects (if present) in the sensing path to ensure that they do not interfere with sensing of the target. Also, the discussion of sensing contrast in Section A explains how contrast may be estimated or measured if a sensor is available for testing.

To determine if the excess gain is high enough for reliable sensing, you must evaluate the conditions of the sensing environment. Then, using the guidelines for minimum required excess gain (Table B-1), check the excess gain curve of each sensor under consideration to determine if that sensor offers enough excess gain at the required sensing distance to overcome the predicted signal loss. An example of this type of evaluation is given in Section A for a diffuse mode sensor (page A-17).

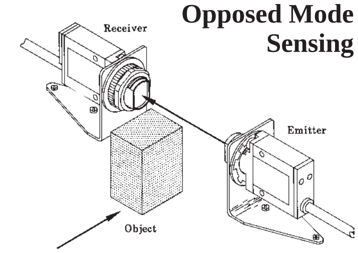
Each sensing mode has its own advantages. Also, there are some specific reasons for *not* using each sensing mode. The following is a summary of the most important considerations.

1. Photoelectric Sensing Modes

A. Opposed Mode Sensing

Uses and advantages - opposed mode

1) General rule: *Use opposed mode photoelectric sensors wherever possible.* The use of opposed mode photoelectric sensors will always result in the most reliable sensing system, as long as the object to be detected is opaque to light (i.e. if the object *completely* blocks the opposed light beam). Exception: An *inductive proximity sensor* becomes a first choice for sensing of *metal* objects that pass close enough to the sensor for reliable detection.



Opposed Mode Sensing

2) High excess gain: Opposed sensors offer the highest excess gain. Applications requiring high levels of excess gain include:

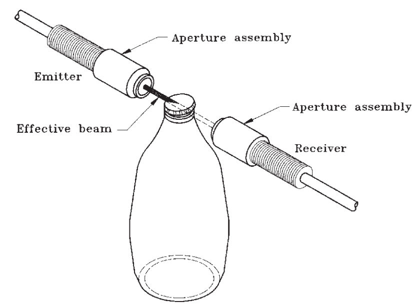
a) Sensing through heavy dirt, dust, mist, condensation, oil film, etc.,

b) Long-range scanning,

c) Precise position sensing or small part detection using small apertures (Figure B.1),

d) Detection of opaque solids or liquids inside closed thin-walled boxes. Opposed mode sensors can sometimes be used to "burn through" thin-walled boxes or containers to detect the presence, absence, or level of the product inside.

Fig. B.1 Apertures are used with opposed sensors for precise position sensing (high cap detection).



3) Parts counting: Opposed sensors are usually the most reliable for accurate parts counting, largely due to their well-defined effective beam.

4) Object reflectivity: Use of opposed mode sensors eliminates the variable of surface reflectivity or color.

5) Mechanical convergence: A pair of opposed mode sensors may be positioned to mechanically converge at a point ahead of the sensor pair (Figure A.34). This type of configuration usually results in more depth-of-field as compared to convergent beam proximity sensors. High-powered emitter-receiver pairs, such as MULTI-BEAM models SBEX and SBRX1, may be configured for long-range mechanical convergent beam sensing.

6) Specular reflection: One specialized use of a mechanically converged emitter and receiver pair is to detect the difference between a shiny and a dull surface. A shiny surface will return emitted light to a receiver if the two units are mounted at equal and opposite angles to the perpendicular to the shiny surface (see Figure A.26). This light will be diffused by any non-reflective surface that covers or replaces the shiny surface. A common example is sensing the presence of cloth (dull surface) on a steel sewing machine table (shiny surface). Specular reflection is also used to monitor or inspect the orientation or the surface quality of a shiny part.

Application Cautions - opposed mode

1) Clear materials: Opposed mode photoelectric sensors should be avoided for detection of translucent or transparent materials. Exceptions:

a) Many translucent and transparent plastic materials can be reliably sensed by the MINI-BEAM clear plastic detection sensors (see Figure B.34). This is a special-purpose opposed mode sensor pair that takes advantage of the polarizing properties of many plastics. In fact, this pair may be used to actually differentiate clear plastic from other clear and translucent (plus all opaque) materials.

b) Most glass containers have a thick bottom section of glass that may usually be used to reliably block an opposed beam that has been properly shaped (if necessary) using rectangular apertures (see Figure B.2).

2) Very small parts: Avoid trying to detect objects that interrupt less than 100 percent of an opposed effective beam area. Use apertures, lenses, or fiber optics to shape the effective beam to match the profile of a small part.

When the cross section of the part to be detected is less than about .03 inch, and when the part passes at a *predictable* distance from the sensor, it is best to use a convergent beam proximity mode sensor. Small parts that pass the sensor at *random* (but close) distances may be sensed with a divergent mode proximity sensor.

When small parts *fall randomly* through an area (i.e. through a sensing "window") use opposed rectangular fiberoptics (e.g. model IR2.53S) with OMNI-BEAM sensor model OSBFAC (see Figure B.44), which has an ac-coupled amplifier. If the parts to be sensed have a minimum profile of 0.1 inch, then the MULTI-BEAM® model LS10 Light Screen System is the best choice. This special opposed pair creates a "curtain" of sensing light that measures 3.5 inches wide and from 4 to 48 inches in its longer dimension.

3) Too much excess gain: Some opposed mode pairs (especially those using an infrared light source) have so much excess gain when they are used at close range that they tend to "burn through" (i.e. "see" through) thin opaque materials like paper, cloth, and plastics. The opposed mode may offer the best sensing contrast, but it becomes difficult to set a sensitivity control operating point, due to too much excess gain. In these situations, opposed mode sensors should be used, but their signal may need to be mechanically attenuated by addition of apertures over the lenses or by intentional sensor misalignment. In some situations, the use of a visible wavelength emitter (e.g. visible red LED) may lower gain to a responsive level, while actually increasing the sensing contrast.

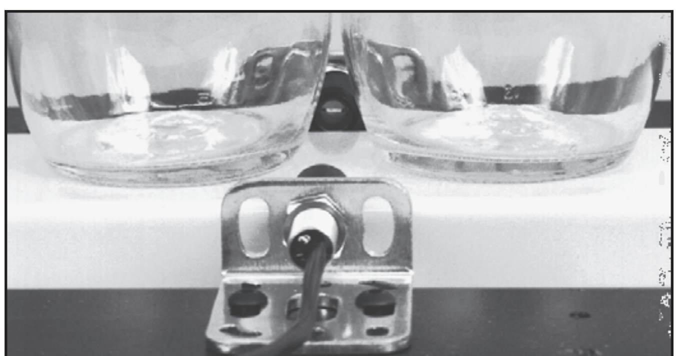


Fig. B.2 Opposed mode sensing of glass bottles using rectangular apertures.

Table B-2. Opposed Mode Sensors

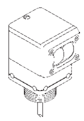
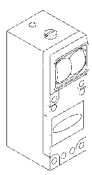
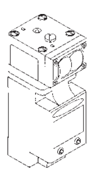
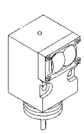
Self-contained Sensor Family	Supply Voltage & Output (E/M = electromechanical)	Response (ms = milliseconds)	Sensing Range	Sensor Model	Features and Uses (All beams infrared unless otherwise noted)
OMNI-BEAM™ 	Choice of power block: 10 to 30V dc or 120, 220, or 240V ac Solid-state output	2ms on/off	150 feet	**OSBE & OSBR**	D.A.T.A.™ self-diagnostic system with alarm output 10-element signal strength indicator General use
NOTE: 2-part assembly requires sensor head and power block. Optional timing module may be added.	24 to 240V ac or 24 to 36V dc SPDT E/M relay output	20ms on/off	150 feet	**OSEE & OSER**	OEM design For general use Optional timing logic
MULTI-BEAM® 	Choice of power block: 10 to 30V or 48V dc or 12, 24, 120, or 240V ac Solid-state or E/M relay output	1ms on/off	150 feet	**SBE & SBR1**	Fast response speed
			10 feet	**SBED & SBRD1**	Small effective beam (1/8"); fast response speed
		10ms on/off	700 feet	**SBEX & SBRX1**	Long-range sensing; very high gain
			100 feet	**SBEV & SBRX1**	Visible (red) emitter
			30 feet	**SBEXD & SBRXD1**	Small effective beam (1/8"); very forgiving alignment
NOTE: 3-part assembly requires scanner block, power block, and logic module. Logic module may have timing logic.	12, 120, 240V ac 2-wire hookup	10ms on/off	150 feet	**SBE & 2SBR1**	2-wire (ac) hookup
MAXI-BEAM® 	Choice of power block: 10 to 30V dc or 120, 220, or 240V ac Solid-state or E/M relay output	0.3, 1, or 10ms	300 feet	**RSBE & RSBR**	Programmable response; general use
NOTE: 3-part assembly requires sensor head, power block, and wiring base. Optional timing logic may be added.			15 feet	**RSBESR & RSBRSR**	Small effective beam (1/8"); forgiving alignment
VALU-BEAM® 	10 to 30V dc Solid-state bi-polar output	8ms on/ 4ms off	200 feet	**SMA91E & SM91R**	Long-range sensing & general use; use where high gain is needed
			10 feet	**SMA91ESR & SM91RSR**	Small effective beam (1/8"); forgiving alignment
	24 to 250V ac Solid-state output 2-wire hookup	8ms on/ 4ms off	200 feet	**SMA91E & SM2A91R**	Long-range sensing & general use; use where high gain is needed
			10 feet	**SMA91ESR & SM2A91RSR**	Small effective beam (1/8"); forgiving alignment
	12 to 28V ac or dc SPDT E/M relay output	20ms on/off	200 feet	**SMA91E & SMW95R**	Long-range sensing & general use; use where high gain is needed
			10 feet	**SMA91ESR & SMW95RSR**	Small effective beam (1/8"); forgiving alignment
	90 to 130V ac SPDT E/M relay output	20ms on/off	200 feet	**SMA91E & SMA95R**	Long-range sensing & general use; use where high gain is needed
			10 feet	**SMA91ESR & SMA95RSR**	Small effective beam (1/8"); forgiving alignment
	210 to 250V ac SPDT E/M relay output	20ms on/off	200 feet	**SMA91E & SMB95R**	Long-range sensing & general use; use where high gain is needed
			10 feet	**SMA91ESR & SMB95RSR**	Small effective beam (1/8"); forgiving alignment

Table B-2. Opposed Mode Sensors (continued)

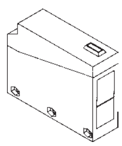
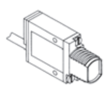
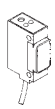
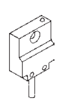
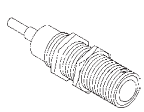
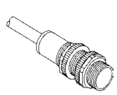
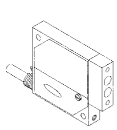
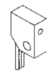
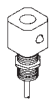
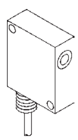
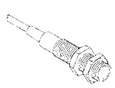
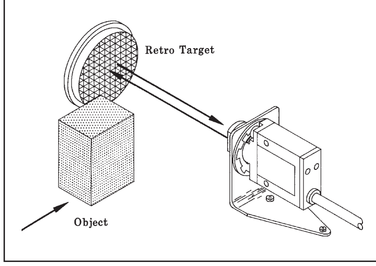
Family	Supply Voltage & Output	Response (ms = milliseconds)	Sensing Range	Sensor Model	Features and Uses (All beams infrared unless otherwise noted)
Q85 Series 	24 to 240V ac or 12 to 240V dc electromechanical relay output	20ms on/off	75 feet	**Q853E emitter and Q85VR3R or Q85VR3R-T9 receiver**	Visible red sensing beam NEMA 6P Wiring chamber Optional built-in timing logic (T9 models)
MINI-BEAM® 	10 to 30V dc Solid-state bi-polar output	1ms on/off	10 feet	**SM31E & SM31R**	Small effective beam; fast response
			100 feet	**SM31EL & SM31RL**	General use; use where high gain is required
	24 to 240V ac Solid-state output 2-wire hookup	2ms on/ 1ms off	10 feet	**SMA31E & SM2A31R**	Small effective beam
			100 feet	**SMA31EL & SM2A31RL**	General use; use where high gain is required
Q19 Series 	10 to 30V dc Solid-state complementary output	1ms on/off	26 feet	**Q196E emitter and Q19SN6R or Q19SP6R receiver**	Very small NEMA 6 construction
ECONO-BEAM™ 	10 to 30V dc Solid-state bi-polar output	10ms on/off	6 feet	**SE61E & SE61R**	Designed for OEM applications where sensing contrast is high (has no gain adjustment)
QØ8 Series 	10 to 30V dc Solid-state output	1ms on/off	20 inches	**SO6Ø-QØ8 emitter & EO6Ø-QØ8 Series receiver**	Very low profile: 8-mm deep die-cast metal housing; use where sensing contrast is high (sensor has no GAIN adjustment)
SM30 Series 	10 to 30V dc Solid-state bi-modal output	10ms on/off	700 feet	**SMA30 Series emitter & SM30 Series receiver**	Extremely high excess gain for demanding environments NEMA 6P construction High immunity to electrical noise VALOX® or stainless steel models
	24 to 240V ac Solid-state output 2-wire hookup	10ms on/off	700 feet	**SMA30 Series emitter & SM2A30 Series receiver**	
S18 Series (an EZ-BEAM sensor) 	10 to 30V dc Solid-state complementary output	2.5ms on 1.5ms off	66 feet	**S186E Series emitter & S18SN6 or S18SP6 Series receiver**	Versatile LED indicator system 18mm threaded VALOX® barrel Low gain alarm output (dc models) NEMA 6P construction Use where sensing contrast is high (sensor has no GAIN adjustment)
	20 to 250V ac Solid-state output 3-wire hookup	16ms on 16ms off	66 feet	**S183E Series emitter & S18AW3 or S18RW3 Series receiver**	
SM512 Series 	10 to 30V dc Solid-state complementary output	1ms on/off	25 feet	**SM51EB & SM51RB**	Narrow profile housing; used with MP-8 multiplexer for custom light curtain
		10ms on/off	100 feet	**SM51EB6 & SM51RB6**	Very high excess gain with small effective beam; used for "burn-through" applications

Table B-2. Opposed Mode Sensors (continued)

Remote Sensors	Used with Amplifiers	Response (ms = milliseconds)	Sensing Range	Sensor Model	Features and Uses (All beams infrared unless otherwise noted)
SP100 Series 	MICRO-AMP™ MA3, MA3P, MPC3	1ms on/off	8 inches	**SP100E & SP100R**	Subminiature package used in tight locations Very small effective beam Hermetically sealed lenses
	MAXI-AMP™ CR Series	0.3, 2, or 10ms			
LR/PT Series 	MICRO-AMP™ MA3-4 or MA3-4P	1ms on/off	8 feet	**LR200 & PT200**	Miniature right-angle housing Hermetically sealed lenses
				LR250 & PT250	Miniature 1/4" tubular housing Hermetically sealed lenses
	MAXI-AMP™ CM Series	0.3, 2, or 10ms		**LR300 & PT300**	Miniature right-angle VALOX® housing Hermetically sealed lenses
				LR400 & PT400	Miniature 3/8" threaded housing Accepts apertures, lenses, and fiberoptic fittings Hermetically sealed lenses
SP300 Series 	MICRO-AMP™ MA3-4 or MA3-4P	1ms on/off	50 feet	**SP300EL & SP300RL**	Used for long-range sensing Used where high gain is needed
	MAXI-AMP™ CM Series	0.3, 2, or 10ms			
SP12 Series 	MAXI-AMP™ CD Series	1.5 or 15ms	200 feet	**SP12SEL or SP12PEL emitter; SP12SRL or SP12PRL receiver**	NEMA 6P construction Used in harsh environments Used when very high gain is needed VALOX® or stainless steel models

B. Retroreflective Mode Sensing

Retroreflective Sensing



Uses and Advantages - retroreflective mode

1) General rule: Use a retroreflective sensor in lieu of the opposed mode where sensing is possible from only one side.

2) Conveyor applications: Retro is the most popular sensing mode in conveyor applications where objects are large (e.g. boxes, cartons, etc.), where the environment is relatively clean, and where scanning ranges are from about 2 to 10 feet (Figure B.3).

Application Cautions - retroreflective mode

1) Excess gain: Avoid using retroreflective sensors on the basis of convenience only, especially where it is important to have high excess gain. Retro sensors offer much less available excess gain as compared to an equivalent opposed sensor pair at the same range. Retro sensors also lose excess gain *twice* as fast as opposed mode sensors, due to dirt build-up on both the retro target *and* the sensor lenses.

2) Effective beam: It is usually difficult to create a small effective beam with a retroreflective sensor (see Figure A.24). Avoid using retro sensors for detecting small objects or for precise positioning control. *Exceptions:* The effective beam of model SM502A is less than 1 inch in diameter through its full 6-foot range, and the effective beam of MINI-BEAM retroreflective sensors is less than 1 inch diameter through the first 2 feet of range.

3) Clear materials: Avoid using retroreflective sensors for detecting translucent or transparent materials. It is true that a retroreflective light beam must pass through a translucent material two times before reaching the receiver, but it is usually difficult to optimize excess gain without sacrificing optical contrast (or vice versa).

4) Shiny materials: Use the retroreflective mode with caution when sensing materials with shiny surfaces. The optics of a good quality retroreflective sensor are designed and assembled with great care to minimize "proxing". Yet, a shiny surface that presents itself perfectly parallel to a retroreflective sensor lens may return enough light to cause that object to pass by the sensor undetected.

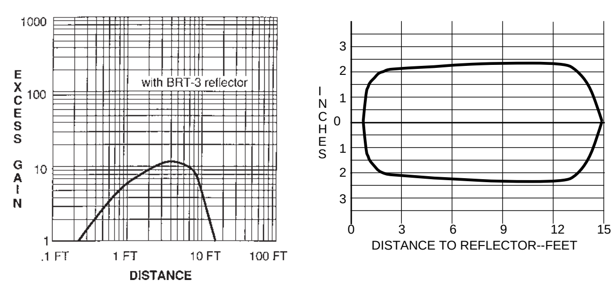
If a retroreflective sensor must be used to sense a shiny material, establish a beam direction that will eliminate any *direct* reflection from the material surface (see Figure A.28). If the material presents itself to the sensor at random angles, consider use of a retroreflective sensor with an anti-glare (polarizing) filter. However, remember that use of a filter cuts the available excess gain by one-half. Also, polarized retro sensors work only with molded corner-cube reflectors (e.g. model BRT-3).

5) Target size: Except at close range, the size of the retro target becomes important. Use as large a target area as is possible or practical. A "cluster" of several standard targets is often most convenient (see Figure A.48). The width of the beam pattern for each retro sensor also serves as an estimate of how much target area should be used to return the maximum amount of light energy at ranges beyond a few feet.

Also, the efficiency of different retro target material types varies widely. The Banner product catalog lists a "reflectivity factor" that indicates the relative efficiency of each target material as compared to the model BRT-3.

Figure B.3. The retroreflective mode is popular for many conveyor applications.

Fig. B.4. Excess gain curves and beam patterns warn of a retroreflective sensor's "blind spot".



6) Short range: Most retroreflective sensors are designed for long-range sensing, and suffer a "blind spot" at close range (see Figure A.49). Excess gain curves and beam patterns warn of this problem (Figure B.4). Retroreflective model SM502A uses a single lens system, and has no blind spot. Also, a short-range retro system may be assembled using a model BT13S bifurcated glass fiberoptic assembly, fitted with an L9 lens assembly (see Figure B.15).

Table B-3. Retroreflective Mode Sensors

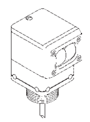
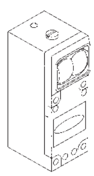
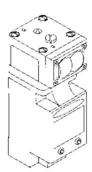
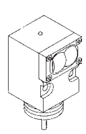
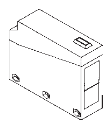
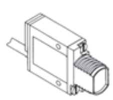
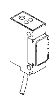
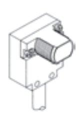
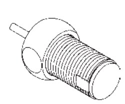
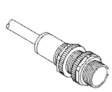
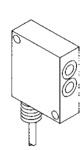
Self-contained Sensor Family	Supply Voltage & Output (E/M = electromechanical)	Response (ms = milliseconds)	Sensing Range	Sensor Model	Features and Uses
OMNI-BEAM™ 	Choice of power block: 10 to 30V dc or 120, 220, or 240V ac Solid-state output	4ms on/off	.5 to 30 feet	**OSBLV**	Visible red beam; general use
			1 to 15 feet	**OSBLVAG**	Anti-glare (polarizing) filter
NOTE: 2-part assembly requires sensor head and power block. Optional timing module may be added.	24 to 240V ac or 24 to 36V dc SPDT E/M relay output	20ms on/off	.5 to 30 feet	**OSELV**	OEM design; general use
			1 to 15 feet	**OSELVAG**	OEM design; anti-glare filter
MULTI-BEAM® 	Choice of power block: 10 to 30V or 48V dc or 12, 24, 120, or 240V ac Solid-state or E/M relay output	1ms on/off	.5 to 30 feet	**SBLV1**	Visible red beam; general use
			1 to 15 feet	**SBLVAG1**	Anti-glare (polarizing) filter
			1 inch to 30 feet	**SBL1**	Infrared beam; high excess gain
		10ms on/off	10 to 75 feet	**SBLX1**	Infrared beam; very high excess gain
NOTE: 3-part assembly requires scanner block, power block, and logic module. Logic module may have timing logic.	12, 120, 240V ac 2-wire hookup	10ms on/off	1 inch to 30 feet	**2SBL1**	Infrared beam; 2-wire hookup
MAXI-BEAM® 	Choice of power block: 10 to 30V dc or 120, 220, or 240V ac Solid-state or E/M relay output	1 or 4ms	.5 to 30 feet	**RSBLV**	Visible red beam; general use
NOTE: 3-part assembly requires sensor block, power block, and wiring base. Optional timing logic may be added.			1 to 15 feet	**RSBLVAG**	Anti-glare (polarizing) filter
VALU-BEAM® 	10 to 30V dc Solid-state bi-polar output	4ms on/off	.5 to 30 feet	**SM912LV**	Visible red beam; general use
			1 to 15 feet	**SM912LVAG**	Anti-glare (polarizing) filter
	24 to 250V ac Solid-state output 2-wire hookup	8ms on/off	.5 to 30 feet	**SM2A912LV**	Visible red beam; general use
			1 to 15 feet	**SM2A912LVAG**	Anti-glare (polarizing) filter
	12 to 28V ac or dc SPDT E/M relay output	20ms on/off	.5 to 30 feet	**SMW915LV**	Visible red beam; general use
			1 to 15 feet	**SMW915LVAG**	Anti-glare (polarizing) filter
	90 to 130V ac SPDT E/M relay output	20ms on/off	.5 to 30 feet	**SMA915LV**	Visible red beam; general use
			1 to 15 feet	**SMA915LVAG**	Anti-glare (polarizing) filter
	210 to 250V ac SPDT E/M relay output	20ms on/off	.5 to 30 feet	**SMB915LV**	Visible red beam; general use
			1 to 15 feet	**SMB915LVAG**	Anti-glare (polarizing) filter

Table B-3. Retroreflective Mode Sensors (continued)

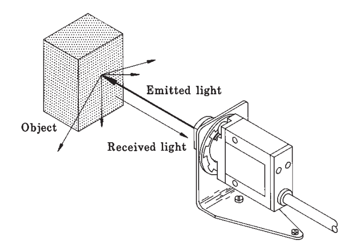
Family	Supply Voltage & Output	Response (ms = milliseconds)	Sensing Range	Sensor Model	Features and Uses
Q85 Series 	24 to 240V ac or 12 to 240V dc SPDT electromechanical relay output	20ms on/off	3 inches to 15 feet	**Q85VR3LP** **Q85VR3LP-T9**	Visible red beam Anti-glare (polarizing) filter NEMA 6P construction Wiring chamber Optional built-in timing logic
MINI-BEAM® 	10 to 30V dc Solid-state bi-polar output	1ms on/off	2 inches to 15 feet	**SM312LV**	Visible red beam; general use
			2 inches to 7 feet	**SM312LVAG**	Anti-glare (polarizing) filter
	24 to 240V ac Solid-state output 2-wire hookup	4ms on/off	2 inches to 15 feet	**SM2A312LV**	Visible red beam; general use
			2 inches to 7 feet	**SM2A312LVAG**	Anti-glare (polarizing) filter
Q19 Series 	10 to 30V dc Solid-state complementary output	1ms on/off	2 inches to 6-1/2 feet	**Q19SN6LP** **Q19SP6LP**	Very small Visible red beam Anti-glare (polarizing) filter For general use NEMA 6P construction
ECONO-BEAM™ 	10 to 30V dc Solid-state bi-polar output	10ms on/off	2 inches to 15 feet	**SE612LV**	Visible red beam Designed for OEM applications where sensing contrast is high (has no gain adjustment)
C3Ø Series 	10 to 30V dc Solid-state output	1ms on/off	4 inches to 16 feet	**C3ØAN7L** **C3ØRN7L** **C3ØAP7L** **C3ØRP7L**	Infrared beam 30mm threaded Lexan® barrel design NEMA 6P construction Use where sensing contrast is high (sensor has no GAIN adjustment)
S18 Series (an EZ-BEAM sensor) 	10 to 30V dc Solid-state complementary output	3ms on/off	4 inches to 6-1/2 feet	**S18SN6L** **S18SP6L**	Infrared beam 18mm threaded VALOX® barrel Versatile LED indicator system Use where sensing contrast is high (sensor has no GAIN adjustment)
	20 to 250V ac Solid-state output 3-wire hookup	16ms on/off		**S18AW3L** **S18RW3L**	
SM512 Series 	10 to 30V dc Solid-state complementary output	1ms on/off	.5 to 15 feet	**SM512LB**	Infrared beam; general use Die-cast metal housing
			0 to 6 feet	**SM502A**	Visible red beam; single-lens optics for close-up sensing and code reading

Remote Sensors	Used with Amplifiers	Response (ms = milliseconds)	Sensing Range	Sensor Model	Features and Uses
SP300 Series 	MICRO-AMP™ MA3-4, MA3-4P	1ms on/off	.5 to 15 feet	**SP300L**	Infrared beam Very rugged Cable conduit fitting
	MAXI-AMP™ CM Series	0.3, 2, or 10ms			

C. Photoelectric Proximity Mode Sensing

Uses and advantages - diffuse mode

Diffuse Proximity Sensing



1) Conveyor applications: Diffuse mode sensors are used for straightforward product presence sensing applications when neither opposed nor retroreflective sensing is practical, and where the sensor-to-product distance is from a few inches to a few feet.

2) Reflectivity monitoring applications: Diffuse mode sensors are sensitive to differences in surface reflectivity. They are useful for applications that require monitoring of surface conditions that relate to differences in optical reflectivity.

3) Convenience and economy: Diffuse mode (and all proximity mode) sensors require mounting of only one item: the sensor itself. However, in order to avoid a marginal sensing situation, this attractive convenience should not take precedence over an analysis of the sensing conditions.

Application Cautions - diffuse mode

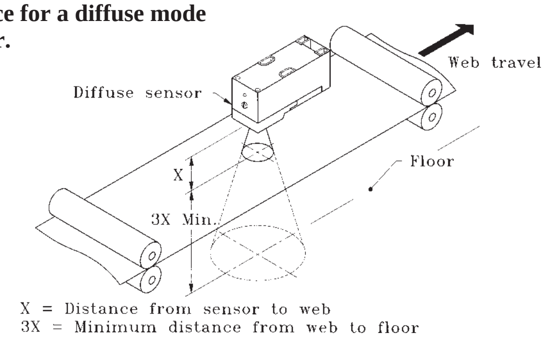
1) Reflectivity: The response of a diffuse sensor is dramatically influenced by the surface reflectivity of the object to be sensed. The performance of diffuse mode (and all proximity mode) sensors is referenced to a 90% reflectance Kodak white test card. Any material may be ranked for its relative reflectivity as compared to the Kodak 90% white reference (see Table A-2).

2) Shiny surfaces: Diffuse sensors use collimating lenses for maximizing sensing range. As a result, response to a specular surface is sensitive to scanning angle (see Figure A.31) Divergent and convergent mode sensors are much more forgiving to orientation of the sensor to shiny surfaces.

3) Background objects: As a general rule, verify that the distance from a diffuse sensor to the nearest background object is *at least four times* the distance from the sensor to the surface to be detected (Fig. B.5). This rule assumes that the reflectivity of the background surface is less than or equal to the reflectivity of the surface to be detected. If the background is *more* reflective than the surface to be detected (e.g. a stainless steel machine member), additional clearance or different sensor orientation may be required. Attempts to "dial-out" the background objects by reducing amplifier gain can do *nothing* to improve the existing optical contrast.

4) Small part detection: Diffuse sensors have less sensing range when used to sense objects with small reflective area than when used to sense objects with larger reflective area. Also, the lensing of most diffuse mode sensors creates a "blind spot" for small parts that pass close to the lens. When opposed mode sensors cannot be used, small parts that pass at a *fixed* distance from the sensor should be sensed using a convergent beam sensor. Small parts that pass the sensor at *random* (but close) distances may be sensed with a divergent mode sensor.

Figure B.5. Minimum distance to reflective background surface for a diffuse mode sensor.

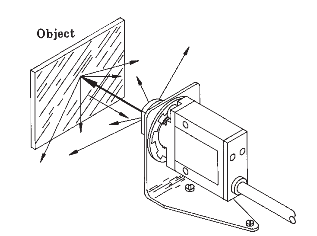


5) Excess gain: Most diffuse mode sensors lose their gain very rapidly as dirt and moisture accumulate on their lenses. In addition, build-up of dirt on the lenses of high-gain diffuse sensors may couple enough light from the emitter to the receiver to "lock-on" the sensor in the light condition.

6) Count accuracy: Diffuse mode sensors are usually a poor choice for applications that require accurate counting of parts. Diffuse sensors are particularly unreliable for counting glass or shiny objects, small parts, objects with irregular surfaces, or parts that will pass by the sensor at varying distances.

Uses and advantages - divergent mode

Divergent Proximity Sensing



1) Clear materials: Divergent sensors forgivingly sense clear materials (Figure B.6). They are particularly useful for reliably sensing clear plastic films or bags that bounce or "flutter". However, sensing range is limited to a few inches (or less). If clear materials are to be sensed beyond a few inches, ultrasonic sensors should be considered.

2) Small objects: Divergent mode sensors do not exhibit the "blind spot" that diffuse sensors have for small objects at close range. Sensor model LP400WB excels at detection of very small profiles (e.g. thread) passing within one inch of the sensor face (Figure B.7).

3) Shiny surfaces: Divergent mode sensors are not sensitive to the angle of view to a specular surface. They reliably sense shiny radiused objects, e.g. cans, and are tolerant of shiny surfaces that vibrate, such as metal foil webs.

4) Background rejection: Divergent mode sensors run out of excess gain very rapidly with increasing range. They often may be used successfully in areas where there is a background object that lies just beyond the sensor's range. Note, however, that highly reflective objects will be recognized at greater distances than objects of low reflectivity.

(continued on page B-13)

Table B-4. Diffuse Proximity Mode Sensors

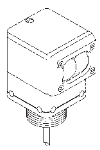
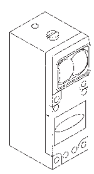
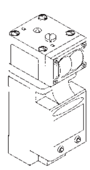
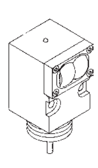
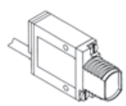
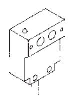
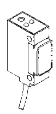
Self-contained Sensor Family	Supply Voltage & Output (E/M = electromechanical)	Response (ms = milliseconds)	Sensing Range (referenced to 90% reflectance white test card)	Sensor Model	Features and Uses (All beams are infrared)
OMNI-BEAM™ 	Choice of power block: 10 to 30V dc or 120, 220, or 240V ac Solid-state output	2ms on/off	12 inches	**OSBD**	Short range; fast response
		15ms on/off	6 feet	**OSBDX**	Long range; high excess gain
	24 to 240V ac or 24 to 36V dc SPDT E/M relay output	20ms on/off	18 inches	**OSED**	OEM design; short range
			6 feet	**OSEDX**	OEM design; long range
	Choice of power block: 15 to 30V dc or 120, 220, or 240V ac Solid-state output	63% of any output transition will occur within 1 ms	36 inches	**OASBD**	Short range; 0 to 10V dc analog voltage output; positive or negative slope
NOTE: 2-part assembly requires sensor block and power block. Optional timing module may be added.			12 feet	**OASBDX**	Long range; 0 to 10V dc analog voltage output; positive or negative slope
MULTI-BEAM® 	Choice of power block: 10 to 30V dc or 48V dc, or 12, 24, 120, 220, or 240V ac	1ms on/off	12 inches	**SBD1**	Short range; fast response
			24 inches	**SBDL1**	Medium range; fast response
		10ms on/off	6 feet	**SBDX1**	Long range; high excess gain
NOTE: 3-part assembly requires scanner block, power block, and logic module. Logic module may have timing logic.	24, 120, or 240V ac 2-wire hookup	10ms on/off	12 inches	**2SBD1**	Short range; 2-wire operation
			30 inches	**2SBDX1**	Medium range; 2-wire operation
MAXI-BEAM® 	Choice of power block: 10 to 30V dc or 120, 220, or 240V ac Solid-state or E/M relay output	0.3, 1 or 10ms on/off	30 inches	**RSBDSR**	Short to medium range; programmable response
NOTE: 3-part assembly requires sensor block, power block, and wiring base. Optional timing logic may be added.			5 feet	**RSBD**	Medium to long range; programmable response
VALU-BEAM® 	10 to 30V dc Solid-state bi-polar output	4ms on/off	15 inches	**SM912DSR**	Short range; wide beam angle
			30 inches	**SM912D**	Medium range
	24 to 250V ac Solid-state output 2-wire hookup	8ms on/off	15 inches	**SM2A912DSR**	Short range; wide beam angle
			30 inches	**SM2A912D**	Medium range
	12 to 28V ac or dc SPDT E/M relay output	20ms on/off	15 inches	**SMW915DSR**	Short range; wide beam angle
			30 inches	**SMW915D**	Medium range
	90 to 130V ac SPDT E/M relay output	20ms on/off	15 inches	**SMA915DSR**	Short range; wide beam angle
			30 inches	**SMA915D**	Medium range
	210 to 250V ac SPDT E/M relay output	20ms on/off	15 inches	**SMB915DSR**	Short range; wide beam angle
			30 inches	**SMB915D**	Medium range

Table B-4. Diffuse Proximity Mode Sensors (continued)

Self-contained Sensor Family	Supply Voltage & Output	Response (ms = milliseconds)	Sensing Range (referenced to 90% reflectance white test card)	Sensor Model	Features and Uses (All beams are infrared)
MINI-BEAM® 	10 to 30V dc Solid-state bi-polar output	1ms on/off	15 inches	**SM312D**	General application
			12 inches	**SM312DBZ**	Low-profile housing
	24 to 240V ac or Solid-state output 2-wire hookup	8ms on/off	15 inches	**SM2A312D**	General application
			12 inches	**SM2A312DBZ**	Low-profile housing
ECONO-BEAM™ 	10 to 30V dc Solid-state bi-polar output	10ms on/off	8 inches	**SE612D**	Designed for OEM applications where sensing contrast is high (has no gain adjustment)
QØ8 Series 	10 to 30V dc Solid-state output	1ms on/off	2 inches	**NO5-QØ8 series**	Rugged, metal housing Very low profile (8mm deep) Use where sensing contrast is high (sensor has no GAIN adjustment)
Q19 Series 	10 to 30V dc Solid-state complementary output	1ms on/off	8 inches	**Q19SN6D Q19SP6D**	Very small NEMA 6P construction
			39 inches	**Q19SN6DL Q19SP6DL**	
C3Ø Series 	10 to 30V dc Solid-state output	1ms on/off	4 inches	**C3ØAN7D C3ØRN7D C3ØAP7D C3ØRP7D**	30-mm threaded Lexan® barrel design NEMA 6P construction Use where sensing contrast is high (sensor has no GAIN adjustment)
S18 Series (an EZ-BEAM sensor) 	10 to 30V dc Solid-state complementary output	3ms on/off	4 inches/ 12 inches	**S18SN6D/DL S18SP6D/DL**	Versatile LED indicator system 18-mm threaded VALOX® barrel NEMA 6P construction Use where sensing contrast is high (sensor has no GAIN adjustment)
	20 to 250V dc Solid-state output 3-wire hookup	16ms on/off		**S18AW3D/DL S18RW3D/DL**	
Q85 Series 	24 to 240V ac or 12 to 240V dc electromechanical relay output	20ms on/off	10 inches	**Q85VR3D Q85VR3D-T9**	NEMA 6P construction Wiring chamber Optional built-in timing logic (T9 models)
			39 inches	**Q85VR3DL Q85VR3DL-T9**	
SM512 Series 	10 to 30V dc Solid-state complementary output	1ms on/off	8 inches	**SM512DB**	Short range; fast response Die-cast metal housing
		10ms on/off	24 inches	**SM512DBX**	High excess gain Die-cast metal housing

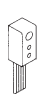
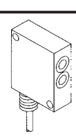
Remote Sensors	Used with Amplifiers	Response (ms = milliseconds)	Sensing Range	Sensor Model	Features and Uses (All beams are infrared)
SP100 Series 	MICRO-AMP™ MA3, MA3P, MPC3	1ms on/off	1.5 inches	**SP100D** **SP100DB**	Sub-miniature package SP100D has right-angle design; SP100DB is 3/8" threaded barrel Hermetically sealed optics
	MAXI-AMP™ CR Series	0.3, 2, or 10ms			
SP300 Series 	MICRO-AMP™ MA3-4 or MA3-4P	1ms on/off	12 inches	**SP300D**	Anodized aluminum housing; hermetically sealed lenses
	MAXI-AMP™ CM Series	0.3, 2 or 10ms		**SP320D**	Miniature housing for tight locations; hermetically sealed lenses

Figure B.6. Divergent mode sensors reliably sense clear materials.

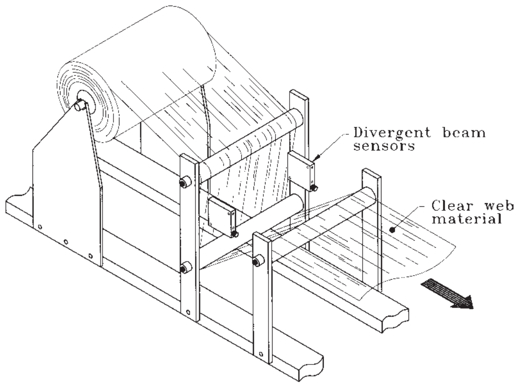
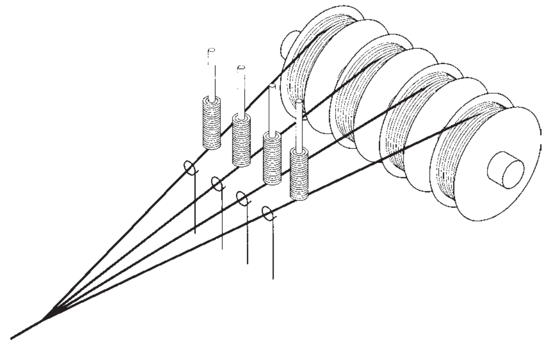


Figure B.7. Model LP400WB is a divergent mode sensor that excels at detecting very small profiles.

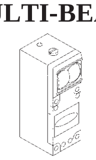
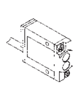
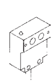


Application cautions - divergent mode

1) Side sensitivity: The field of view of a divergent mode sensor is extremely wide. Objects that are off to any side of the sensor (e.g. conveyor guide rails) may be sensed. Divergent mode optics should not be recessed into a mounting hole.

2) Excess gain: The divergent sensing mode is very inefficient. Most divergent sensors offer only low levels of excess gain at sensing distances beyond one inch. They should be used only in clean to slightly dirty environments.

Table B-5. Divergent Proximity Mode Sensors

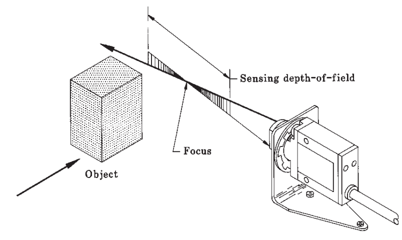
Self-contained Sensor Family	Supply Voltage & Output	Response (ms = milliseconds)	Sensing Range (referenced to 90% reflectance white test card)	Sensor Model	Features and Uses (All beams are infrared)
MULTI-BEAM® 	Choice of ac or dc power blocks	10ms on/off	24 inches	**SBDX1MD**	Very high excess gain
MINI-BEAM® 	10 to 30V dc	1ms on/off	5 inches	**SM312W**	Fast response
	24 to 240V ac 2-wire operation	8ms on/off	5 inches	**SM2A312W**	2-wire hookup
ECONO-BEAM™ 	10 to 30V dc	10ms on/off	3 inches	**SE612W**	For OEM applications (has no gain adjustment)
SM512 Series 	10 to 30V dc	10ms on/off	6 inches	**SM512LBDX**	Die-cast metal housing Excellent for clear web detection

Remote Sensor	Used with Amplifiers:	Response (ms = milliseconds)	Sensing Range	Sensor Model	Features and Uses
LP Series 	MICRO-AMP™ MA3-4 or MA3-4P	1ms on/off	3 inches	**LP400WB**	Has ability to sense objects with very small profile (e.g. thread)
	MAXI-AMP™ CM Series	0.3, 2 or 10ms			

Uses and advantages - convergent mode

1) High excess gain: Convergent beam sensors make the most efficient use of reflective sensing energy. As a result, it becomes possible to detect some objects with low optical reflectivity when opposed or retroreflective sensors cannot be used. In fact, high powered models, e.g. the MULTI-BEAM SBCX1, are able to reliably sense totally flat black surfaces, such as black (heavily inked) paper webs. The high excess gain at the focus of a convergent beam sensor makes the angle of view to a shiny surface forgiving, as compared to the diffuse mode.

Convergent Sensing



2) Counting radiused objects: Convergent beam sensing is a good choice for counting bottles, jars, or cans, where there is no space between adjacent products (i.e. where opposed sensors cannot be used - Figure B.8). The sensor is positioned to "see" light from the near point of each container and to go dark in the "valley" between adjacent containers. Usually, convergent beam sensors with infrared light sources provide the most reliable count.

3) Accurate positioning: The effective beam of most convergent sensors is well defined, especially at the focus point. It is a good second choice, after opposed, for accurate position sensing of edges that travel through the focus point at right angles to the scan direction. Convergent beam sensing becomes a first choice for accurate position sensing of clear material, such as plate glass (Figure B.9).

4) Fill level applications: Convergent beam sensors may be used in some applications for detecting the fill level of materials in an open container, where the opening is too small or the surface to be sensed is too unstable to allow use of an ultrasonic proximity detector.

5) Color sensing: Convergent beam sensors with visible green LED light sources (e.g. MULTI-BEAM SBCVG1 & MINI-BEAM SM312CVG) are used for color registration (color mark) sensing (see Figure B.41). Convergent beam sensors with visible red LED light sources may also be used for sensing large color differences, like black-on-white. However, visible red convergent sensors will not sense the combination of red- (or orange-, or pink-) on-white.

6) Height differential: Convergent beam sensors can sometimes be used for sensing height difference or for detecting the presence of an object ahead of an immediate background (e.g. parts riding on a conveyor), when opposed, retroreflective, fixed-field, or ultrasonic proximity sensors cannot be used.

Figure B.8. Convergent beam sensors accurately count radiused containers where there is no space between adjacent products.

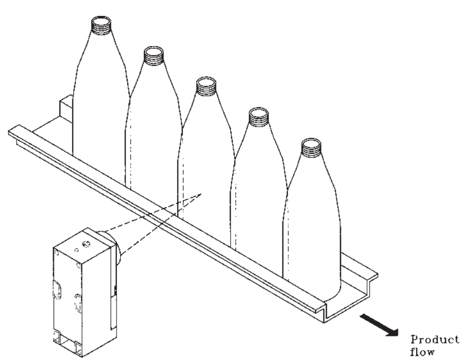


Figure B.9. Convergent beam sensors are the first choice for accurate positioning of clear materials.

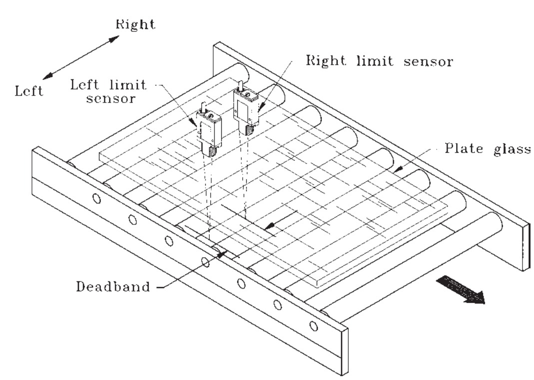
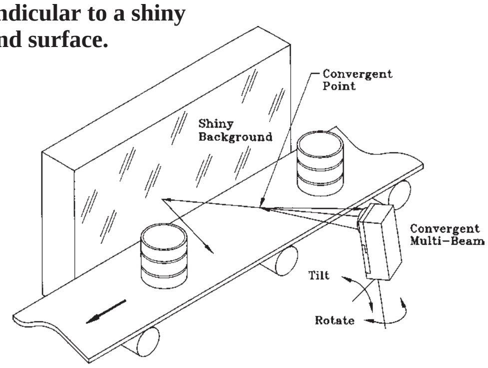


Figure B.10. Tilt or rotate a convergent sensor away from the perpendicular to a shiny background surface.



Application cautions- convergent mode

1) Depth of field: Convergent beam sensors require that the surface to be detected pass at (or close to) the focus distance from the sensor lens. Avoid use of convergent beam sensors for detection of objects that pass at an unpredictable distance from the sensor.

2) Effect of relative surface reflectivity: Consider the reflectivity of the surface to be detected. The distance within which a convergent beam sensor will detect an object (i.e. the sensor's "depth-of-field") is relative to that object's optical reflectivity. If a shiny background object returns unwanted light, tilt or rotate the sensor to move the sensing beam away from perpendicular to the shiny surface (Figure B.10).

Table B-6. Convergent Proximity Mode Sensors

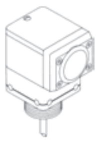
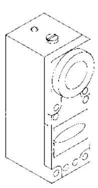
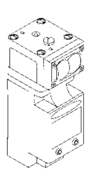
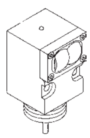
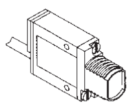
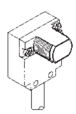
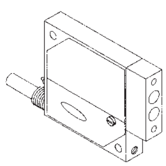
Self-contained Sensor Family	Supply Voltage & Output (E/M = electromechanical)	Response (ms = milliseconds)	Focus at (E.G. = Excess Gain with object of 90% reflectance)	Sensor Model	Features and Uses
OMNI-BEAM™ 	Choice of power block: 10 to 30V dc or 120, 220, or 240V ac; Solid-state output	2ms on/off	1.5 inch (E.G. = 15x)	**OSBCV**	Visible red sensing image D.A.T.A.™ self-diagnostic system with alarm output 10-element signal strength indicator
	24 to 36Vdc or 24 to 250V ac; E/M relay output	20ms on/off	1.5 inch (E.G. = 15x)	**OSECV**	OEM design For general use Optional timing logic
NOTE: 2-part assembly requires sensor block and power block. Optional timing module may be added.	Choice of power block: 15 to 30V dc or 120, 220, or 240V ac Solid-state output	63% of output transition occurs within 1 ms	1.5 inch	**OASBCV**	Visible red sensing image Analog output; positive or negative slope 10-element output voltage indicator
MULTI-BEAM® 	Choice of power block: 10 to 30V dc or 48V dc, or 12, 24, 120, 220, or 240V ac Solid-state or E/M relay output	1ms on/off	1.5 inch E.G. = 10x	**SBCV1**	Visible red sensing image
			1.5 inch E.G. = 5x	**SBCVG1**	Green sensing image for color registration sensing
			1.5 inch E.G. = 35x	**SBC1**	Infrared light source for higher gain (or longer range) with narrow depth of field
			4 inches E.G. = 5x	**SBC1-4**	
			6 inches E.G. = 2x	**SBC1-6**	
		10ms on/off	1.5 inch E.G. = 900x	**SBCX1**	Very high excess gain for reflective sensing of materials of low reflectivity; wide depth of field
			4 inches E.G. = 400x	**SBCX1-4**	
			6 inches E.G. = 250x	**SBCX1-6**	
NOTE: 3-part assembly requires scanner block, power block, and logic module. Logic module may have timing logic.	24, 120, or 240V ac 2-wire hookup	10ms on/off	1.5 inch E.G. = 35x	**2SBC1**	Infrared sensing image; 2-wire operation
			4 inches E.G. = 5x	**2SBC1-4**	
MAXI-BEAM® 	Choice of power block: 10 to 30V dc or 120, 220, or 240V ac Solid-state or E/M relay output	1 or 4ms on/off	1.5 inch E.G. = 15x	**RSBCV**	Visible red sensing image
NOTE: 3-part assembly requires sensor block, power block, and wiring base. Optional timing logic may be added.			1.5 inch E.G. = 40x	**RSBC**	Infrared sensing image
VALU-BEAM® 	10 to 30V dc Solid-state bi-polar output	4ms on/off	1.5 inch E.G. = 15x	**SM912CV**	Visible red sensing image
			1.5 inch E.G. = 100x	**SM912C**	Infrared sensing image; high excess gain
	24 to 250V ac Solid-state output 2-wire hookup	8ms on/off	1.5 inch E.G. = 15x	**SM2A912CV**	Visible red sensing image
			1.5 inch E.G. = 100x	**SM2A912C**	Infrared sensing image; high excess gain
	12 to 28V ac or dc	20ms on/off	1.5 inch E.G. = 15x	**SMW915CV**	Visible red sensing image
	90 to 130V ac	20ms on/off	1.5 inch E.G. = 15x	**SMA915CV**	Visible red sensing image
	210 to 250V ac	20ms on/off	1.5 inch E.G. = 15x	**SMB915CV**	Visible red sensing image

Table B-6. Convergent Proximity Mode Sensors (continued)

Self-contained Sensor Family	Supply Voltage & Output	Response (ms = milliseconds)	Focus at (E.G. = Excess Gain with object of 90% reflectance)	Sensor Model	Features and Uses
MINI-BEAM® 	10 to 30V dc Solid-state bi-polar output	1ms on/off	.65 inch E.G. = 15x	**SM312CV**	Visible red sensing image; fast response
			1.7 inch E.G. = 8x	**SM312CV2**	
			.65 inch E.G. = 5x	**SM312CVG**	Visible green sensing image; for color mark sensing
	24 to 240V ac or Solid-state output 2-wire hookup	4ms on/off	.65 inch E.G. = 15x	**SM2A312CV**	Visible red sensing image; 2-wire hookup
			1.7 inch E.G. = 8x	**SM2A312CV2**	
ECONO-BEAM™ 	10 to 30V dc Solid-state bi-polar output	10ms on/off	.65 inch E.G. = 15x	**SE612CV**	Visible red sensing image; for OEM applications (has no gain adjustment)
			.5 inch E.G. = 40x	**SE612C**	Mechanical convergence for high excess gain and wide depth of field (has no gain adjustment)
SM512 Series 	10 to 30V dc Solid-state complementary output	1ms on/off	1.2 inch E.G. = 10x	**SM512CV1**	Visible red sensing image; fast response
			1.2 inch E.G. = 100x	**SM512C1**	Infrared sensing image; high excess gain, fast response
			.17 inch E.G. = 8x	**SM512DBCV**	Very small visible red sensing image (.010 inch diameter) for precise resolution and high repeatability

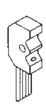
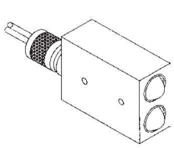
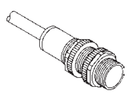
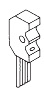
Remote Sensors	Used with Amplifiers	Response (ms = milliseconds)	Focus at (E.G. = Excess Gain with object of 90% reflectance)	Sensor Model	Features and Uses
SP100 Series 	MICRO-AMP™ MA3, MA3P, MPC3	1ms on/off	0.1 inch E.G. = 100x	**SP100C**	High excess gain with rapid gain fall-off beyond sensing point Flexible ribbon cable Includes aperture to further narrow depth of field
	MAXI-AMP™ CR Series	0.3, 2, or 10ms		**SP100CCF**	SP100CCF has very narrow profile for tight locations
SP1000 Series 	MICRO-AMP™ MA3-4 or MA3-4P	1ms on/off	3.8 inches E.G. = 75x	**SP1000V**	Anodized aluminum housing; precise 0.1 inch diameter infrared sensing spot Sharp drop-off of gain beyond sensing point
	MAXI-AMP™ CM Series	0.3, 2 or 10ms			
LP Series 	B3-4 high-gain non-modulated amplifier	1ms on/off	.17 inch E.G. = 30x	**LP510CV**	Very small visible red sensing image (.010 inch diameter) for precise resolution and high repeatability 1/2" diameter threaded barrel for precise adjustment

Table B-6A. Fixed-field Proximity Mode Sensors

Self-contained Sensor Family	Supply Voltage & Output	Response (ms = milliseconds)	Sensor Model	Sensing Distance	Features and Uses
S18 Series (an EZ-BEAM sensor) 	20 to 250V ac Solid-state output	16ms on/off	**S18AW3FFxx S18RW3FFxx**	2 inch far cutoff for FF50 models	18mm threaded barrel style housings, infrared sensing beam, dual-LED indicator system, alarm output hookup option for dc units
	10 to 30V dc Solid-state output	2.5ms on/off	**S18SN6FFxx S18SP6FFxx**	4 inch far cutoff for FF100 models	
SP100 Series ***remote* sensors** 	Use with MICRO-AMP™ amplifiers MA3A or MPC3A	1 ms on/off (a function of the amplifier)	**SP100FF**	.20 inches (nominal)	Miniature modulated remote sensor, infrared sensing beam, ideal for OEM applications

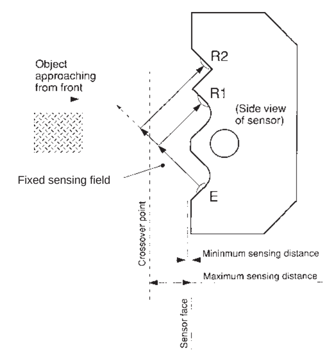
Uses and advantages - fixed-field mode

1) Definite range limit: Fixed-field sensors have a defined cutoff point at the far end of their range. Even highly reflective background objects may be ignored.

2) Height differential: Fixed-field sensors may be used to verify the presence of a part or feature of an assembly that is directly ahead of another reflective surface.

3) High excess gain: The available excess gain inside the fixed sensing field is usually high, allowing proximity mode sensing of many surfaces of very low reflectivity

Fixed-field Mode: SP100FF Sensor



Application cautions - fixed-field mode

1) Shiny surfaces: The beam angle to a specular (shiny) surface may affect the location of a background suppression sensor's cutoff point.

2) Blind spot: The optical design of most fixed-field sensors creates a *minimum* sensing distance for small surfaces and for objects of low reflectivity.

D. Fiber optic modes

Fiber optic ("light-pipe") assemblies are used *in addition to* a photoelectric sensor to fill a variety of sensing requirements. The configuration of the fiber optic assembly (or assemblies) determines the sensing mode:

A.) Opposed mode fiber optics: Opposed mode fiber optic sensing calls for two individual fiber optic assemblies. They usually plug into the same fiber optic sensor, and the fibers (often of unequal lengths) are routed to opposite sides of the process (Figure B.11). However, separate emitter and receiver sensors are available, and are used when it is inconvenient to route fibers to both sides of the process from a single sensor (Figure B.12). Threaded individual fibers accept lens assemblies, when needed, for increased range and/or higher excess gain. Lensed, individual fiber pairs may be mechanically converged for specular sensing (Figure B.13).

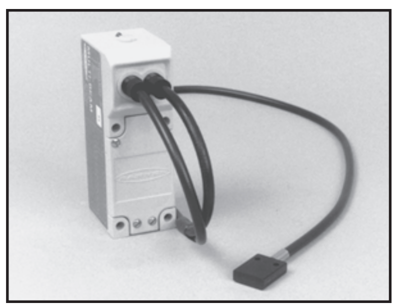
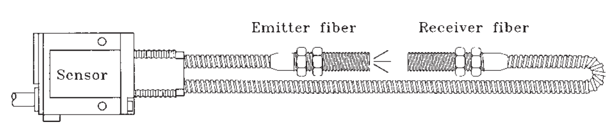


Figure B.11. Two individual fiber optic assemblies plug into a fiber optic sensor for opposed mode sensing.



B.) Proximity mode fiber optics: A bifurcated fiber optic plugs into a fiber optic sensor to become a wide beam diffuse (divergent beam) proximity mode sensor (Figure B.14). For longer-range proximity sensing, two individual glass fiber optic assemblies may be run together, side-by-side, and pointed in the same direction. All bifurcated plastic fiber optics are actually constructed in this way.

C.) Retroreflective mode fiber optics: (Figure B.15) The retroreflective sensing mode is configured using a bifurcated glass fiber optic assembly with a threaded end tip and a small bundle size (e.g. model BT13S, 1/16" diameter bundle) plus a model L9 lens threaded onto the sensing end.

The following procedure is used when adding a lens to a BT13S fiber optic assembly for retroreflective sensing or for extending the range of opposed individual fiber assemblies (Figure B.16):

1) Illuminate the threaded end (sensing end) of the fiber optic bundle by holding the opposite end (sensor end) toward a visible light source (e.g. an incandescent bulb, visible LED, sunlight, etc.).

2) Thread the lens onto the fiber optic assembly until the end of the fiber optic bundle comes into sharp focus as seen through the lens (just as it would appear through a magnifying glass).

3) Finally, back-off (unthread) the lens assembly from the point of sharpest focus by one to three full turns. The illuminated bundle should now appear slightly blurred.

Uses and advantages - Glass and plastic fiber optics

1) Tight sensing locations: The small size and flexibility of fiber optic assemblies allows positioning and mounting in tight spaces. The photoelectric sensor itself may be mounted in a more convenient location. Plastic fiber optics comprise the smallest group of non-contact presence sensors. Fiber optic assemblies are routinely made with sensing tips as small as a hypodermic needle (Figure B.17).

2) Inherent noise immunity: A fiber optic assembly is a mechanical part, and is completely immune to electrical noise (RFI and EMI). Fiber optics allow the electronics of a sensing system to be kept isolated from known sources of interference.

3) Explosion-proof design: Fibers can safely pipe light into and back out of hazardous areas. However, the photoelectric sensor itself must be kept outside of the explosive environment, unless it is a model SMI912F or SMI912FP intrinsically-safe sensor.

4) Vibration and shock: Optical fibers are very low in mass, enabling fiber optic assemblies to withstand high levels of vibration and/or mechanical shock. This characteristic makes fiber optic sensors a frequent choice for applications on punch presses, vibratory feeders, and other types of heavy machinery.

5) Custom sensor design: It is relatively easy, fast, and inexpensive to make a special fiber optic assembly to fit a specific sensing or mounting requirement.

Application cautions - Glass and plastic fiber optics

1) Sensing system cost: Fiber optics always add cost to a system, since a fiber optic assembly is always a part in addition to a basic photoelectric sensor.

2) Excess gain: A large percentage of the sensing light energy is lost when coupling light to and from a fiber. Fibers also "leak" some light along their length. As a result, sensing ranges are relatively short and excess gain levels are generally low.

Figure B.12. Separate fiber optic emitter and receiver sensors are used for long-distance opposed mode sensing.

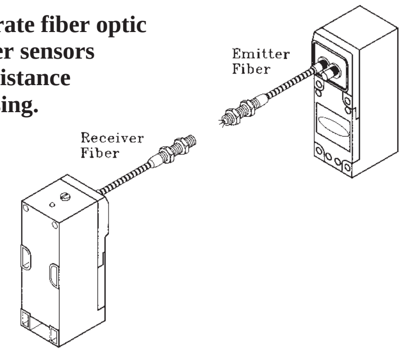


Figure B.13. Lensed individual fibers may be converged for specular sensing.

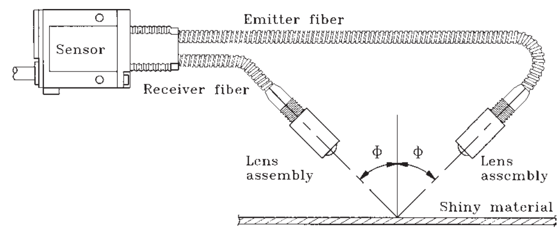


Figure B.14. A bifurcated fiber optic assembly is used for proximity mode sensing.

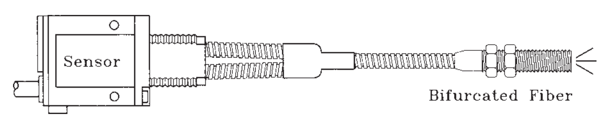


Figure B.15. Model BT13S fiber optic assembly is used with an L9 lens for the retroreflective sensing mode.

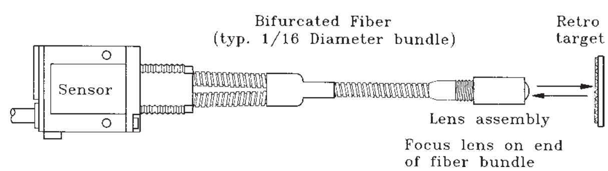
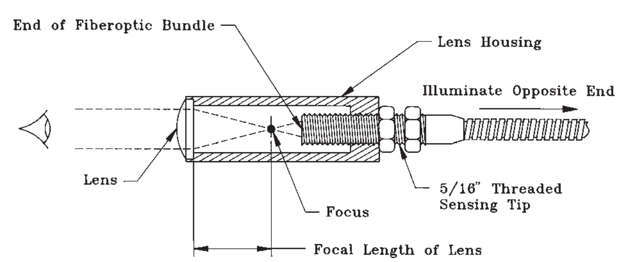


Figure B.16. Adjustment of a lens on a fiber optic assembly.



Additional uses and advantages - Glass fiber optics

1) High temperature applications: Most glass fiber optic assemblies are constructed to withstand continuous duty at 480°F. Fiber assemblies, using a special bonding agent, can withstand temperatures up to 600°F. Some assembly configurations can be manufactured without a bonding agent, and can withstand operating temperatures up to 900°F.

2) Extreme sensing environments: A glass fiber optic assembly can be constructed to survive mechanically in areas of corrosive materials and/or extreme moisture. The low mass of the glass fiber strands, themselves, allows a fiber assembly to withstand high levels of shock and/or vibration.

3) Shaping of effective beam: The bundle of glass fibers often can be terminated on the sensing end to match the profile of a small object. This can increase sensing contrast and ease sensor response requirements.

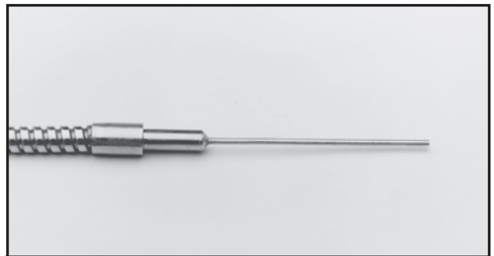


Figure B.17. Fiber optic assemblies may be terminated in needle-like probes.

Additional application cautions - glass fiber optics

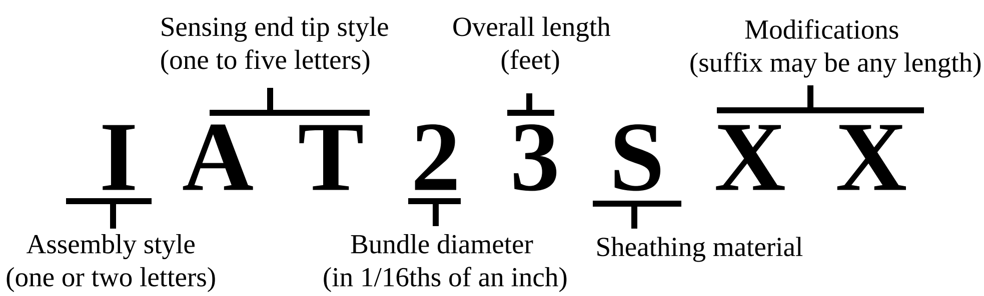
1) Fiber breakage: Glass fiber strands fracture if bent too sharply or if repeatedly flexed. Contact of the sensing tip with an abrasive material may result in a serious loss in sensing performance. Glass fiber optic assemblies generally cannot be repaired or shortened.

2) Radiation: Glass fibers tend to darken and lose their light transmission properties in the presence of heavy X-radiation.

Glass fiberoptic model numbering scheme

The model numbers used for glass fiber optic assemblies consist of numbers and letters that describe the style of fiber assembly, the type of end tip, the diameter of the glass fiber bundle, the overall assembly length, and the type of outer sheath. A model number suffix calls out special modifications. A general understanding of the model numbering scheme makes it possible to describe and specify a special fiber in most situations.

A very abbreviated form of the Banner glass fiber optic numbering scheme is given here. For the complete numbering scheme, see the Banner product catalog.



First Letter(s): assembly style

B = Bifurcated: emitter and receiver to one sensing point
I = Individual: emitter and receiver to two sensing points

Second Letter(s): sensing tip end style

A = Angled tip (90 degrees)
F = Ferruled (3/16" dia. x 1/2" long) tip; same as sensor end tip
M = Miniature (.059" dia. x 1" long sensing tip)
P = Probe (.090" dia. x 3" long); bendable tip
R = Rectangular bundle termination
T = Threaded (5/16"-24 x 1-1/2" long); brass end tip

First Number: fiber bundle diameter

.44 = .027 inch (0,7mm)
.5 = .032 inch (0,8mm)
.75 = .046 inch (1,2mm)
1 = .062 inch (1,6mm)
1.5 = .090 inch (2,3mm)
2 = .125 inch (3,2mm)
2.5 = .156 inch (4,0mm) - maximum bundle diameter

Second Number: overall length

The second number calls out the length of the fiber optic assembly in feet. Fractional amounts are possible: for example, 1.5 = 18 inches.

Third Letter: sheathing material

S = Stainless steel flexible conduit (maximum fiber protection)
P = PVC with monocoil reinforcing wire
L = Silicone rubber tubing (maximum flexibility, minimum fiber protection
T = Teflon tubing (maximum chemical resistance, minimum flexibility
HDP = High-density polyethylene (maximum electrical isolation, minimum flexibility)

Table B-7. Fiber Optic Mode Sensors

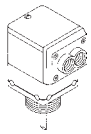
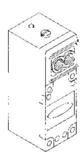
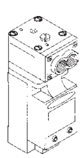
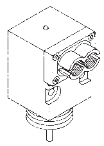
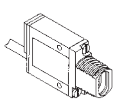
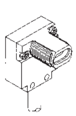
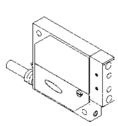
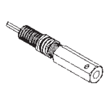
Self-contained Sensor Family	Supply Voltage & Output (E/M = electromechanical)	Response (ms = milliseconds)	Glass or Plastic Fibers	Sensor Model	Features and Uses
OMNI-BEAM™  NOTE: 2-part assembly requires sensor block and power block. Optional timing module may be added.	Choice of power block: 10 to 30V dc or 120, 220, or 240V ac Solid-state output	2ms on/off	Glass	**OSBF**	Infrared beam; high speed
		15ms on/off	Glass	**OSBFX**	Infrared beam; high excess gain
		2ms on/off	Plastic	**OSBFP**	Visible red beam; high speed
	24 to 240V ac or 24 to 36V dc SPDT E/M relay output	20ms on/off	Glass	**OSEFX**	OEM design; infrared beam
			Plastic	**OSEFP**	OEM design; visible red beam
	Choice of power block: 15 to 30V dc or 120, 220, or 240V ac Solid-state output	63% of any output transition occurs within 1 ms	Glass	**OASBF**	Infrared beam; short range; analog output
			Glass	**OASBFX**	Infrared beam; long range; analog output
			Glass	**OASBFV**	Visible red beam; analog output
			Plastic	**OASBFP**	Visible red beam; analog output
MULTI-BEAM®  NOTE: 3-part assembly requires scanner block, power block, and logic module. Logic module may have timing logic.	Choice of power block: 10 to 30V or 48V dc or 12, 24, 120, or 240V ac Solid-state or E/M relay output	1ms on/off	Glass	**SBEF1 & SBRF1**	Infrared beam; high speed opposed
		10ms on/off	Glass	**SBEXF & SBRXF1**	Infrared beam; long range opposed
			Glass	**SBFX1**	Infrared beam; high excess gain
		1ms on/off	Glass	**SBF1**	Infrared beam; high speed
		0.3ms on/off	Glass	**SBF1MHS**	Infrared beam; very high speed
		1ms on/off	Glass	**SBFV1**	Visible red beam
			Glass	**SBFVG1**	Visible green beam; color sensing
	12, 120, 240V ac 2-wire hookup	10ms on/off	Glass	**2SBF1**	Infrared beam; 2-wire hookup
MAXI-BEAM®  NOTE: 3-part assembly requires sensor block, power block, and wiring base. Optional timing logic may be added.	Choice of power block: 10 to 30V dc or 120, 220, or 240V ac Solid-state or E/M relay output	0.3, 1, or 10ms	Glass	**RSBEF & RSBRF**	Infrared beam; long range opposed
			Glass	**RSBF**	Infrared beam; general use
		1ms on/off	Glass	**RSBFV**	Visible red beam
		1ms on/off	Plastic	**RSBFP**	Visible red beam

Table B-7. Fiber Optic Mode Sensors (continued)

Family	Supply Voltage & Output (E/M = electromechanical)	Response (ms = milliseconds)	Glass or Plastic Fibers	Sensor Model	Features and Uses
VALU-BEAM® 	10 to 30V dc Solid-state bi-polar output	8ms on/ 4ms off	Glass	**SMA91EF & SM91RF**	Infrared beam; long range opposed
		4ms on/off	Glass	**SM912F**	Infrared beam; general use
	24 to 250V ac Solid-state output 2-wire hookup	8ms on/off	Glass	**SMA91EF & SM2A91RF**	Infrared beam; long range opposed
			Glass	**SM2A912F**	Infrared beam; general use
	12 to 28V ac or dc SPDT E/M relay output	20ms on/off	Glass	**SMW915F**	Infrared beam; general use
			Plastic	**SMW915FP**	Visible red beam
	90 to 130V ac SPDT E/M relay output	20ms on/off	Glass	**SMA915F**	Infrared beam; general use
			Plastic	**SMA915FP**	Visible red beam
	210 to 250V ac SPDT E/M relay output	20ms on/off	Glass	**SMB915F**	Infrared beam; general use
			Plastic	**SMB915FP**	Visible red beam
MINI-BEAM® 	10 to 30V dc Solid-state bi-polar output	1ms on/off	Glass	**SM312F**	Infrared beam; high speed
			Glass	**SM312FV**	Visible red beam
			Plastic	**SM312FP**	Visible red beam
	24 to 240V ac Solid-state output 2-wire hookup	4ms on/off	Glass	**SM2A312F**	Infrared beam
			Plastic	**SM2A312FP**	Visible red beam
ECONO-BEAM™ 	10 to 30V dc Solid-state bi-polar output	10ms on/off	Glass	**SE612F**	Infrared beam
			Plastic	**SE612FP**	Visible red beam
SM512 Series 	10 to 30V dc Solid-state output	1ms on/off	Glass	**SM512LBFO**	Infrared beam; high speed
		10ms on/off	Glass	**SM51EB6FO & SM51RB6FO**	Infrared beam; very high excess gain

Remote Sensors	Used with Amplifiers	Response (ms = milliseconds)	Glass or Plastic Fibers	Sensor Model	Features and Uses
LR/PT Series 	MICRO-AMP™ MA3-4 or MA3-4P	1ms on/off	Glass	**LR400 & PT400** (used with Banner model FOF-400 fiberoptic fittings)	Infrared beam Fast response High excess gain Hermetically sealed lenses
	MAXI-AMP™ CM Series	0.3, 2, or 10ms			

Additional uses and advantages - Plastic fiber optics

1) Cut-to-length: Most plastic fiber optic assemblies are made with the sensor end left unterminated, and are supplied with a cutter.

2) Flexibility: Unlike their glass counterparts, plastic fiber optic assemblies are constructed to withstand many thousands of flexing cycles. Some models are pre-coiled for millions of cycles on reciprocating mechanisms (Figure B.18).

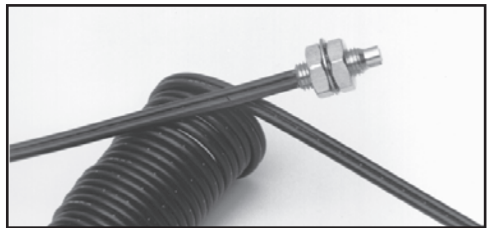


Figure B.18. Some plastic fiber optic assemblies are coiled for use in applications requiring repeated bending or reciprocating motion.

Additional applications cautions - Plastic fiber optics

1) Temperature extremes: Temperatures below -20°F will cause embrittlement of the plastic materials, but will not cause transmission loss. Temperatures above +160°F will cause both transmission loss and fiber shrinkage.

2) Chemical resistance: The acrylic core of the monofilament optical fiber will be damaged by contact with acids, strong bases (alkalis), and solvents. The polyethylene jacket will protect the fiber from most chemical environments. However, materials may migrate through the jacket with long-term exposure.

Plastic fiber optic numbering scheme

The following is an explanation of the numbering scheme used to specify Banner plastic fibers. The example is for model PBP46UC.

P B P 4 6 U C

PLASTIC FIBER FAMILY designator (same for all plastic fibers)

STYLE designator:
I = Individual fiber
B = Bifurcated fiber

SENSING END designator:
U = Unterminated
F = Ferruled
T = Threaded
A = Angled
P = 3.5" probe

CORE FIBER DIAMETER designator:
2 = .020" (0,5mm)
4 = .040" (1,0mm)

FIBER LENGTH designator:
6 = 6 ft.

CONTROL END designator (describes end of fiber which attaches to the sensor):
U = Unterminated*
UC = Coiled cable

*Plastic fibers having the letter "U" in the suffix of their model numbers have unterminated control ends, and may be cut by the customer to the required length. Use cutters supplied with fiberoptic cable. Individual plastic fibers are sold in pairs.

2. Ultrasonic proximity sensing mode

Uses and advantages - ultrasonic proximity mode

1) Long-range proximity sensing: Electrostatic-type ultrasonic proximity detectors are able to sense large targets at up to 20 feet away. By comparison, the maximum range of high-powered diffuse mode photoelectric proximity detectors is about 10 feet.

2) Sensing is not dependent on surface color or optical reflectivity: An ultrasonic proximity detector's response to a clear glass plate is exactly the same as to a shiny steel plate.

3) Sensing repeatability: Ultrasonic proximity mode sensors with digital (switched) outputs have excellent repeat sensing accuracy along the scan direction. Switching hysteresis is relatively low, making it possible to ignore immediate background objects, even at long sensing distances.

4) Analog response: The response of analog ultrasonic proximity sensors is highly linear with sensing distance. This makes ultrasonic sensors ideal for many level monitoring or linear motion monitoring applications.

Analog response makes it possible for an ultrasonic sensor to sense within a *window* (Figure B.19), where a near and a far sensing limit are selected. This type of sensing is called *windowing.* It is sometimes referred to as *ranging.*

Figure B.19. Some ultrasonic proximity sensors have a "windowing" feature.

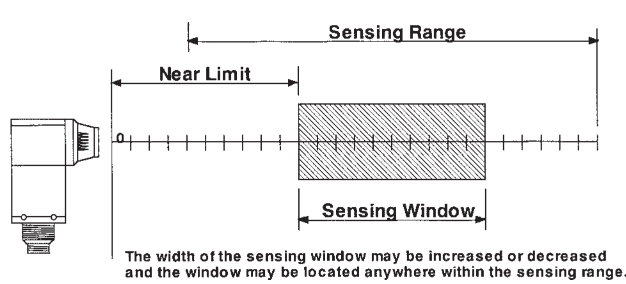
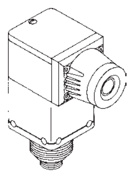
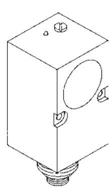


Table B-8. Ultrasonic Proximity Mode Sensors

Self-contained Sensor Family	Supply Voltage & Output (E/M = electromechanical)	Response (ms = milliseconds)	Sensing Range	Sensor Model	Features and Uses
OMNI-BEAM™ 	105 to 130V ac, SPDT E/M relay	Program-mable from 25ms - up	4 to 26 inches adjustable sensing window	OSBUSR	Requires OPBA5 power block Programmable for ON/OFF or HIGH/LOW level logic
	210 to 250V ac, 0 to +10V SPDT E/M relay				Requires OPBB5 power block
	15 to 30V dc, 0 to +10V dc analog				Requires OPBT3 power block
	105 to 130V ac, 0 to +10V dc analog				Requires OPBA3 power block
	210 to 250V ac, 0 to +10V dc analog				Requires OPBB3 power block
ULTRA-BEAM™ 	105 to 130V ac, SPDT E/M relay	100ms on/off	20 inches to 20 feet	SUA925QD	Very long reflective sensing Best choice for large bin level sensing
	210 to 260V ac, SPDT E/M relay			SUB925QD	
	18 to 30V dc, analog output	100ms	Sensing window of any depth may be placed anywhere within sensing range of 20 inches to 20 feet	SU923QD	0 to +10V dc analog output or 0 to 20mA analog output
	105 to 130V ac, analog output			SUA923QD	
	210 to 260V ac, analog output			SUB923QD	

Application cautions - ultrasonic proximity mode

1) Sensitivity to sensing angle: Ultrasonic proximity sensors must view a surface (especially a hard, flat surface) squarely (perpendicularly) in order to receive enough sound echo. This is especially true of short-range piezoelectric types. Also, reliable sensing requires a minimum target surface area, which is specified for each sensor type.

2) Minimum sensing range: Most ultrasonic proximity sensors have a minimum specified sensing distance. At closer range, it is possible for a double-bounce echo (sensor-to-target-to-sensor-to-target-to-sensor) to be falsely sensed.

3) Affects of ambient changes: Changes in the sensing area such as temperature, pressure, humidity, air turbulence, and airborne particles affect ultrasonic response. However, these variables are usually noticed only in distance measurement applications, or in ranging applications where the sensing window is small.

4) False response to background noise: Ultrasonic sensors evaluate a series of ultrasonic impulses instead of a single pulse. This gives them good immunity to the harmonics of background noise. Even so, any ultrasonic sensor is likely to falsely respond to some loud noises. The "hissing" sound produced by air hoses and relief valves is particularly troublesome.

5) Slow response: Ultrasonic proximity sensors require time to "listen" for their echo and to allow the transducer to stop ringing after each transmission burst. As a result, sensor response times are typically slow, at about 0.1 second. This is usually not a disadvantage in most level sensing and distance measurement applications. Extended response times are advantageous in some applications. In fact, Sonic OMNI-BEAM™ sensors are programmable to allow additional response time where needed.

6) Effects of target density and surface texture: Targets of low density, like foam and cloth, tend to absorb sound energy. Some materials may not be sensed at longer range. Smooth surfaces reflect sound energy more efficiently than rough surfaces; however, the sensing angle to a smooth surface is generally more critical than to a rough surface.

3. Application-specific sensing modes

A. Optical Edgeguiding

There are many approaches to edgeguide control of web or sheet materials. One of the most compact optical edgeguide systems takes advantage of the self-contained design of MULTI-BEAM sensors. The MULTI-BEAM *Optical Edgeguide System* consists of two sensors (Figure B.20). One sensor is placed on each side of the material or web being edgeguided. The two sensors have identical makeup, consisting of:

Scanner block - 3SBG
Logic module - 3LM5-14
Power block - 3PBA or 3PBB.

Power block 3PBA is for 115V ac operation and model 3PBB is used for 220/240V ac applications. The components for Optical Edgeguide System sensors are unique and do not interchange with the components used in other MULTI-BEAM sensors. The components of the Optical Edgeguide System are identified by the number "3" in their model number prefix. An Optical Edgeguide System sensor is usually purchased pre-assembled, with all three sensor components. The model number for the 115V ac sensor is 3GA5-14; the 220/240V ac unit is 3GB5-14. A quantity of two of either model number is required for a complete system.

A pair of Optical Edgeguide Sensors look the same as any opposed mode MULTI-BEAM emitter-receiver pair. However, each Optical Edgeguide System sensor contains a modulated emitter that is sensed only by the receiver of the opposing unit. The scanner block works together with the power block such that the emitter is gated "on" only during positive half cycles of the 50/60Hz sensor supply power, and the receiver is gated "on" only during the negative half cycles. The opposing sensor operates the same way, except that it is wired with power leads L1 and L2 *reversed* from the way they are connected to the first sensor (see Figure B.21). As a result, the emitter of sensor A will only operate the receiver of sensor B, and vice-versa.

This synchronization of the two sensors prevents unwanted crosstalk, while permitting very high excess gain. The high level of excess gain may be put to work in very dirty environments. The Optical Edgeguide System may be used for edgeguiding of sanding belts and conveyor belts in sawmills.

The logic module includes both ON- and OFF-DELAY timing functions. The ON-DELAY works to ignore short-term "nuisance" signals, and the OFF-DELAY permits a controlled amount of timed correction.

The logic modules have a LIGHT/DARK OPERATE programming jumper. Typically, the inboard receiver is programmed for LIGHT OPERATE, and the outboard receiver is programmed for DARK OPERATE. In this way, the edge being guided is properly positioned in the *deadband* between the two sensing beams when one beam is interrupted and the other is not. The spacing between the two beams is fixed at 1/2 inch and this becomes the deadband for edgeguiding. If tighter control is required, the two sensors may be mounted at an angle to the edge of the material so that the effective beam spacing is reduced to 1/2 inch multiplied by the cosine of the angle (Fig. B.22).

The power block output has the same 3/4 amp solid-state switch used in the standard MULTI-BEAM ac power blocks. This switch will operate most ac solenoids, relays, or ac inputs to programmable logic controllers (PLCs).

The Optical Edgeguide System is a highly reliable edgeguiding system, but it is basically an opposed system and cannot be used for guiding transparent or translucent materials. The warnings do apply that go along with high excess gain and "burn through" of thin materials like thin paper webs or opaque plastic sheets.

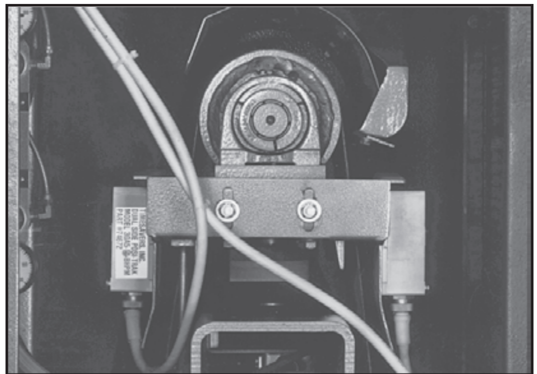


Figure B. 20. MULTI-BEAM® Optical Edgeguide System in use.
Photo courtesy of Timesavers, Inc.

Figure B. 21.
The "secret" of the MULTI-BEAM Optical Edgeguide System is in the wiring.

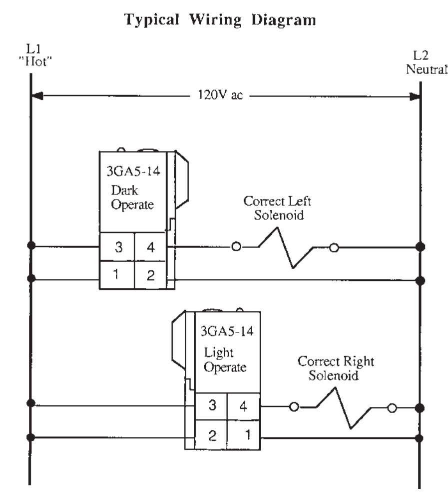
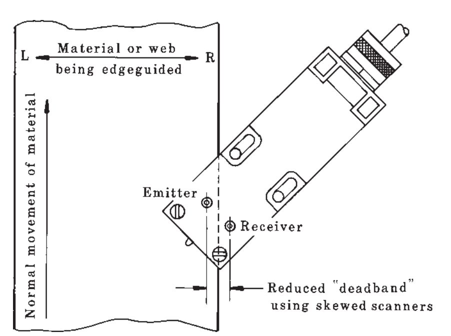
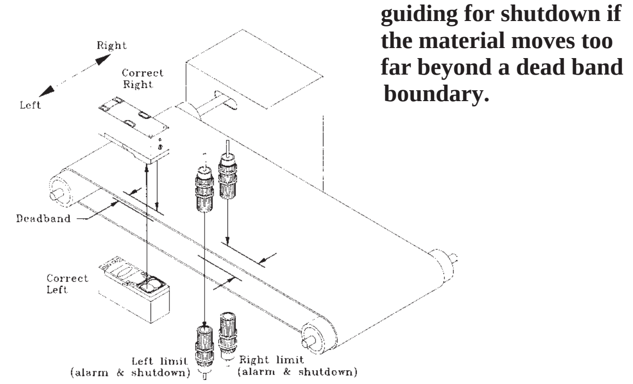


Figure B. 22. The "deadband" may be reduced by mounting the sensors at an angle to the material edge.



When opposed mode sensors cannot be used for edgeguiding, convergent mode sensors should be considered. A pair of self-contained convergent mode sensors, with ON- and OFF-DELAY logic installed, is a good substitute for the Optical Edgeguide System in these situations. The small sensing area that is defined by a convergent beam lensing system offers good to excellent edge position sensing repeatability. The focused sensing energy of convergent beam sensors minimizes the potential for optical crosstalk between two sensors that are mounted on the same side of the material being guided. The MULTI-BEAM offers convergent mode scanner blocks with very high excess gain (models SBCX1, SBCX1-4, and SBCX1-6) that overcome signal attenuation due to dirt, clear materials, or non-reflective materials. Model SBCX1 will even reliably sense a flat black material.

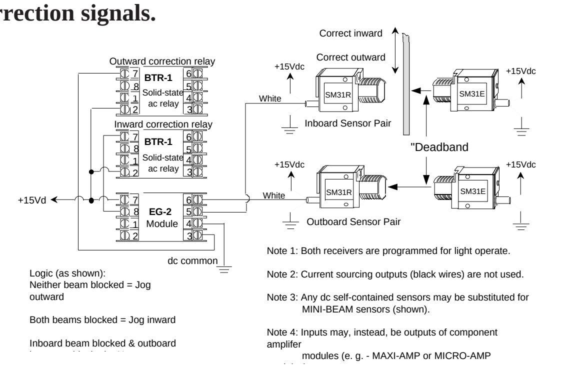
Figure B. 23. "Limit sensors" are sometimes used in edge guiding for shutdown if the material moves too far beyond a dead band boundary.



Edgeguiding systems often include *limit sensors*. Limit sensors are located to the right and/or left of the deadband to trigger a shutdown if the material ever moves too far outside of the deadband (Figure B.23). Timing logic is usually not required for limit sensors because shutdown is most often an immediate command if the material ever crosses the limit.

Sometimes it is desireable to "jog" the material back toward the center of the deadband. This is easily accomplished using the model EG-2 Edgeguide Control Module. The EG-2 accepts the outputs from two dc self-contained sensors or component systems. The EG-2 has two dc-level outputs (correct right and correct left) that are usually connected to the correction mechanisms via an interposing relay. The outputs of the EG-2 are pulse trains with adjustable pulse width and period. Figure B.24 shows a typical edgeguide system that uses the EG-2 module for correction logic.

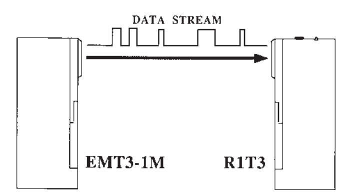
Figure B. 24. Logic module model EG-2 provides "jogging" correction signals.



B. Optical Data Transmission

Data communication between system components and their host computer is typically transmitted by wire or by fiberoptic data link. However, there are situations where it is inconvenient or impossible to physically connect to (or between) system components. Examples include communication with remote controlled rail-mounted systems such as overhead cranes, and transfer of data to and from automatic rotary index tables. In these locations, data may be transferred across an area via an opposed mode photoelectric emitter-receiver pair.

Figure B. 25. Optical data transmission concept.



The MULTI-BEAM *Optical Data Transmitter System* provides a simple and very economical method for transmitting logic-level data using a modulated light beam. The data transmitter, model EM3T-1M, consists of a special MULTI-BEAM scanner block (model SBEM3) and dc power block (model PBT-1M). The emitter uses a modulated infrared *carrier light signal* that is gated "on" and "off" by the data signal. The data signal is applied to an optical coupler in the power block. The carrier light is inhibited (turned "off") when voltage is applied to the optical coupler.

The data receiver, model R1T3, is composed of standard MULTI-BEAM components: scanner block SBR1, power block PBT, and logic module LM3. The output is an open-collector NPN transistor that follows the data stream as input to the emitter. The LIGHT/DARK operate jumper of the logic module is used to program the output so that a logic "1" is represented by the presence or the absence of the carrier light from the emitter.

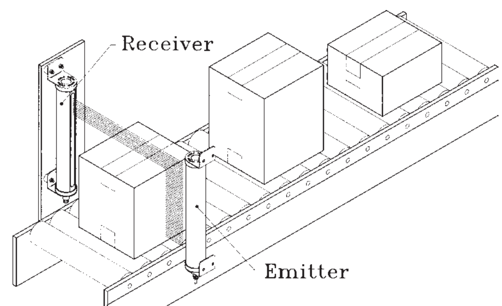
Data may be transmitted over a distance of up to 200 feet (in a clean environment). The data rate (BAUD rate) is limited by the modulation frequency (30 kHz) and by the receiver response speed. The response time of the R1T3 receiver is 1 millisecond on and off (light and dark). This results in a theoretical maximum data rate (assuming a square wave) of 500 BAUD, suggesting a maximum practical data rate of 300 BAUD. The receiver may be factory modified for 0.3 millisecond response (3 times faster). However, this modification comes at the expense of a 50 percent reduction in excess gain.

Data rates of up to 9600 BAUD (and faster) are possible using non-modulated data transmitters manufactured by companies that specialize in optical data links. However, these systems are much larger in size (due to very large lenses), require exact alignment, and typically cost 50 times more than the MULTI-BEAM Optical Data Transmitter System.

C. Measurement Light Curtain

Applications that call for measurement or *profiling* of an object as it passes an inspection point are handled by an *array* of opposed beams. Whenever two or more opposed beams are placed on close centers to one another, the potential exists for optical "crosstalk". This means that a receiver in the array may recognize the light from an emitter other than its own, thereby providing false measurement information. Optical crosstalk may be eliminated by *multiplexing* the emitters and receivers in the array. Multiplexing is a scheme in which an electronic control circuit interrogates each sensor pair of an array in sequence. "True" photoelectric multiplexing enables each modulated emitter only during the time that it samples the output of the associated receiver.

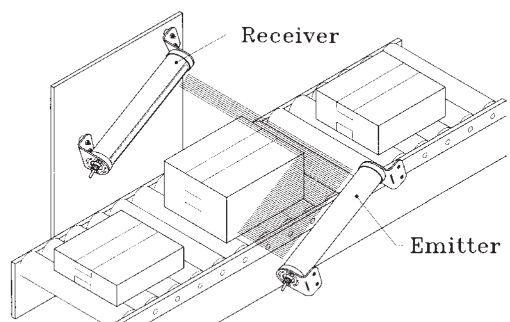
Figure B. 26. Banner BEAM-ARRAY™ multiplexed light curtain.



The BEAM-ARRAY™ is an example of a multiplexed measurement light curtain in a self-contained configuration (Figure B.26). The BEAM-ARRAY is available in 1, 2, 3, or 4 foot lengths, with sensing beams placed on 1/4 inch centers. Resolution may be increased from 1/4 inch by tilting the array at an angle to the plane of measurement (Figure B.27). The emitter and receiver units may be placed up to 10 feet apart from each other.

Measurement of an object may be accomplished using the 0 to +10V dc sourcing analog output of the BEAM ARRAY, which is proportional to the number of beams blocked. Data needed for profiling of a moving object (in one plane) may be gathered from the logic level serial data stream output. *Sizing* of an object, as with boxes on a conveyor, may be accomplished using three BEAM-ARRAY systems (Figure B.28). Also, a logic level *"trip"* output is available for applications, such as part ejection verification, where an output is required if any one (or more) of the beams is interrupted.

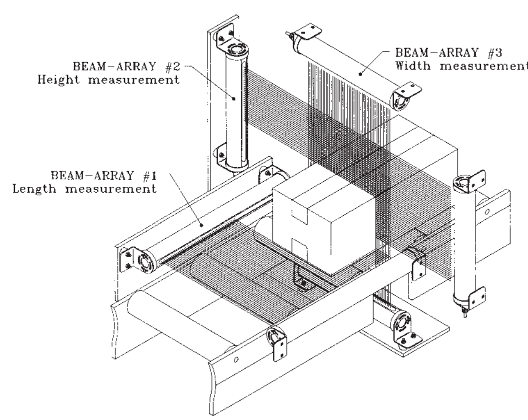
Figure B. 27. The measuring resolution of the BEAM-ARRAY may be increased by tilting the array with respect to the measurement plane.



The BEAM-ARRAY may be wired for either continuous scanning of the array or *on-demand* scanning, as controlled by a computer. The rate of scan may also be controlled, either internally or externally. The BEAM-ARRAY also features rugged NEMA-12 construction, and is supplied with anti-vibration mounting brackets.

A second alternative is to use a BEAM-ARRAY Controller (BC2A or BC2B) or Serial Control Module (BC1T) in conjunction with the BEAM-ARRAY sensors. These systems may be configured to "watch" for specified scanning beam conditions and to control a solid-state output switch and/or output the scan data via a built-in serial interface to a computer or PLC. The BC2A and BC2B have four on/off outputs and two analog outputs. The BC1T is designed to transmit scan data to a computer or PLC, and has no switching outputs. A gate sensor input is included on all models. These systems are ideal for a variety of profiling and inspection applications.

Figure B. 28. Objects may be "sized" by using three BEAM-ARRAYs.



Still another approach to creating a measurement light curtain uses specially-designed MINI-BEAM emitter-receiver pairs and the model MP-8 multiplexing module (Figure B.29). This approach allows a light curtain to be customized for exactly the area and resolution that is required. The MINI-BEAM pairs are mounted to create the required sensing pattern, and up to eight pairs are wired to one MP-8 (Figure B.30). The MP-8 controls the multiplexing of the individual emitter-receiver pairs. Two or more MP-8 modules may be run together either in series or in parallel.

The MP-8 offers eight separate sinking (NPN) outputs (one for each beam condition) that are used to supply data to the system's computer or process controller. The array may be clocked either internally or externally.

The MINI-BEAM sensors for use with the MP-8 are emitter models SM31EM or SM31EML (long range) and the receivers are SM31R or SM31RL. The MP-8 also works with SM51EB and SM51RB, which have metal housings, or with the MULTI-BEAM Optical Data Transmitter and receiver pair (see Figure B.25).

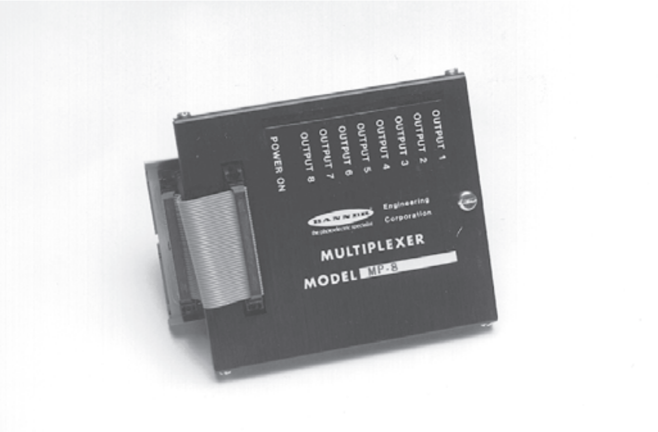
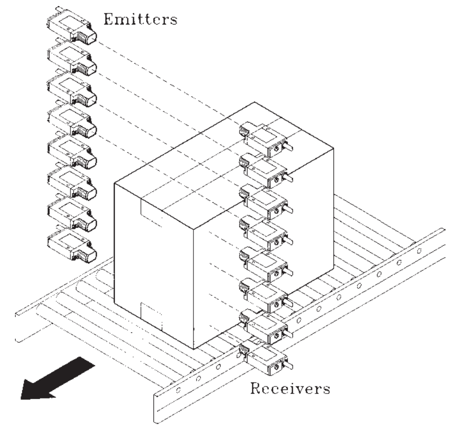


Figure B. 29. Banner MP-8 Multiplexer Module.

Figure B. 30. The MP-8 allows the building of a custom light curtain.



D. Parts Sensing Light Curtains

Light curtains are often the perfect solution to applications that require parts sensing or part ejection verification, and are especially useful when parts pass randomly through an area. The output of a parts-detection light curtain is energized whenever one or more of the curtain's sensing beams is broken. These sensors are often interfaced to counters for parts counting applications. BMLV Series retroreflective light curtain systems are designed for large-parts detection and counting, and are also useful in many wharehousing applications such as load overhang detection. LS10E/R Light Screens are useful for detecting smaller parts passing through a smaller area.

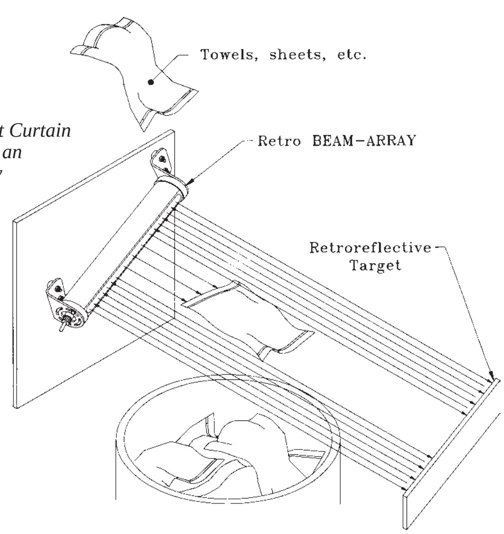
BMLV systems consist of a retroreflective sensor array and a high-grade retroreflective tape reflector (below, left). These systems do not require external controllers or control modules.

BMLV arrays are available in lengths of 1, 2, 3, and 4 feet. Maximum sensor-to-reflector spacing is conservatively rated at 10 feet when BRT-THG-3 reflective tape is used. Based on these figures, a sensing area up to 4' x 10' may be created. The system will respond to objects falling through this sensing area at any point. The minimum object cross section needed for reliable detection is 2 inches.

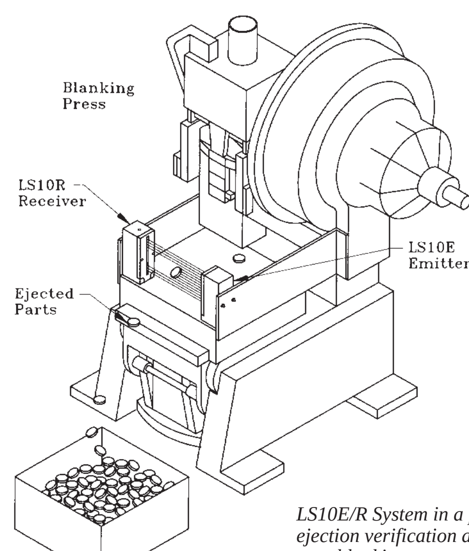
LS10E/R Light Screens (below, right) generate an opposed mode sensing curtain 3.5 inches in height. Depending upon the model, the width of the sensing area (distance between emitter and receiver) may be either a maximum of 8 or a maximum of 48 inches. Minimum object detection profile is 0.1 or 0.2 inches, depending upon the Light Screen model.

WARNING: Parts sensing light curtains are NOT suitable for personnel safety applications.

Figure B.31. Parts sensing light curtains



BMLV Series Light Curtain counting towels in an automated laundry



LS10E/R System in a parts ejection verification application on a blanking press

Instead, consider Banner MACHINE-GUARD and PERIMETER-GUARD Systems, page B-35.

E. Count Totalizing

The 990 Series VALU-BEAM™ is a self-contained photoelectric sensor with a built-in 6-digit LCD totalizing counter (Figure B.32). It is the most compact and economical approach to non-contact counting applications.

990 Series VALU-BEAMs are offered in both long and short range opposed models. Opposed mode sensing should be used for parts counting whenever possible (see discussion of opposed mode sensing advantages, page B-3).

The 990 series offers visible retroreflective sensors with and without an anti-glare filter. The retroreflective mode would typically be used on a conveyor system where it is impractical or impossible to install opposed mode sensors. An infrared retroreflective version, model SMA990LT, is available that is specifically designed for counting people passing through a doorway or turnstile (Figure B.33). Model SMA990LT includes a short delay to avoid multiple counts per person.

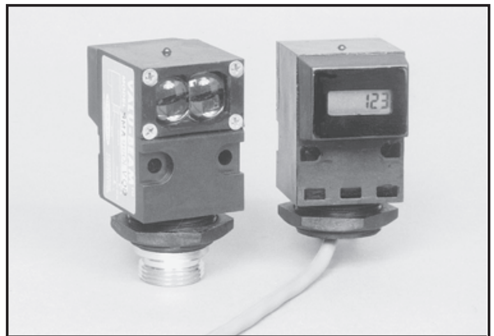


Figure B.32. A VALU-BEAM® 990 Series sensor is a complete totalizing system.

A convergent mode model is available for counting transparent or translucent objects. The convergent mode is particularly useful for counting of radiused clear glass or plastic bottles. The sensor is positioned to "see" light from the near point on each bottle, and to go dark in the "valley" between adjacent bottles (see Figure B.8).

The 990 Series also offers fiber optic models for both glass and plastic fibers. Opposed fiber optics are used extensively for counting small parts in otherwise inaccessible areas of machines, or in areas of extreme vibration, such as on vibratory feeder bowl tracks.

SMA990 Series sensors wire directly to either ac or dc voltage (there is no output). The voltage range is very wide (10 to 250V ac, 12 to 115V dc) to fit into any wiring situation. The count is reset by touching the top of the sensor with a permanent magnet or by removing and re-applying power. Models are also available that retain the count during periods of power loss or shutdown.

Figure B. 33. The SMA990LT is a retroreflective model designed specifically for "people counting".

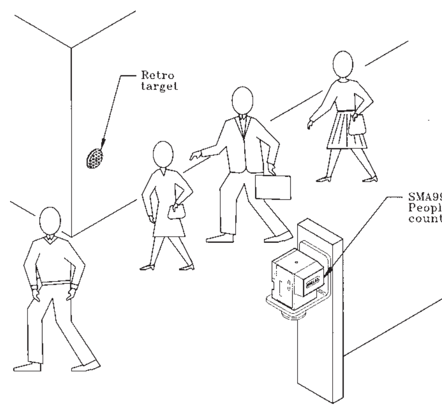
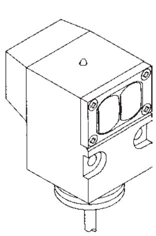


Table B-9. Sensors with Built-in Totalizing Counters

Self-contained Sensor Family	Sensing Mode	Sensing Range	Sensor Model	Notes
VALU-BEAM® 990 Series	Long range opposed	200 feet	**SMA99R**	Use SMA91E emitter; 0.5" diameter effective beam
	Short range opposed	10 feet	**SMA99RSR**	Use SMA91ESR emitter; .12" diameter effective beam; Wide beam angle (forgiving alignment).
	Visible red retroreflective	30 feet	**SMA990LV**	For general retroreflective application
	Polarized retroreflective	15 feet	**SMA990LVAG**	Anti-glare (polarizing) filter to minimize unwanted reflections from shiny objects
	Infrared retroreflective	30 feet	**SMA990LT**	Built-in delays; Designed for "people counting"
	Visible red convergent	focus at 1.5 inch	**SMA990CV**	.06" diameter sensing spot
	Glass fiber optic	(see catalog)	**SMA990F**	For all glass fiberoptic assemblies
	Plastic fiber optic	(see catalog)	**SMA990FP**	For all plastic fiberoptic assemblies

F. Clear Plastic Detection

There is a strong warning to not use opposed mode sensors for sensing of transparent materials. However, there is one definite exception to that rule. The MINI-BEAM® *Clear Plastic Detection System* consists of a special emitter and receiver with a unique optical arrangement that *actively* detects the presence of a clear plastic material in the beam (Figure B.34).

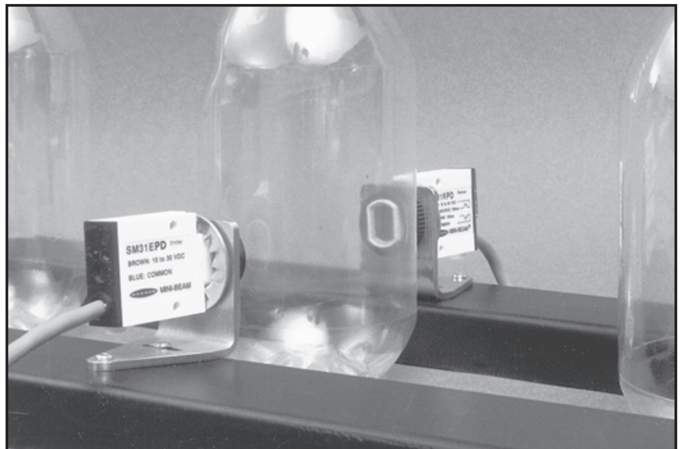


Figure B. 34. Banner MINI-BEAM® Clear Plastic Detection System.

When a clear plastic material is introduced in the beam, there is a dramatic *increase* in the intensity of the light that reaches the receiver. This increase is on the order of 10 to 1 or more. There is no need for critical sensitivity adjustments. Clear plastic is reliably detected and differentiated from all other materials.

Most transparent plastics, whether clear or colored will be detected. There are a few materials, however, (e.g. some acrylics) that will not be detected due to their molecular structure. This can be used as a benefit to sort between some different types of clear plastic materials.

Some common applications include those involving the manufacture or reclamation of plastic bottles and the processing of clear plastic webs. This system may also be used to inspect clear plastic containers for label, cap, or product presence. In fact, because a light signal is established through a clear plastic container only when there is a missing item, there is usually no need for an interrogation scheme.

The MINI-BEAM Clear Plastic Detection System is available in either ac or dc powered models.

G. Ambient Light Detection

The biggest benefit of a modulated receiver is its ability to reject all *ambient* light and respond only to its own modulated light source. However, there are several categories of photoelectric sensing applications that require detection of non-modulated light. For example, massive materials, like metals, glass, or thick-walled plastics emit infrared energy when they are hot. These materials may be detected directly by an *ambient light receiver* (see figure A.7).

Figure B.35. Two MULTI-BEAM Ambient Light Receivers (at upper right) detect passage of red-hot steel in a steel mill.

The MULTI-BEAM® family offers three models of self-contained ambient light receiver. Scanner block model SBAR1 is for general applications (Figure B.35). Model SBAR1GH is a high-gain (more sensitive) version. Model SBAR1GHF is also a high-gain version, with the hardware to attach an individual glass fiber optic assembly. Fiber optics are useful for sensing in tight areas and where the amount of heat at the sensing point exceeds the 70°C (158°F) limit of the scanner block.

An ambient receiver may be used as an opposed mode receiver, where the light source is the factory lighting. For example, the receiver may be mounted underneath a roller conveyor, and directed up at the overhead lighting (Figure B.36). All objects passing over the receiver will be sensed as they cast their shadow.

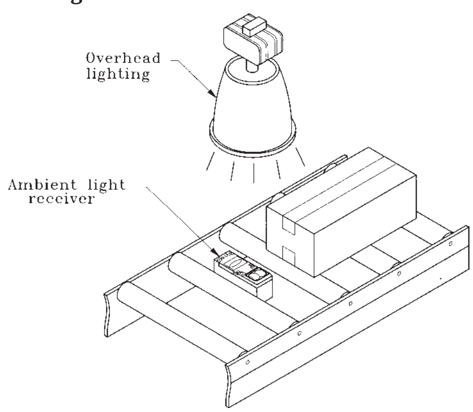
Ambient receivers are used to sense daylight for control of lighting and other functions. The model LM5-14 ON and OFF-DELAY timing logic module is used for daylight sensing applications. Ambient light receiver scanner blocks work together with all MULTI-BEAM 3 & 4-wire *or* 2-wire power blocks and logic modules.

These ambient light receivers use a phototransistor as the sensing element. As a result, they respond very well to the infrared energy radiated by hot materials and the red-orange light emitted by red-hot objects (see Figure A.6, Spectral Response of Phototransistor). A special version may be built with the phototransistor replaced by a photocell for sensing green, blue, or ultraviolet energy (e.g. a gas pilot light). However, in applications where ultraviolet light is to be sensed, the use of glass fiberoptics should be avoided (see Figure A.16).

Model SBAR1GH is about 20 times more sensitive to light as compared to model SBAR1. It is important to remember that success in ambient light detection relies not so much upon the intensity of the light source, but upon the *contrast* in intensity between the source and the rest of the ambient light in the viewing area. Sensing range is dependent upon both light intensity and contrast.

Remote ambient light receivers are also available. Models PT410 (phototransistor) and PC400 (photocell) are 3/8 inch diameter threaded barrels that are used with B Series non-modulated amplifiers (Figure B.37). The PC400 may be used with optional lens model L4 (shown) to extend sensing range or narrow the field of view. High-gain amplifiers, such as model B3-4, are recommended for most applications.

Figure B. 36. Boxes are sensed as they cast their shadows on an ambient light receiver.



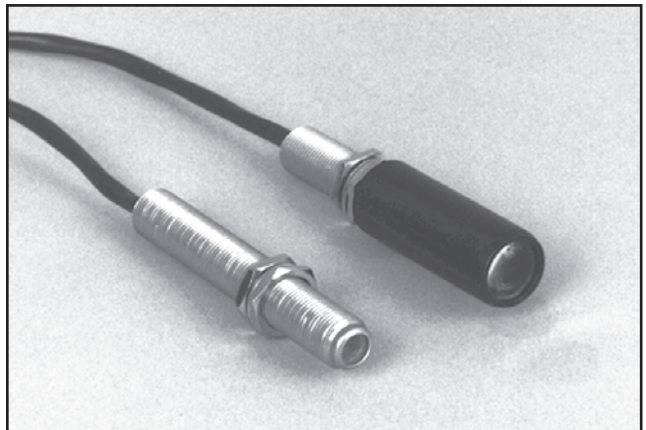


Figure B.37. Remote sensors like models PT410 and PC400 may be used as ambient light receivers.

H. Color Mark Detection

Color marks are also known as *registration marks* or *index marks.* They are used extensively in packaging applications for registering the cutoff of wrapping or bagging materials so that product names and other information always appear in the same location (Figure B.38). Color marks are also used in tube sealing operations (e.g. for toothpaste tubes) so that the information that is printed on the tube is consistently oriented to the seal.

The color of printing ink that has the greatest optical contrast to the color of the material being printed is used for the mark color. Black-against-white is the best color combination and is relatively easy to sense. Sensing challenges are created by light inks on light materials and dark inks on dark materials. Also, special consideration must be given to sensor selection when sensing a red (or a derivative of red: orange, pink, etc.) against white (or light-colored) contrast.

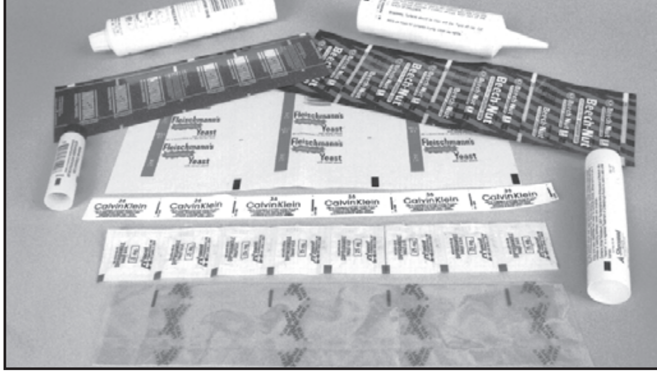
A photoelectric proximity mode sensor is used for most color mark sensing applications to sense the amount of light that is reflected from a printed surface. However, when sensing marks that are printed on a clear material, like a clear poly web, the best approach is usually to let the printed mark block the light of an opposed mode sensor pair.

When using reflected light to sense color differences, it is necessary to use a visible emitter. Infrared (invisible) light may be used only to sense differences in reflectivity. The best source of light for color sensing is incandescent or "white" light, which contains all colors. However, single-color visible LEDs (see Figure A.2) may be used effectively to sense the difference between most color combinations. Table B.10 lists the measured contrast of various colors against white and against kraft, using a green, red, white, or infrared light source.

Visible red LEDs emit more light and are a better spectral match to a phototransistor, compared with green LEDs (see Figure A.6). However, for the combination of red (or orange, or pink) against a light color, a visible red LED is ineffective. This is because the amount of red light that is reflected from a red material is almost as great as the amount that is reflected by a white material. Color mark sensors with visible green LED emitters are used to sense most color differences in applications where low excess gain is permitted.

The best optics for color sensing are those which receive reflected light in exactly the same pattern as the emitted light. This is the nature of a randomly-mixed bifurcated glass fiber optic bundle. It is very important that the sensing area does not "spill-over" the mark. This is important for optimizing optical contrast between the color mark and the material, and from the standpoint of easing the sensor response time requirement. The shape and the size of the fiber optic bundle at the sensing tip of a bifurcated assembly can be selected to match the size and the shape of the color mark. Rectangular terminations are often used to maximize the available excess gain (i.e. the maximum fiber area), the sensing contrast, and the time that the sensing image is totally contained within the boundaries of a square or rectangular-shaped color mark (Figure B.39).

Figure B. 38. Examples of materials with color registration marks.



The divergent nature of bifurcated fiber optic sensing makes it relatively insensitive to movement of the material toward and away from the sensor, as is the case with web flutter. However, *small* color differences that produce poor contrast demand that the material move steadily (i.e. no bouncing), even when using a bifurcated fiber optic sensing system (see "Contrast", Section A).

Figure B. 39. Glass fibers with rectangular bundle terminations are ideal sensors for rectangular color registration marks.

Although they are more sensitive to vertical material movement, visible convergent beam mode sensors are often a very good solution to color mark sensing applications. The sensing area at the focus of a convergent beam sensor is usually very small (Figure B.40). Consequently, very small color marks may sometimes be reliably sensed. Also, a convergent mode sensor is always less expensive than a comparable fiberoptic sensing system. Convergent beam sensors are available with either visible red or visible green LED emitters.

Figure B. 40. Visible convergent beam sensors are a good solution to many color mark sensing applications.

If the sensor is mounted perpendicular to a shiny material, convergent or diffuse mode color mark sensors can become overwhelmed by the amount of light returned from specular reflection. By tilting the sensor away from perpendicular by 10 degrees, or more, the specular reflection is cancelled, and the sensor is able to concentrate on the color contrast (Figure B.41).

Table B-10. Color Mark Contrast Ratios Using Randomly-mixed Bifurcated Glass Fiber Optic Sensor

Color of Mark:	Contrasted against white background:				Contrasted against kraft-colored background:			
	Infrared source (940 nm)	Visible red source (650nm)	Green source (560 nm)	White light source*	Infrared source (940 nm)	Visible red source (650nm)	Green source (560 nm)	White light source*
Bright red (magenta)	1.0	1.0	2.0	1.7	1.0	1.0	1.8	1.4
Moderate red	1.0	1.0	2.0	1.7	1.0	1.0	1.8	1.4
Deep red	1.4	1.5	2.3	2.9	1.0	1.0	2.0	1.6
Medium orange	1.0	1.0	1.3	1.4	1.0	1.0	1.2	1.3
Yellow	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1
Yellow-green	1.0	1.3	1.1	1.5	1.1	1.9	1.4	2.0
Medium green	1.0	2.7	1.9	3.0	1.1	2.5	1.9	3.1
Dark green	2.1	2.7	2.7	4.4	1.7	3.3	2.5	4.4
Light blue	1.0	1.4	1.5	1.9	1.3	1.9	1.5	1.9
Medium blue	1.0	3.0	3.0	3.6	1.2	3.3	2.3	3.7
Dark blue	1.5	3.7	3.5	5.0	1.1	2.7	2.5	3.7
Medium purple	1.0	1.1	2.4	1.9	1.0	1.0	2.1	1.7
Dark purple	1.0	3.0	4.0	5.0	1.1	2.7	2.5	4.1
Light brown	1.0	1.1	1.4	1.5	1.4	1.2	1.7	1.7
Medium brown	1.0	1.1	2.1	2.4	2.3	2.0	2.1	3.8
Dark brown	1.8	1.5	2.6	3.8	3.3	2.7	2.5	5.2
Light gray	1.2	1.3	1.4	1.7	1.0	1.2	1.2	1.2
Medium gray	1.5	1.7	1.9	2.5	2.5	1.8	1.7	2.1
Dark gray	2.0	2.5	2.7	4.0	3.0	2.5	2.1	3.4
Black	2.7	3.0	3.7	6.0	4.3	3.5	2.7	5.3
White	1.0	1.0	1.0	1.0	1.0	1.1	1.2	1.2

*Note: Photocell with blue-green filter is used as receiver with white light source (model FO2BG). Receiver used with all LED sources is a phototransistor.

Some color differences, such as pink or light orange against white or yellow against light green, are too low in contrast for either a visible red or a visible green LED sensor to *reliably* sense. For these situations, a non-modulated color sensing system has the best chance of good performance. It consists of a bifurcated fiber optic assembly, a model FO2BG fiberoptic interface, and an ac-coupled amplifier, such as model B4-6 (see Figs. A.53 and A.54). The FO2BG uses a special focused incandescent light source and a photocell receiver. The signal from the photocell is fed directly to an ac-coupled amplifier that amplifies very small *changes* in received light intensity, as with a passing color mark.

The sensitivity of any ac-coupled amplifier is very high. This allows some very small color contrasts to be sensed; however, this high sensitivity makes the system likely to react to any number of unwanted changes, like material flutter or electrical "noise". Because of this, the ac-coupled approach to color sensing should be used only when it is required for response to poor color contrasts.

Table B-11 lists the sensors that are available for color mark sensing applications. All of the choices are capable of interfacing to a dc load. AC loads are rarely encountered because of the importance of response time and repeat accuracy in almost every color mark registration application.

Figure B.41. Include a "skew" angle to the sensor mounting angle when sensing color marks on a shiny material.

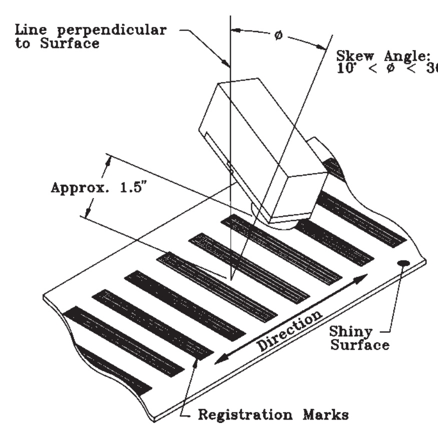
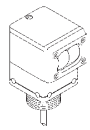
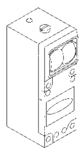
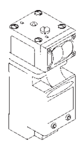
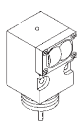
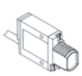
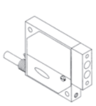
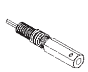


Table B-11. Sensors for Color Mark Sensing

Self-contained Sensor Family	Sensing Mode	Sensor Model	Response (in milliseconds)	Notes
OMNI-BEAM™ 	Visible red convergent	**OSBCV**	4	OSBCV: 1.5 inch focus with 0.05 inch diameter spot size Both models require a dc power block (e.g. model OPBT2) D.A.T.A. system LED array displays contrast Both models may be programmed for low hysteresis
	Visible red glass fiberoptic	**OSBFV**	2	
MULTI-BEAM® 	Visible red convergent	**SBCV1**	1	SBCV1: 1.5 inch focus; 0.06 inch diameter spot size
	Visible green convergent	**SBCVG1**	1	SBCVG1: 1.5 inch focus; 0.12 inch diameter spot size
	Visible red glass fiberoptic	**SBFV1**	1	All four models require a dc power block (e.g. model PBT or PBP) and a model LM3 logic module
	Visible green glass fiberoptic	**SBFVG1**	1	All four models are available modified for 0.3 millisecond response. Specify model suffix "MHS".
MAXI-BEAM® 	Visible red convergent	**RSBCV**	1	RSBCV: 1.5 inch focus; 0.06 inch diameter spot size
	Visible red glass fiberoptic	**RSBFV**	1	Both models require dc power block model RPBT and wiring base model RWB4.
VALU-BEAM® 	Visible red convergent	**SM912CV**	4	1.5 inch focus; 0.06 inch diameter spot size
MINI-BEAM® 	Visible red convergent	**SM312CV**	1	SM312CV: 0.65 inch focus; 0.05 inch dia. spot size
	Visible red convergent	**SM312CV2**	1	SM312CV2: 1.7 inch focus; 0.12 inch dia. spot size
	Visible green convergent	**SM312CVG**	1	SM312CVG: 0.65 inch focus; 0.04 inch dia. spot size
	Visible red glass fiberoptic	**SM312FV**	1	All four models are available modified for 0.3 millisecond response. Specify model suffix "MHS".
SM512 Series 	Visible red convergent	**SM512CV1**	1	1.25 inch focus; 0.04 inch diameter spot size
	Precise focus visible red convergent	**SM512DBCV**	1	0.17 inch focus; 0.01 inch diameter spot size
Remote Sensors 	Visible red glass fiberoptic	**LR400VH**	(see note)	Both models require (1) PT400 receiver, (2) FOF-400 fiberoptic fittings, and (1) amplifier: **MAXI-AMP CM Series** (response: 0.3 or 2ms) or **MICRO-AMP MA3-4 or MA3-4P** (response: 1ms) MAXI-AMP CM Series modules are programmable for low hysteresis.
	Visible green glass fiberoptic	**LR400VG**		
	Visible incandescent glass fiberoptic	**FO2BG**	(see note)	Requires ac-coupled amplifier: **B4-6** (response 1ms) or **B4-1500A** (response: 0.2ms)
	Precise focus visible red convergent	**LP510CV**	(see note)	Requires B3-4 amplifier or ac-coupled amplifier (see above). Response of B3-4 is 1ms, but may be factory modified for 300 or 50µs.

I. Close Differential Sensing

Most color mark sensing situations fall into the category of close differential sensing applications (see Section A). There are many other types of sensing applications where no sensing configuration can yield a contrast level of **3** or higher. There are two possible approaches to solving these difficult sensing situations.

1) AC-coupled amplification:
AC-coupled amplifiers may sometimes be used for close differential sensing applications, since they highly amplify only quickly changing (ac) signals. AC-coupled amplifiers completely ignore steady (dc) signals and changes that occur slowly. If a sensing event occurs quickly, even if it represents a very small light level change, an ac-coupled amplifier may be able to recognize the event. AC-coupled amplifiers may be used to recognize light level changes as small as 10 percent (contrast of 1.1).

Examples of close differential sensing events that occur quickly include: a color mark passing a sensor, a small part ejected from a press through a large opposed beam, and a broken thread falling through an opposed beam. As a general rule, ac-coupled amplifiers require that the part (or mark) to be sensed must be traveling through the sensing area at a minimum of one inch per second.

AC-coupled amplifiers such as model B4-6 require an analog input. This may be directly from a photocell (e.g. from an FO2BG) or a phototransistor (e.g. model LP510CV). An analog input may also be obtained from modulated self-contained sensors models SM53E and SM53R (Figure B.42). This opposed mode sensor pair is specially-designed to be compatible with ac-coupled amplifiers. It has an *automatic gain control* (AGC) feedback system that adjusts the light intensity of the emitter so that the system is always maintained at exactly the right sensitivity, regardless of the sensing range or of slow signal changes, such as dirt buildup on the lenses.

Figure B.42. Opposed pair SM53E and SM53R are modulated sensors designed to work with an ac-coupled amplifier.

The SM53E/SM53R has an opposed sensing range of 4 feet. Optional L51 lens blocks may be added to extend the opposed sensing range to 10 feet. The pair may be used side-by-side for diffuse proximity mode sensing, or angled for mechanical convergent or specular mode sensing. Also, optional FOF-500 fiber optic attachment blocks may be added to allow the connection of either individual or bifurcated glass fiber optic assemblies.

This sensor pair has all of the benefits of a modulated sensor, including immunity to ambient light changes and high excess gain. A popular use for the SM53E and SM53R positions them opposed, across a textile or wire manufacturing process to sense a broken thread or wire as it falls (Figure B.43). Rectangular individual fiber optics, e.g. model IR2.53S are used in the opposed mode to create a light curtain for ejected or falling small parts (Figure B.44).

Figure B.43. SM53E and SM53R scanning underneath the process to sense a broken strand.

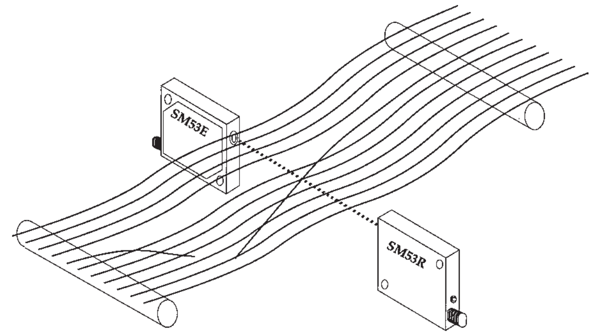
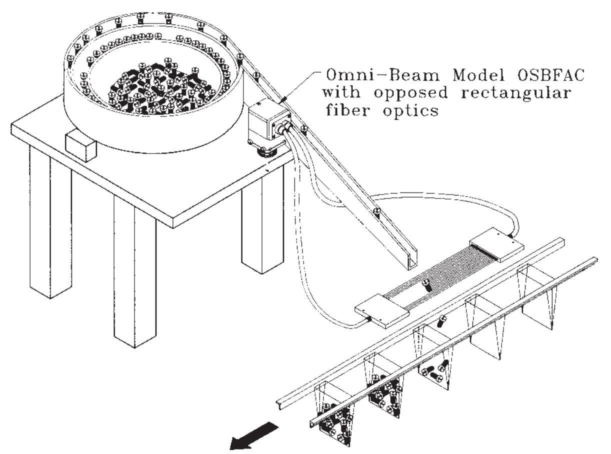


Figure B.44. AC-coupled OMNI-BEAM with opposed mode individual rectangular fiber optics.



Banner's OMNI-BEAM self-contained sensor family includes an ac-coupled fiber optic sensor head, model OSBFAC. No external amplifier is required. This sensor head uses an automatic gain control feedback system that adjusts the power output of the emitter so that the system is always maintained at exactly the same sensitivity regardless of the range, background, or degree of contamination. The output of the OSBFAC is a pulse that may be conditioned to the desired duration using a model OLM8 pulse timer logic module. The OSBFAC is identical in appearance to the sensor shown in figure B.45.

AC-coupling should not be used if the sensing contrast is high enough for a dc-coupled sensor. AC-coupled amplifiers are highly sensitive, and can respond to unwanted conditions such as sensor vibration or electrical "noise". Remember, too, that ac-coupled amplified sensors will not respond at all to gradual changes.

2) Low hysteresis:
The sensing event does not occur quickly in all close differential sensing applications. For example, applications that require moni-

toring of the transparency of a material or the clarity of a liquid may exhibit very gradual changes. An ac-coupled sensing scheme would be ineffective for such types of close differential applications.

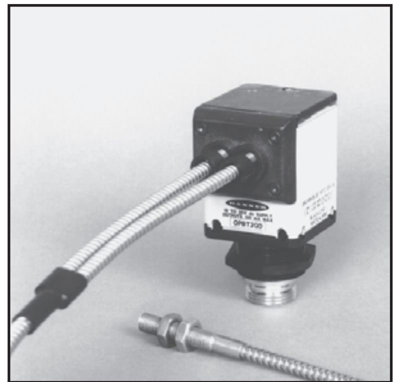


Figure B.45. OMNI-BEAM sensors may be programmed for low hysteresis and offer an alternative solution in some close-differential sensing applications.

All sensors have an amount of switching hysteresis designed into them to prevent the sensor output from becoming unstable whenever the received signal is at or near the amplifier threshold. Standard OMNI-BEAM photoelectric sensors are programmable for either NORMAL or LOW hysteresis (Figure B.45). By programming out most of the hysteresis, OMNI-BEAM sensors may be used successfully in some poor contrast applications, without the use of an ac-coupled amplifier.

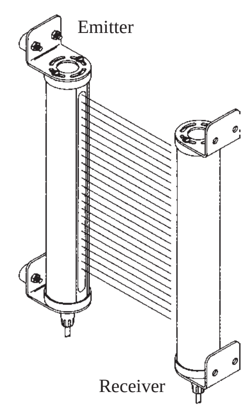
An OMNI-BEAM sensor that is programmed for low hysteresis can sense contrasts as small as **1.2** (20 percent signal change). However, unlike the ac-coupled approach, low hysteresis sensing *does* respond to gradual changes, like dirt buildup or sensor misalignment. All sensing variables, including the mechanics of the sensing system, must remain constant for the low hysteresis approach to close differential sensing to be successful. The OMNI-BEAM **D.A.T.A.** system includes self-diagnostics that will energize an alarm output if a gradual upward or downward drift of light and dark signal levels is detected. The alarm output will also energize if the sensing contrast level drops below **1.2** in the LOW hysteresis mode (or below **2** in the NORMAL hysteresis mode).

Finally, if a close differential sensing application calls for use of a remote modulated sensor, CM Series and CR Series MAXI-AMP modulated amplifier modules are also programmable for low hysteresis. The low hysteresis modes of the OMNI-BEAM and MAXI-AMP offer a practical alternative solution to many close-differential sensing applications. However, if it is known that sensing variables might change over time, ac-coupled amplification may still be the best solution.

J. Personnel Safety

In recent years, photoelectric devices have become the preferred means of guarding entry to areas of hazardous machine motion. Compared to mechanical hard guards, photoelectrics allow easy access to the point of operation, thus decreasing operator fatigue and increasing productivity compared to pull-backs, restraints, and two-hand controls. Significant advancements have been made in the reliability of photoelectric safeguarding methods. Improvements such as higher optical power, faster response times, and the use of microprocessors have made photoelectric light curtains well-suited to safety-related uses.

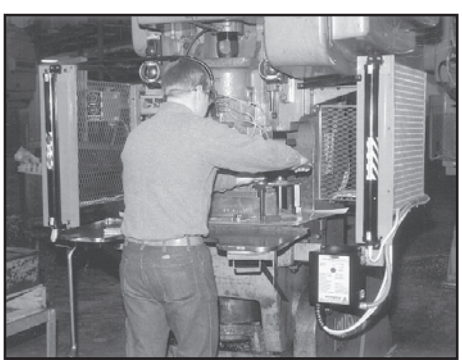
Multiplexed light curtain concept.



A photoelectric "safety light curtain" system may consist of one or more single-beam opposed mode sensors or a "curtain" of multiplexed opposed sensing beams (right). Whenever one or more light beams are broken, the safety light curtain system sends a "stop" signal to the guarded machinery, thereby causing it to stop its dangerous motion.

The effectiveness of a specific light curtain in a safety application depends upon its *control reliability*. The light curtain must be able to provide a "stop" signal to the guarded machine even if the light curtain system itself has experienced an internal component failure. This requires that every light curtain system circuit component be "backed up" to the extent that, if the failure of

Figure B-46. MACHINE-GUARD Point-of-operation Guarding System



A Banner MACHINE-GUARD System consists of an opposed mode emitter-receiver pair, a control box, and interconnecting cables.

Maximum emitter-receiver separation distance is 45 feet, with 3X excess gain remaining.

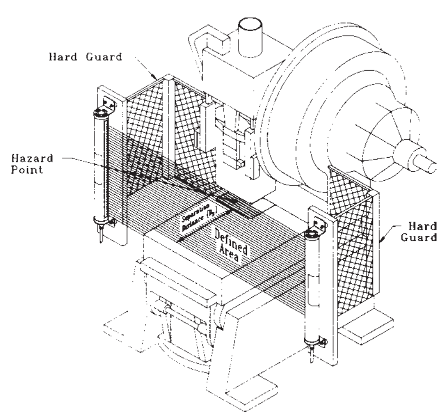
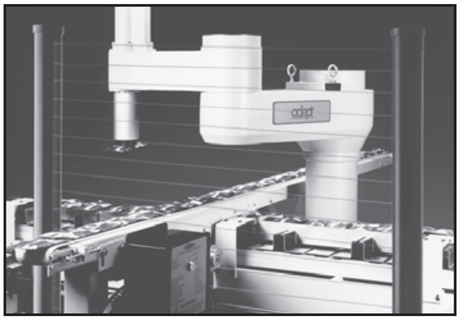
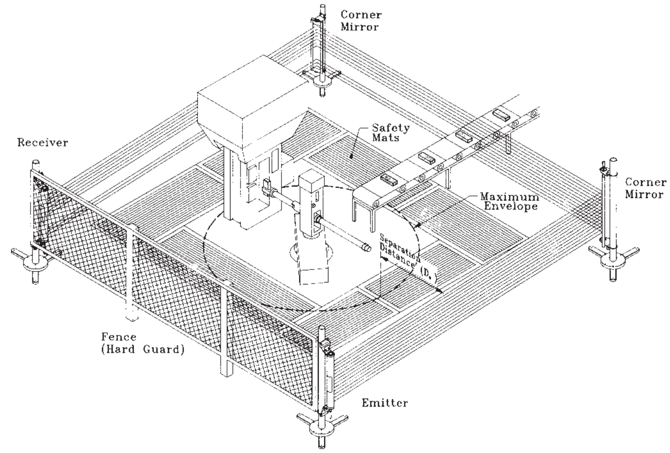


Figure B-47. PERIMETER-GUARD Boundary Guarding System

A Banner PERIMETER-GUARD System consists of an opposed mode emitter-receiver pair, a control box, and interconnecting cable. Corner mirrors (right) may also be used.



Maximum emitter-receiver separation distance is 45 feet, with 3X excess gain remaining.



any single component will prevent effective stopping action when needed, that component must have a *redundant* counterpart to perform the same function. The best systems are designed with *diverse redundancy*. Diverse redundant components are of different designs, and the microprocessor programs used by them run from different instruction sets written by different programmers. Banner MACHINE-GUARD and PERIMETER-GUARD Systems are extensively FMEA (Failure Mode and Effects Analysis) tested to establish a high degree of confidence that no system component, even if it does fail, will cause the system to operate in an unsafe manner. Various standards and approval agencies govern the design and use of safety light curtains. For a summary of their functions, see the box at right.

Because they lack control reliability and component redundancy, conventional photoelectric sensors cannot be used in safety light curtains. A component failure in such a system could cause serious injury or death if that component failure were to prevent stoppage of machine motion under appropriate conditions.

Safety light curtains fall into two general categories, based on function: machine-guard systems and perimeter-guard systems. Banner MACHINE-GUARD Systems are designed for use as *point-of-operation guarding devices* on production machinery (see Figure B.46). MACHINE-GUARD Systems send a "stop" signal to the guarded machinery for as long as an object (hand, arm, workpiece, etc) larger than a certain size blocks one or more sensing beams. The stop signal is automatically removed when the object is removed, and machine motion is allowed to resume. Banner PERIMETER-GUARD Systems are *boundary-guarding devices* for *areas* of dangerous machine motion (Figure B.47). PERIMETER-GUARD Systems send a "stop" signal to the guarded machinery whenever one or more light beams are broken. The stop signal remains after the object that broke the beam(s) is removed, and machine motion can resume only upon manual reset of the PERIMETER-GUARD System.

Both MG and PG System light curtains must be set back from the boundary of the area of machine motion by a distance known as the *separation distance.* Separation distance is based on the response time of the light curtain system, the stopping time of the guarded machine, a safety factor, and a "hand speed constant". Separation distance is necessary to ensure that the object that breaks the curtain cannot reach the dangerous moving machine parts before the

Design and Application Standards for Safety Light Curtain Systems

There is an important basic distinction between *design standards* and *application standards*.

UL (Underwriters Laboratories) 491 and **BSI** (British Standards Institute) 6491 Standards are ***design*** *standards*. They present criteria for safe design of safety light curtain systems. BSI 6491 standards are somewhat more stringent than UL 491 standards. Therefore, safety light curtains available in North America that carry approval per BS 6491 afford the highest level of safety. BS 6491 standards are the model for a new European standard under **CENELEC** (European Committee for Electrotechnical Standardization). The CENELEC standard is expected soon.

OSHA (the Occupational Safety and Health Administration), **ANSI** (the American National Standards Institute), and **RIA** (the Robotics Institute of America) have less to do with the design of safety light curtain systems, and do not certify safety light curtains for use. Rather, they are concerned primarily with creating guidelines for the proper and practical ***application*** of these systems in real situations. OSHA and ANSI put forth recommendations on issues such as machine interface requirements, bypassing (muting) of curtain control, separation distance, supplemental guarding, and maintenance and inspection of systems.

In summary, when you are narrowing your choices for a safety light curtain system, look for those that carry approval per UL 491 and BS 6491. Before installing your safety light curtain system, review OSHA 29 CFR 1910.217, ANSI B11.19, and whatever other ANSI standards apply to your machine. Pay particular attention to the formulas used to calculate the safe distance between the light curtain and the dangerous areas of the machine.

All Banner MACHINE-GUARD and PERIMETER-GUARD systems have approval per UL 491, and most have approval per BS 6491.

moving parts come to rest. Note that these systems may *not* be used with machinery having full-revolution clutches, as these machines are not able to stop immediately.

A Banner MACHINE-GUARD or PERIMETER-GUARD system consists of sensors (multiplexed emitter and receiver), a control box, interconnecting cables, and (in some systems) corner mirrors. MACHINE-GUARD and PERIMETER-GUARD Systems (depending upon the model) offer floating blanking and/or exact blanking. Floating blanking allows an object of limited size to pass through the curtain, at any point, without causing the system's output relays to trip. Exact blanking, available on some systems, allows the system to be programmed so that it will not respond to fixtures, brackets, etc. that will *always be present* within the curtain. In the PERIMETER-GUARD System shown in Figure B-47, exact blanking allows the conveyor to be present within the defined area, and floating blanking allows objects of limited height to pass through the defined area without causing a stop signal.

Banner MACHINE-GUARD and PERIMETER-GUARD System sensors are available in ten length increments between 6 inches and 6 feet. Maximum emitter-receiver separation distance is conservatively rated at 45 feet (with 3x excess gain remaining).

K. Optical Touch Buttons

Optical touch buttons are photoelectric switches that require no physical pressure to operate. They are ergonomically designed to eliminate the hand, wrist, and arm stresses associated with the repeated operation of mechanical switches. Optical touch buttons greatly reduce the risk of carpal tunnel syndrome (CTS, see "box", below), and strongly contribute toward increased worker productivity and comfort. Optical touch buttons are activated whenever a hand breaks the opposed mode sensing beam that is set up across the "saddle" area of the touch button's upper housing (see Figure B.48 and photo at bottom of page).

Momentary-action optical touch buttons are designed to replace capacitive touch switches and mechanical push buttons. The output goes "on" whenever an operator's finger (introduced into the touch area of the switch) interrupts the sensing beam, and stays "on" only as long as the operator's finger remains in the touch area. They are ideal replacements for mechanical push buttons on many types of production machinery. The Banner OTB Series optical touch buttons are momentary-action switches.

Figure B.48. Banner OTB and LTB Series optoelectronic touch buttons require no physical pressure to operate.

Alternate-action optical touch buttons replace mechanical on/off push buttons and toggle switches. Their output changes state (alternating between "off" and "on") whenever a finger, introduced into the touch area of the switch, interrupts the sensing beam. This alternating output makes them especially suitable for room lighting applications. The Banner LTB Series optical touch buttons are alternate action switches.

Models of OTBs and LTBs are available to operate from 105 to 130V or 210 to 250V ac. Two additional OTB models operate from 10 to 30V dc. AC models have an SPDT electromechanical output relay capable of switching up to 7 amps. DC OTBs are offered with a choice of either complementary sinking or complementary sourcing outputs, and switch up to 150 mA dc (continuous). OTBs and LTBs are totally immune to ambient light interference, and highly immune even to the simultaneous sources of EMI and RFI that are found in many industrial settings.

OTBs and LTBs are designed for reliable service in rugged industrial environments. Housings are of black polysulfone and VALOX®, and are completely non-metallic and fully sealed. Separate LED indicators light for "power on" and "output activated" conditions.

CTS (Carpal Tunnel Syndrome) is one type of CTD (Cumulative Trauma Disorders), a family of injuries that are caused by repeated stresses on particular body parts over time. Carpal tunnel syndrome is caused by using the fingers while the wrist is in a flexed or extended (other than neutral) position. The further the wrist is bent from the neutral position, the more muscle pressure and tendon tension is required to do a given amount of work.

Under such conditions, tendons in the underside of the wrist become compressed and inflamed and press on the median nerve, which supplies feeling to the thumb, index, middle, and ring fingers. Health effects can range from slight numbness and tingling to severe pain and muscle atrophy.

Repeated pushing of mechanical push buttons can cause CTS. *Banner OTBs and LTBs (right) greatly reduce the risk by requiring* ***no physical pressure*** *to operate.*

Sensor Selection Category B - Sensor Package

1) Sensor type

Sensors may be grouped as either s*elf-contained* or *remote* types. Self-contained sensors are those types that contain the sensing element(s), amplifier, power supply, and output switch all in a single package (see Figure A.10).

Remote sensors, on the other hand, contain only the sensing element(s). The other circuitry is contained within an *amplifier module* that is located somewhere else, typically in a control panel. Remote sensors, plus their module and power supply comprise a *component system* (see Figure A.9).

Fiber optics may be thought of as a third type of sensor package. Fiber optics are used *in additon to* either a self-contained or remote sensor. The benefits of fiber optics as an alternative sensor package are discussed in "Sensing Modes", on pages B-17 to B-22.

A) Self-contained Sensors

Uses and advantages - self-contained sensors

1) Simplicity of wiring: Self-contained sensors require only a source of voltage to power them, and they can interface directly to a load. Placing the power supply, amplifier, output circuitry and even (sometimes) timing logic right in the sensor can considerably reduce required cabinet space and associated wiring.

The attention given to the design of the output configuration of Banner self-contained sensors has centered around their interface-ability to programmable logic controllers. "PLCs" have been adopted by today's automated factory to integrate process control. Today's sensor is more likely used to supply data to a computer or controller than to perform an actual control function. Without a need to house control relays and timing logic modules in a control cabinet, self-contained sensors are usually the most cost-effective choice.

The rules governing cable runs for self-contained sensors are much less strict as compared to remote sensors. Cable lengths well in excess of 100 feet are usually possible.

2) Ease of alignment: Self-contained sensors contain the amplifier circuitry, so they also have alignment indicators as an integral part of the sensor.

Application cautions - self-contained sensors:

1) Accessibility of controls: Self-contained sensors should be avoided where it is known that the sensitivity or timing logic controls must be adjusted frequently. The adjustment controls of self-contained sensors are sometimes difficult to access.

The need for sensitivity adjustment always should be eliminated by optimizing sensing contrast. The need for timing adjustment always should be engineered out of a sensing system through use of mechanical references. However, there are times when either sensitivity or timing must be changed for different setups. In these situations, it is often much more convenient to adjust the controls of component amplifiers and/or timing logic modules that are located in a control panel.

2) Temperature limitations: Avoid using self-contained sensors in temperatures exceeding 70° C (158° F). The specifications for some self-contained sensors are even lower.

Self-contained sensor types and features

Self-contained sensors are either *modular* or *one-piece* . Modular self-contained sensors were first introduced in 1978 with the design of the MULTI-BEAM® (Figure B.49). Modular sensors offer the great benefit of flexibility in sensing system design and revision. From the standpoint of system design, the modular approach permits tailoring exactly the right sensor for the application from a relatively small selection of sensor components. Also, as sensing requirements change, a modular sensor may be modified by a simple swap of a sensor block, power block, or logic module. In addition to the MULTI-BEAM family, the OMNI-BEAM™ and MAXI-BEAM® families are modular self-contained designs.

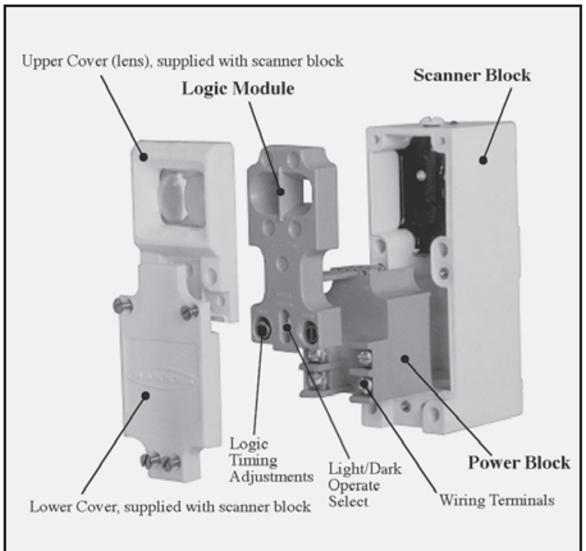


Figure B.49. Modular self-contained sensors, like the MULTI-BEAM®, permit a large variety of sensor configurations, resulting in exactly the right sensor for any photoelectric application.

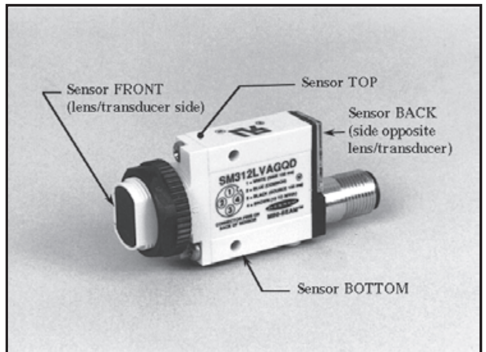


Figure B.50. The MINI-BEAM® is an example of a one-piece self-contained sensor. Sensor sides, as referenced in Table B-12, are indicated.

One-piece self-contained sensors (Figure B.50) are not as versatile as modular designs. The sensing mode, input voltage, and output configuration are dictated by the particular model. However, since some Banner self-contained photoelectric sensors are designed so that the lens may be replaced., the sensing mode of an installed sensor may sometimes be converted with a simple lens change. These sensing mode conversions are listed for each sensor family in the product catalog.

Most one-piece self-contained sensors are built with an integral cable. But VALU-BEAM, MINI-BEAM, ULTRA-BEAM, OPTO-TOUCH, QØ8, Q19, Q85, S18, and SM3Ø Series sensors may be ordered with a quick disconnect ("QD") style connector. Quick disconnect connectors and cable with mating plugs are available also for all modular self- contained sensors.

Many self-contained sensors are equipped with a sensitivity (or ultrasonic range) control. Modular sensors equipped with a timing logic module have one or two controls for the timing range(s). These controls are either single-turn or 15-turn potentiometers. The 15-turn controls are especially rugged, with a slotted brass trim element that is clutched at both ends of travel to prevent any possibility of damage.

Access to sensor controls is often an important consideration when selecting a sensor. Table B-12 indicates which side of the sensor housing has access to the controls. The "front" side of any sensor is the lens (or transducer) side. Figure B.50 defines the other sides of a sensor. Table B-12 also compares the features offered by each family of self-contained sensors.

Table B-12. Self-contained Sensors

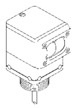
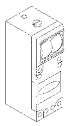
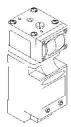
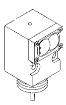
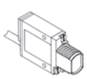
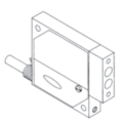
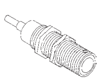
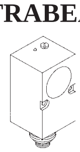
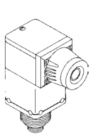
Sensor Family	Modular or One-piece	AC Models	DC Models	Controls	Control Access (See figure B.46)	Timing Logic Option
OMNI-BEAM™ 	MODULAR: Sensor head & power block (logic module is optional)	210 to 250V ac 105 to 130V ac	10 to 30V dc	15-turn gain 15-turn timing	Top	Yes
				Programming switches	Inside sensor	
MULTI-BEAM® 	MODULAR: Scanner block, power block, & logic module	210 to 250V ac 105 to 130V ac 22 to 28V ac 11 to 13V ac	44 to 52V dc 10 to 30V dc	15-turn gain	Top	Yes
				Single-turn timing	Front	
MAXI-BEAM® 	MODULAR: Sensor head & power block (logic module is optional)	210 to 250V ac 105 to 130V ac	10 to 30V dc	15-turn gain	Top	Yes
				15-turn timing	Front, back, or either side (rotatable)	
VALU-BEAM® 	ONE-PIECE	24 to 250V ac 12 to 28V ac	10 to 30V dc	Single-turn sensitivity	Back	No
				Light/Dark Operate switch	Back	
MINI-BEAM® 	ONE-PIECE	24 to 240V ac	10 to 30V dc	15-turn sensitivity	Back	No
				Light/Dark Operate switch	Back	
ECONO-BEAM™ 	ONE-PIECE	No	10 to 30V dc	None	N/A	No
SM512 Series 	ONE-PIECE	No	10 to 30V dc	Single-turn sensitivity	Side	No
SM30 series 	ONE-PIECE	24 to 240V ac	10 to 30V dc	None	N/A	No
ULTRABEAM™ 	ONE-PIECE	210 to 260V ac 105 to 130V ac	18 to 30V dc	923 Series: 15-turn null & span 925 Series: 15-turn range adjust	Top	No
Sonic OMNI-BEAM™ 	MODULAR: Sensor head and power block	105 to 130V ac	No	15-turn NEAR limit and window WIDTH	Top	No

Table B-12. Self-contained Sensors (continued)

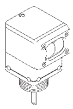
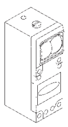
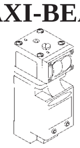
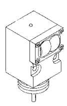
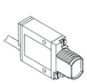
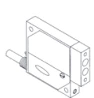
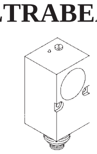
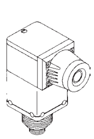
Sensor Family	Quick-disconnect Option	Replaceable Lens	Alignment Indicator	Notes
OMNI-BEAM™ 	Yes	Yes	D.A.T.A.™ light system (10-element LED array)	Programmable for: light/dark operate, alarm polarity, hysteresis, and meter scale factor D.A.T.A. self-diagnostic system with alarm output Available also in OEM version
MULTI-BEAM® 	Yes (Installed in scanner block by user)	Yes (Replace upper cover assembly)	AID™ (flashing signal strength indicator)	Jumper wire in logic module for dark operate Remove lower cover for access to timing controls
MAXI-BEAM® 	Yes (Installed in wiring base by user)	Yes	AID™ (flashing signal strength indicator)	Rotatable logic module Rotatable sensor head Programmable response and light/dark operate Permanent wiring base
VALU-BEAM® 	Yes	Yes	Yes (AID™ indicator on some models)	Models available with: 1) Built-in totalizer 2) Intrinsically-safe design
MINI-BEAM® 	Yes	Yes	Yes (AID™ indicator on dc models)	Miniature size
ECONO-BEAM™ 	Yes (by special order)	Yes (models SE612CV and SE612LV only)	Yes	Designed for OEM applications
SM512 Series 	No	Yes (models SM512LB, SM512C, C1, & SM51EB6/RB6 only)	Yes	Shallow (1/2 inch wide) metal housing
SM30 Series 	Yes	Yes (factory repair)	Yes	For extremely hostile sensing areas, NEMA 6P Opposed mode only
ULTRABEAM™ 	Yes (standard)	N/A	Yes	Ultrasonic proximity: switched output or analog
Sonic OMNI-BEAM™ 	Yes	N/A	Yes (10-element target location indicator)	Ultrasonic proximity: ranging or high/low limit sensing

Table B-12. Self-contained Sensors (continued)

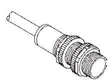
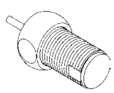
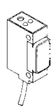
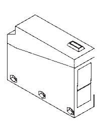
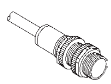
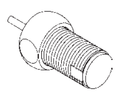
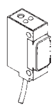
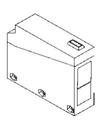
Sensor Family	Modular or One-piece	AC Models	DC Models	Controls	Control Access (See figure B.46)	Timing Logic Option
THIN-PAK™ 	ONE-PIECE	No	10 to 30V dc	None	N/A	No
S18 Series (an EZ-BEAM sensor) 	ONE-PIECE	20 to 250V ac	10 to 30V dc	None	N/A	No
C3Ø Series 	ONE-PIECE	No	10 to 30V dc	None	N/A	No
Q19 Series 	ONE-PIECE	No	10 to 30V dc	Single-turn sensitivity	Top	No
Q85 Series 	ONE-PIECE	24 to 240V ac	12 to 240V dc	Single-turn sensitivity Light/DarkOperate switch Optional timing switches, single-turn timing	Top, inside wiring chamber	Yes

Table B-12. Self-contained Sensors (continued)

Sensor Family	Quick-disconnect Option	Replaceable Lens	Alignment Indicator	Notes
THIN-PAK™ 	Yes	No	Yes	Miniature size (8 mm deep) Metal housing Designed for OEM applications Opposed and diffuse (proximity) sensing modes
S18 Series (an EZ-BEAM sensor) 	Yes	No	Yes	18-mm threaded VALOX® barrel housing Low excess gain alarm output (dc models) NEMA 6P
C3Ø Series 	No	No	Yes	30-mm LEXAN® threaded barrel housing Retroreflective and diffuse (proximity sensing modes) NEMA 6
Q19 Series 	Yes (pigtail)	No	Yes	Miniature size NEMA 6 ABS housing LED indicators for DC power on, output overload, output on, and low excess gain
Q85 Series 	Yes (installed by user)	No	Yes	NEMA 6P ABS housing Wiring chamber with gasketed cover

B) Remote Sensors

Uses and advantages

1) Small sensor size: The remote sensors of a component system contain only the sensing element(s). As a result, they may be used where small sensor size is required (Figure B.51). (Exception: remote sensor model SP1000V; see "Sensor Size" for explanation.)

2) Accessibility of control: The amplifiers of a component system typically have easily accessible sensitivity and timing controls. This is a consideration when it is known that adjustments will have to be made frequently.

3) High temperature: Some remote sensors may be placed in locations with temperatures up to 100°C (212°F). However, the amplifier and timing modules of any component system must be kept relatively cool, typically below 50°C (120°F). Exception: MICRO-AMP modules are specified for up to 70°C (158°F). NOTE: SP100 Series miniature remote sensors are rated for 70°C maximum.

4) Price advantage: Multiple remote sensors may sometimes be wired into a single amplifier to reduce the overall cost of a sensing system. The MAXI-AMP™ modulated amplifier modules allow up to three sensors per amplifier. However, each sensor added will noticeably reduce the range (excess gain) of each sensor. For more information, see Section D ("Sensing Logic"). NOTE: MICRO-AMP® modules only allow one sensor (or emitter/receiver pair) to be connected to one amplifier module.

Application cautions

1) Alignment indicator: Most remote sensors do not have an amplifier, and so they cannot have an integral alignment indicator. Instead, an alignment indicator is housed with the amplifier module, back in a control cabinet.

2) Wiring precautions: When using component systems, it is very important to follow the rules for connecting the remote sensors to their amplifiers. This is especially true for modulated remote sensors:

a) Avoid running remote sensor cables in wireways together with power carrying conductors.

b) *Always* use shielded cables, and connect the shield ("drain wire") at the amplifier (see exception discussed at right).

c) Avoid running remote sensor cables through areas of known extreme electrical interference (e.g. areas of inductive welding or arc welding, etc.).

d) Avoid running remote sensor cable lengths longer than specified for the amplifier to be used.

e) When splicing additional cable length to remote sensor leads, never combine emitter and receiver wires in one common cable. The result in a modulated system will be electrical "crosstalk" within the cable, causing a "lock-up" condition in the amplifier. Banner offers shielded extension cable for all remote sensors which, if used, will minimize cable crosstalk (see MICRO-AMP section of Banner product catalog).

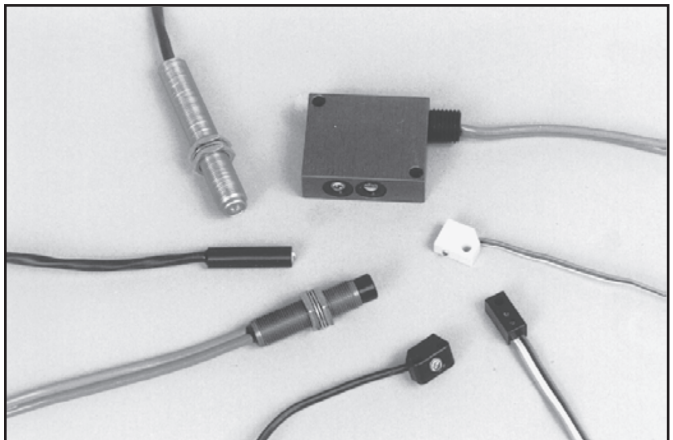


Figure B. 51. A remote sensor may be used when small sensor size is required.

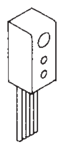
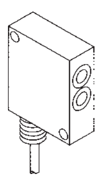
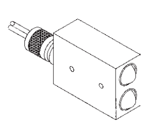
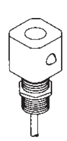
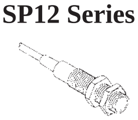
Amplifiers for use with Remote Sensors

There is a distinction between two types of remote sensors. The very small SP100 Series of sensors use ribbon cable for connection to their modulated amplifier. Ribbon cable lacks a true shield wire. To avoid cable crosstalk, low-gain modulated amplifiers are recommended for use with the SP100 Series. In the MAXI-AMP™ Amplifier Series, the models for use with SP100 Series sensors have the letter "R" in their model number prefix which designates ribbon cable (e.g. model CR3RA).

The modulated amplifiers in the MICRO-AMP® line for use with SP100 Series sensors are models MA3, MA3P, and MPC3. Model MA3 has complementary sinking outputs. Model MA3P has complementary sourcing (PNP) outputs. Model MPC3 is for use in 5V dc circuits, and is usually mounted directly onto a printed circuit (PC) board. A special MICRO-AMP amplifier module (model MA3A or MPC3A) is used with background suppression model SP100FF, which has *two* received signal outputs.

All other remote sensors operate with a full-power modulated amplifier, except for model LP510CV which works best with a high-gain *non-modulated* amplifier. Table B-13 lists the model numbers of the amplifiers for use with each remote sensor.

Table B-13. Remote Sensors

Sensor Family	Amplifier Module	Sensing Mode	Range	Sensor Model	Comments
SP100 Series Miniature modulated 	**MAXI-AMP™ CR3RA, CR3RB, CR5RA, CR5RB**	Opposed	8 inches	**SP100E & SP100R**	For very tight locations. Wide beam angle; hermetically sealed lenses
		Diffuse	1.5 inches	**SP100D**	Tight right-angle design; hermetically sealed lenses
		Diffuse	1.5 inches	**SP100DB**	3/8" short threaded barrel; hermetically sealed lenses
		Convergent beam	0.1 inch focus	**SP100C**	High excess gain; rapid fall-off of gain past convergent point
	MICRO-AMP® MA3, MA3P, MPC3	Convergent beam	0.1 inch focus	**SP100CCF**	Optically same as SP100C, but has narrow profile for tight locations
	MICRO-AMP® MA3A, MPC3A	Fixed-field	0.2 inch crossover	**SP100FF**	High excess gain with absolute rejection of background reflections
SP300 Series 	**MAXI-AMP™ CM3RA, CM3RB, CM5RA, CM5RB** **MICRO-AMP® MA3-4, MA3-4P**	Opposed	50 feet	**SP300EL & SP300RL**	High excess gain. Anodized aluminum housing; conduit fitting.
		Retroreflective	15 feet	**SP300L**	Anodized aluminum housing; conduit fitting
		Diffuse	12 inches	**SP300D**	Anodized aluminum housing; hermetically sealed glass lenses
		Diffuse	12 inches	**SP320D**	Miniature VALOX® housing for tight locations
SP1000 Series 	**MAXI-AMP™ CM3RA, CM3RB, CM5RA, CM5RB** **MICRO-AMP® MA3-4, MA3-4P**	Convergent beam	3.8 inch focus	**SP1000V**	Anodized aluminum housing. Precise 0.1 inch diameter sensing spot. Ideal for precise position control. Sharp drop-off of excess gain beyond the convergent point.
LR/PT Series 	**MAXI-AMP™ CM3RA, CM3RB, CM5RA, CM5RB**	Opposed	8 feet	**LR200 & PT200**	Right-angle design, Delrin® housing; hermetically sealed lenses
		Opposed	8 feet	**LR250 & PT250**	1/4" diameter unthreaded Delrin® housing; hermetically sealed lenses
		Opposed	8 feet	**LR300 & PT300**	Miniature right-angle VALOX® housing; hermetically sealed lenses
		Opposed	8 feet	**LR400 & PT400**	3/8" diameter aluminum threaded housing; hermetically sealed lenses
	MICRO-AMP® MA3-4, MA3-4P	Fiberoptic (glass)	Dependent on fiber used	**LR400 & PT400 w/FOF-400 fiberoptic fittings**	FOF-400 anodized aluminum fittings accept any Banner glass fiberoptic assembly
LP Series 	**MAXI-AMP™ CM3RA, CM3RB, CM5RA, CM5RB** **MICRO-AMP® MA3-4, MA3-4P**	Divergent	3 inches	**LP400WB**	For reflective sensing of mechanically unstable clear materials. Also ideal for sensing of small wires or threads. (Not for precise position sensing)
	B Series B3-4 (non-modulated)	Precise focus convergent beam	0.17 inch focus	**LP510CV**	Anodized aluminum housing. 1/2" dia. fine thread for precise position adjustment.
SP12 Series 	**MAXI-AMP™ CD3(R)A, CD3(R)B, CD5(R)A, CD5(R)B**	Opposed	200 feet	**SP12SEL or SP12PEL & SP12SRL or SP12PRL**	Preamplified sensors; highly noise-immune 12-mm threaded barrel housings VALOX® or stainless steel; NEMA 6P

2) Sensor Size

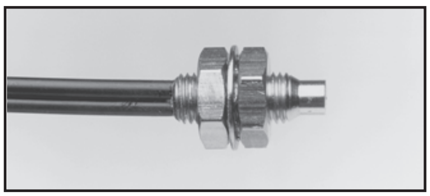
The size, shape, and mounting configuration of any sensor are important criteria for most sensing applications. The sensors that follow are listed in order of their overall size (volume) from smallest to largest.

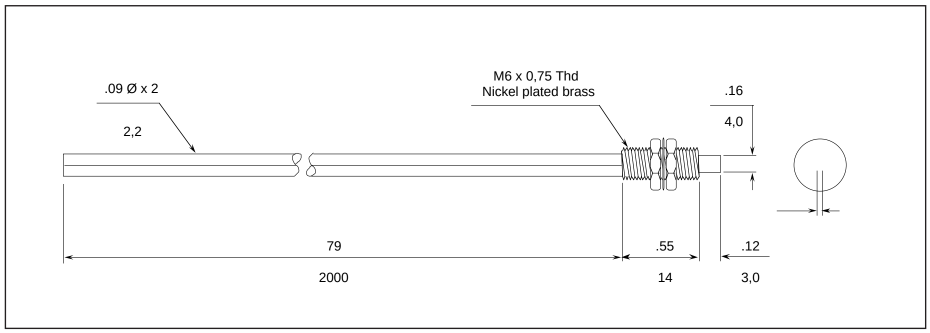
a) Plastic Fiber Optics

Plastic fiber optics comprise the smallest group of noncontact presence sensors. Common fiber diameters include 0.02 and 0.04 inch. Sensing with fibers as small as 0.01 inch in diameter is possible in some applications. Plastic fiber optic assemblies are "cut-to-length" (cut by the user to an appropriate length for the application). The main size and mounting considerations involve the termination of the sensing end. A plastic fiber optic assembly is connected to a fiber optic sensor that is mounted in a convenient location away from the sensing area.

A typical bifurcated plastic fiber optic assembly is shown here. See the Banner product catalog for descriptions of the full line of standard plastic fiber optic assemblies.

PBT46U
Bifurcated threaded plastic fiber optic assembly for proximity sensing mode



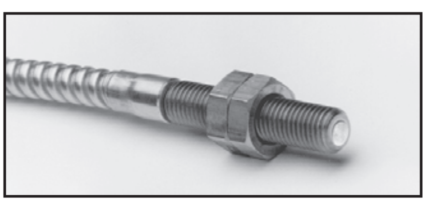


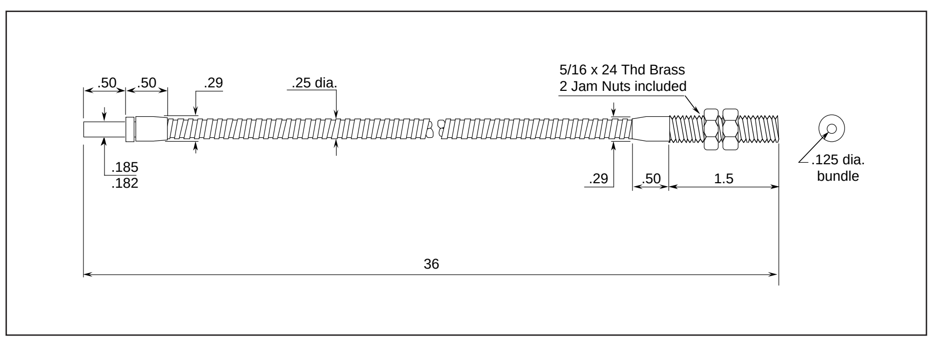
b) Glass Fiber Optics

Glass fiber optic assemblies are a close second to plastic fiber optics for being the smallest sensors. In fact, some special glass fiber optics are even smaller than the mainstream plastic fiber optic assemblies. The majority of glass fiber optic assemblies use a 1/8" diameter bundle of glass fibers, with each fiber measuring about .001 to .002 inch in diameter. The most popular sheath material is armored stainless steel, but there are several options including PVC, latex, or teflon tubing. Sensing tip styles are many and varied, and special designs are often used to solve challenging sensing applications. A glass fiber optic assembly is connected to a fiber optic sensor that is mounted in a convenient location, away from the sensing area.

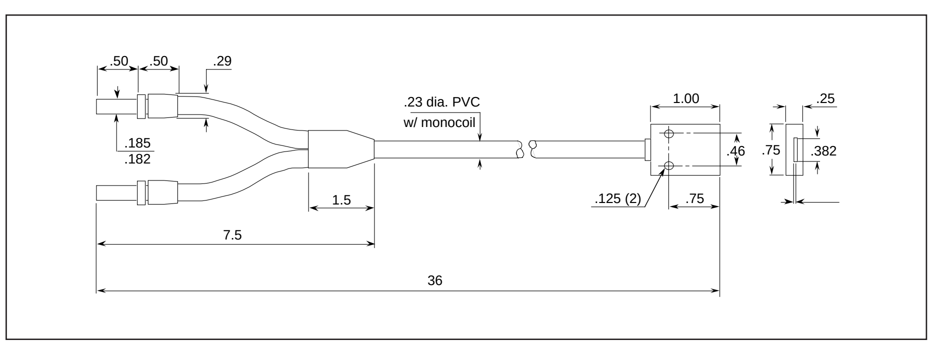
Typical individual and bifurcated glass fiber optic assemblies are shown here. The Banner product catalog has an extensive listing of both standard and special glass fiber optic designs.

IT23S
Individual threaded glass fiber optic assembly for opposed sensing mode





BR23P
Bifurcated glass fiberoptic assembly for proximity sensing mode

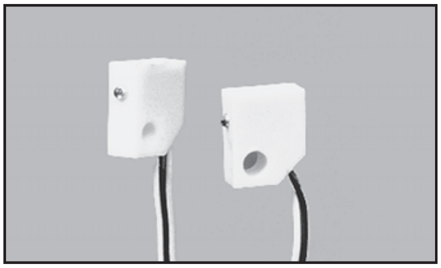


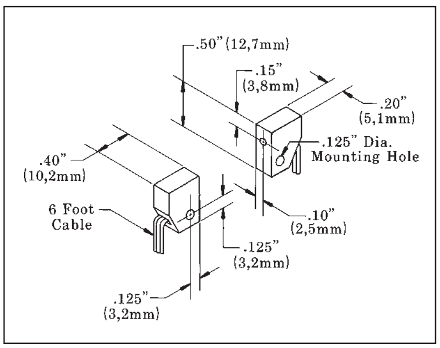
c) SP100 Series Remote Sensors

The SP100 Series is a family of miniature modulated remote photoelectric sensors. They are designed to mount in very tight locations, and are connected to their amplifiers using slim and flexible ribbon cable.

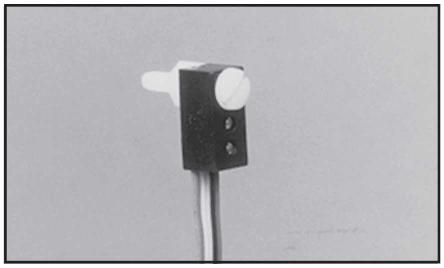
These sensors use MICRO-AMP® modulated amplifier model MA3, MA3P, or MPC3. They may also be used with MAXI-AMP™ modulated amplifier models CR3RA, CR3RB, CR5RA, or CR5RB. Dimensional information for the SP100 Series is shown below. See the Banner product catalog for additional specifications.

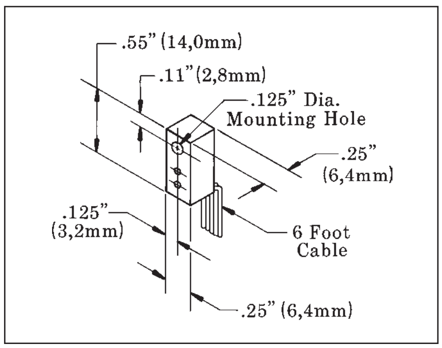
SP100E & SP100R Opposed Mode



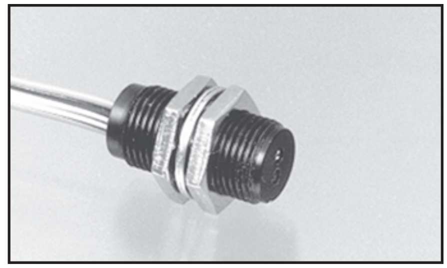


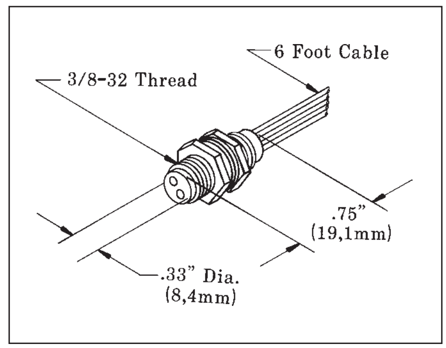
SP100D Diffuse Mode



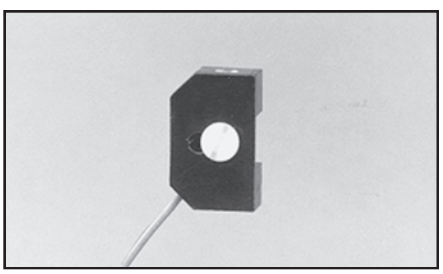


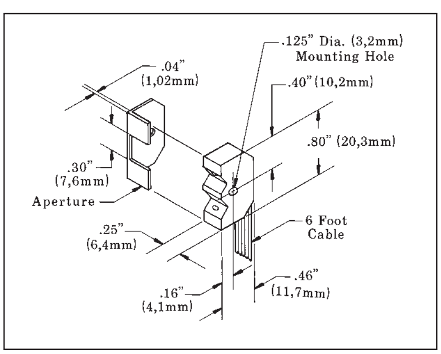
SP100DB Diffuse Mode



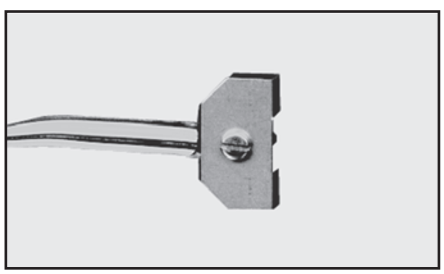


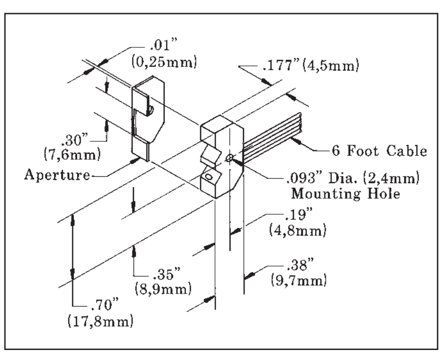
SP100C Convergent Mode



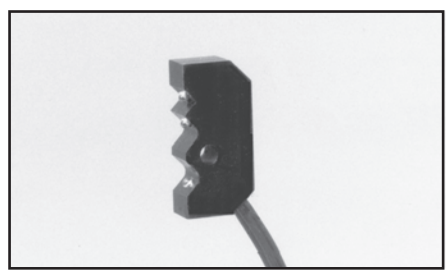


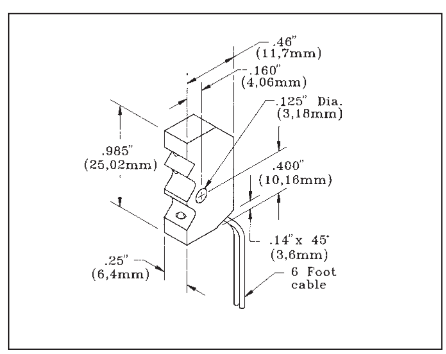
SP100CCF Convergent Mode





SP100FF Fixed-field Mode

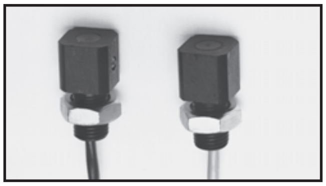


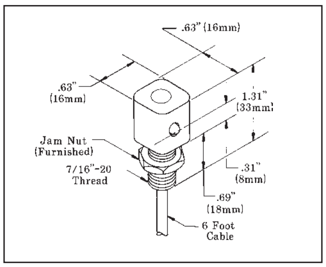


d) Modulated Remote Sensors (continued at bottom of page B-50)

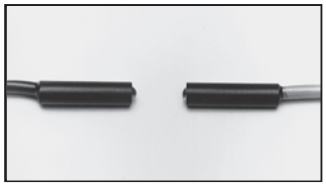
Remote sensors house only the sensing element(s). This enables a remote sensor to be physically smaller than a self-contained sensor that has comparable performance. The only exception in this size comparison is model SP1000V, which is a long-range (yet precise-focus) convergent beam remote sensor. The superior performance of the SP1000V is accomplished by the use of large-diameter, long focal length lenses. The result is a remote sensor that is larger than many self-contained sensors. All other remote sensors are very compact and encapsulated for extremely rugged performance. The Banner product catalog is the source for complete specifications for these remote sensors. This section is continued at the bottom of page B-50.

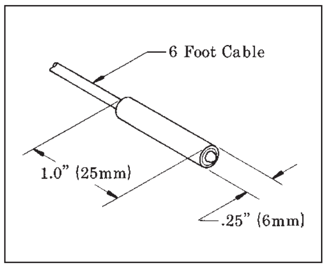
LR200 & PT200 Opposed Mode



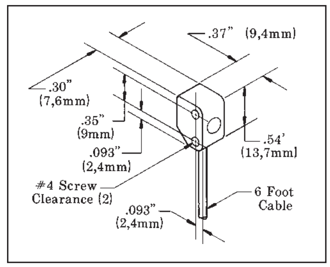


LR250 & PT250 Opposed Mode

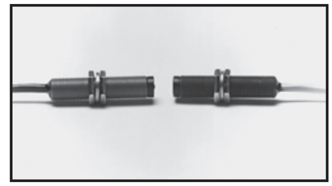


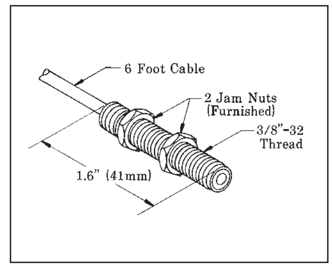


LR300 & PT300 Opposed Mode



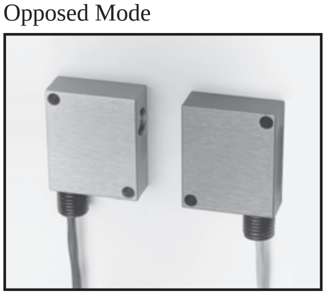
LR400 & PT400 Opposed Mode

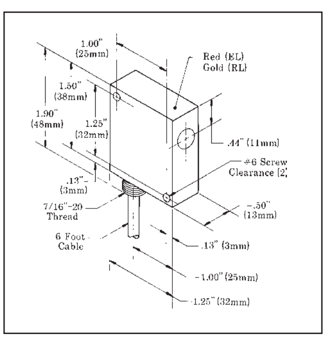




SP300EL & SP300RL

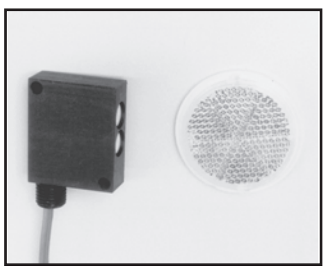
Opposed Mode

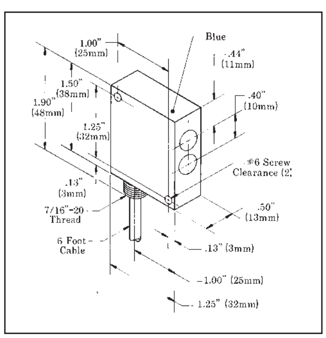




SP300L

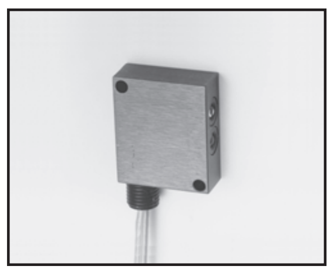
Retroreflective Mode

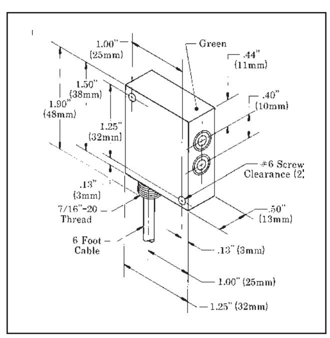




SP300D

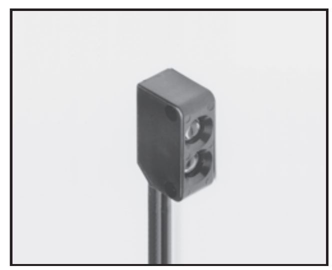
Diffuse Mode

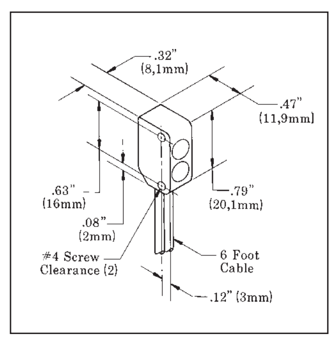




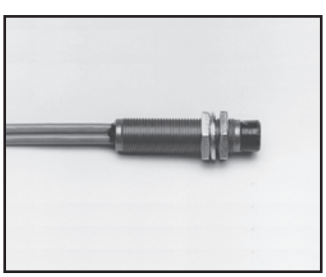
SP320D

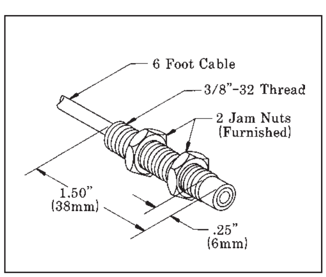
Diffuse Mode



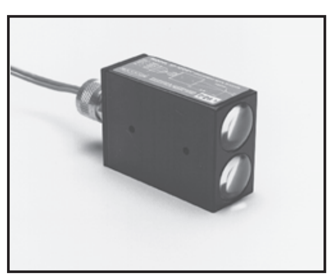


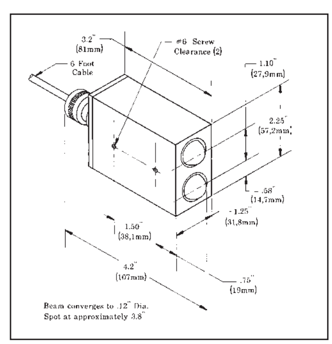
LP400WB Divergent Mode





SP1000V Convergent Mode

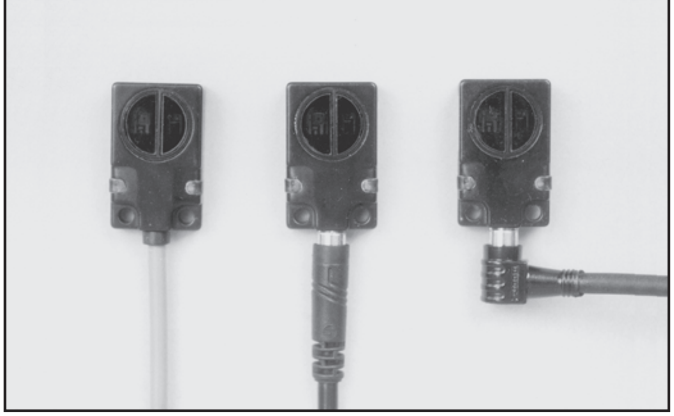




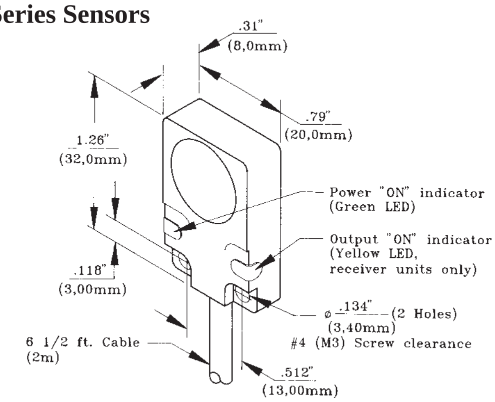
e) QØ8 Series Self-contained Sensors

QØ8 Series THIN-PAK™ sensors are the smallest self-contained sensors and are built in 8 millimeter deep die-cast metal housings. The compactness of these sensors makes them especially suitable for limited-space applications. These sensors are rated NEMA 6, and have two through-mounting holes which accomodate M3 hardware.

QØ8 Series Sensors

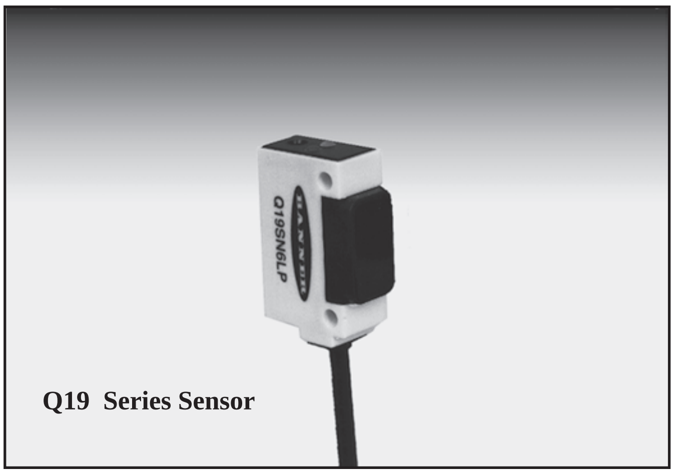


QØ8 Series Sensors



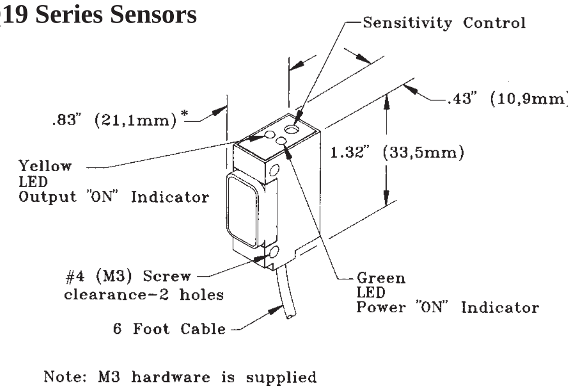
f) Q19 Series Self-contained Sensors

Q19 Series sensors are full-featured NEMA 6-rated sensors in very small ABS housings. They feature a versatile, innovative dual-LED indicator system and an o-ring sealed SENSITIVITY control. Two through-mounting holes accomodate M3 hardware.



Q19 Series Sensor

Q19 Series Sensors



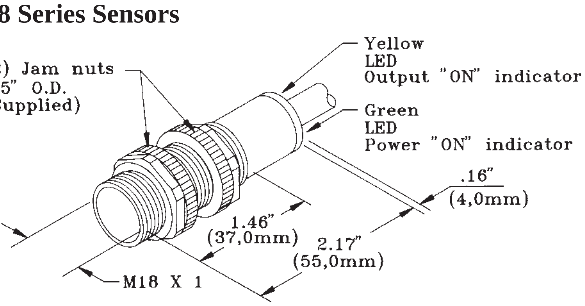
*Polarized retro model shown. This dimension decreases for other models.

g) S18 Series Self-contained Sensors

S18 Series sensors are high-performance sensors in 18 millimeter diameter threaded barrel style VALOX® housings. They are rated NEMA 6P (IEC IP67) and mount through 18-mm clearance holes or using one of several available mounting brackets.


S18 Series Sensors

S18 Series Sensors

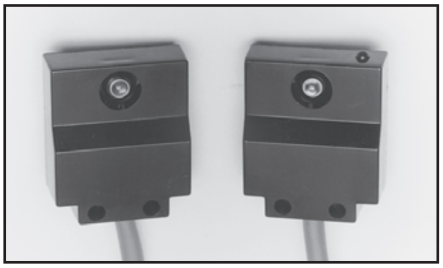


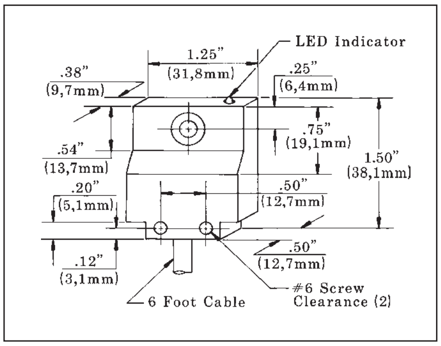
Dimensions above are for dc opposed, retro, and diffuse mode sensors (models with attached cable). Fixed-field, ac, and QD style sensors are longer. Length of longest S18 sensor is 4.05" overall.

h) ECONO-BEAM™ Self-contained Sensors

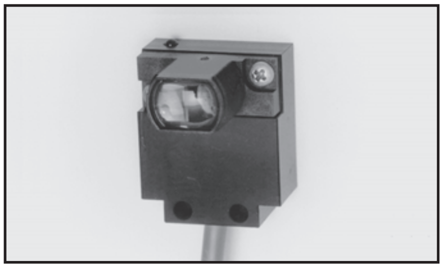
ECONO-BEAM sensors are miniature "right-angle" self-contained dc (only) sensors, used primarily for OEM applications. Their right-angle design makes them especially well-suited to conveyor and web applications. They mount using two #6 bolts. Actual dimensions differ with sensing mode due to differing lens configurations.

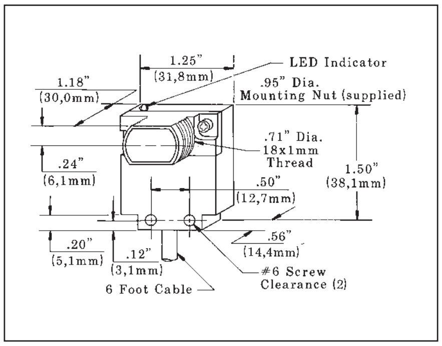
SE61E & SE61R Opposed Mode



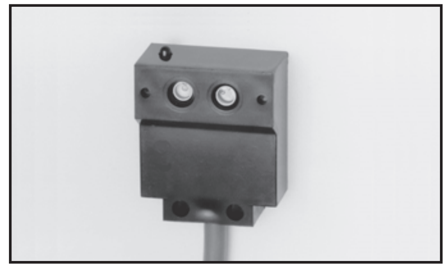


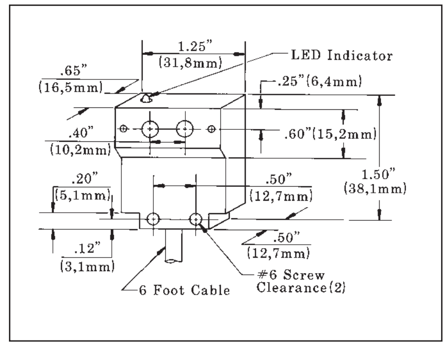
SE612LV RetroreflectiveMode
SE612CV Convergent Mode



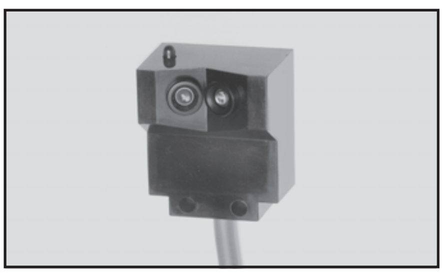


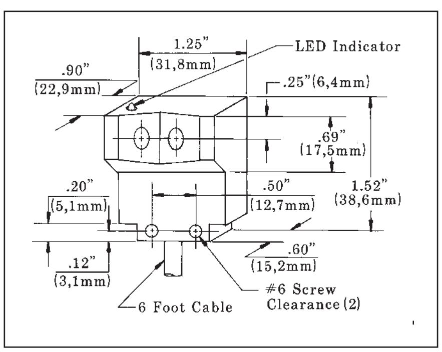
SE612D Diffuse Mode
SE612W Divergent Mode



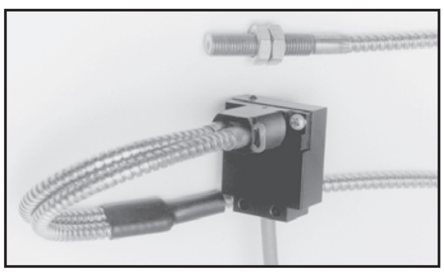


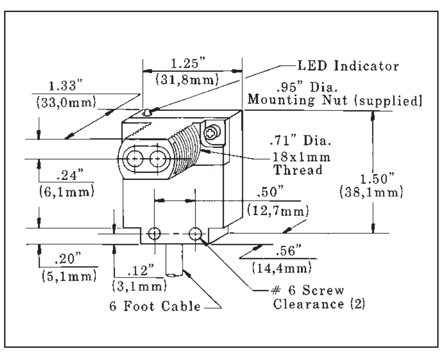
SE612C Mechanical Convergent



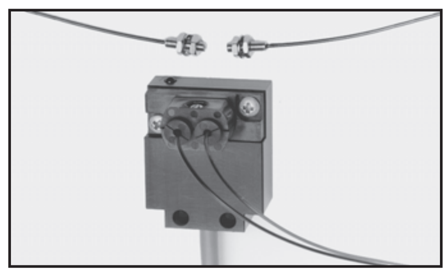


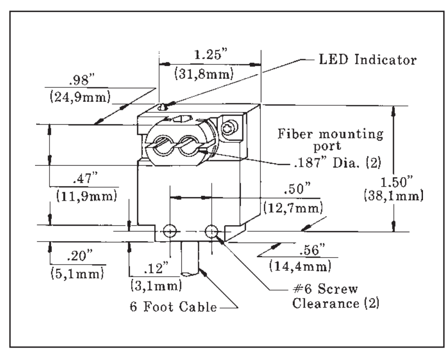
SE612F Glass Fiber Optic





SE612FP Plastic Fiber Optic



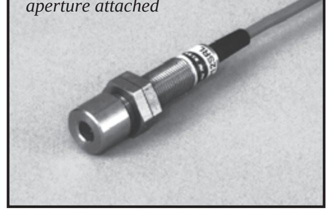


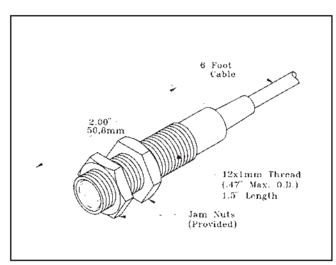
Modulated Remote Sensors (continued from page B-48)

SP12 Series Opposed Mode

SP12 Series sensors are *preamplified remote sensors* designed for use with CD Series MAXI-AMP modules. The circuit inside the receiver preamplifies the signal, making the power and noise immunity of these sensors equal to that of self-contained sensors.

Shown with accessory aperture attached

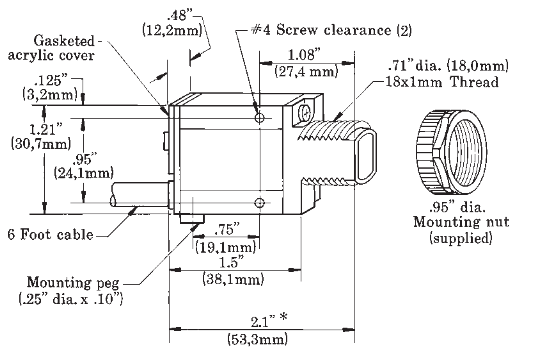




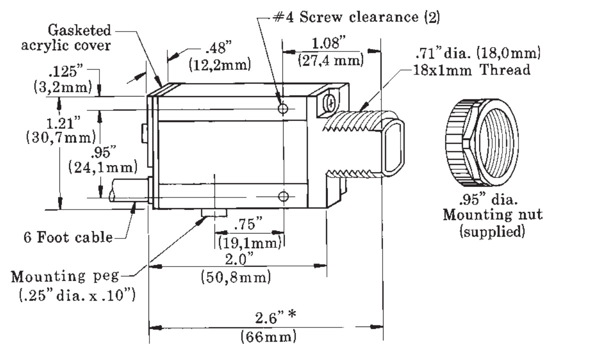
i) MINI-BEAM® Self-contained Sensors

MINI-BEAM sensors are miniature "in-line" self-contained sensors with a high performance-to-size ratio. Their design allows either front (18-mm), bottom, or side mounting. Brackets are available for each mounting approach. Access to the controls is from the rear. Models that are powered by ac voltage are slightly larger than dc models.

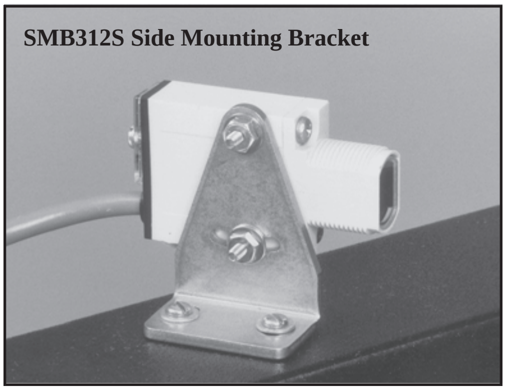
DC MINI-BEAM Sensors

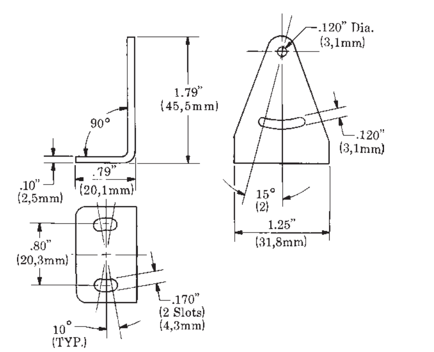


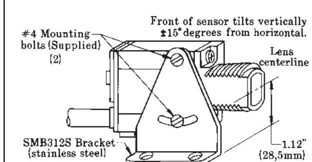
AC MINI-BEAM Sensors



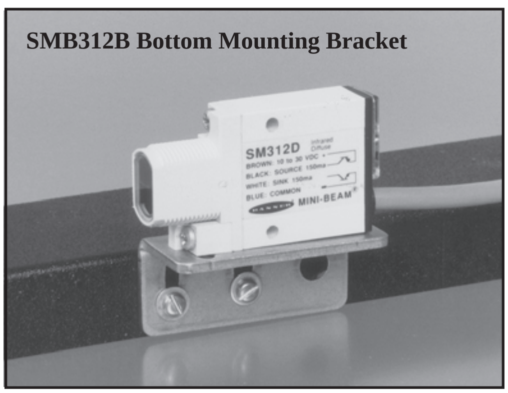
SMB312S Side Mounting Bracket

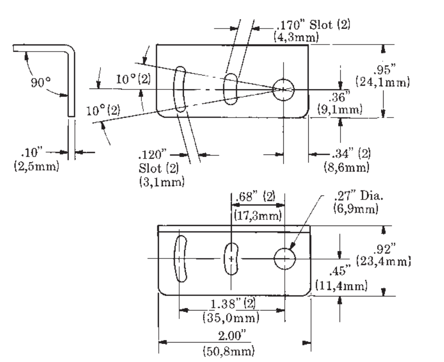


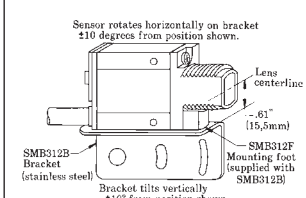




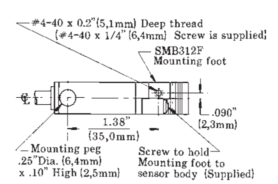
SMB312B Bottom Mounting Bracket





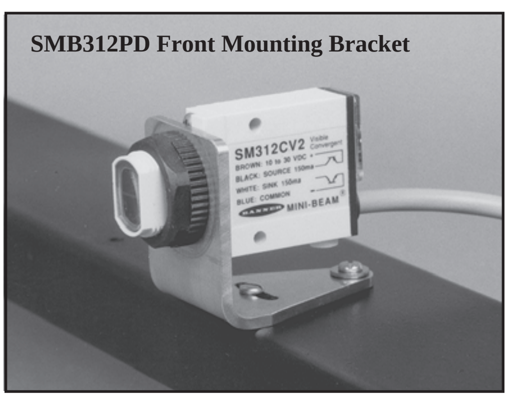


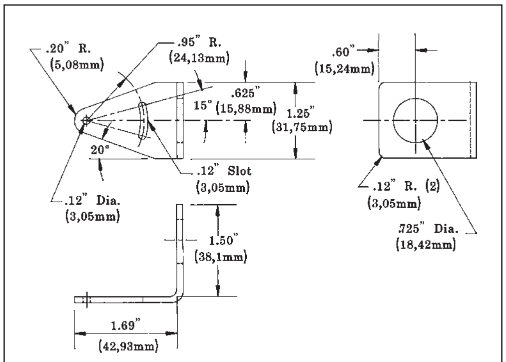
SMB312F Mounting Foot



(supplied with SMB312B bracket)

SMB312PD Front Mounting Bracket



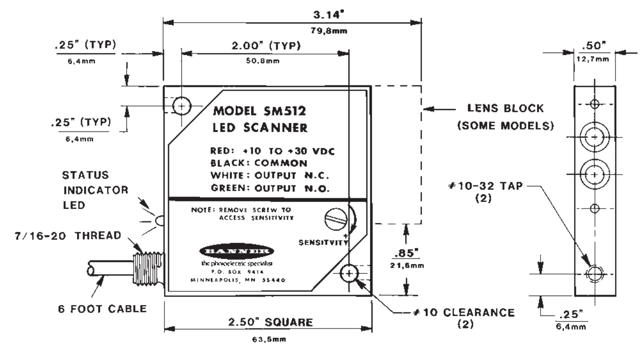


j) SM512 Series Self-contained Sensors

The SM512 Series sensors are older self-contained sensors that, due to their mechanical design, are still used in new sensing system designs. The SM512 Series is built using an aluminum-zinc alloy die-cast housing that measures only 1/2" thick. This design was originally used for retroreflective code reading, but has evolved into a complete family of photoelectric sensors that has acquired the nickname of the "flat-pack" sensor.

SM512 Series Sensors

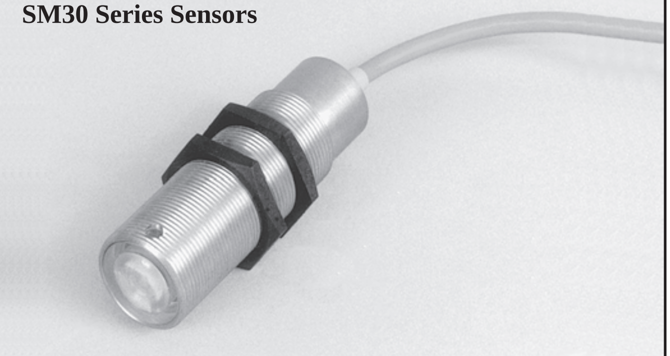
SM512 Series Sensors



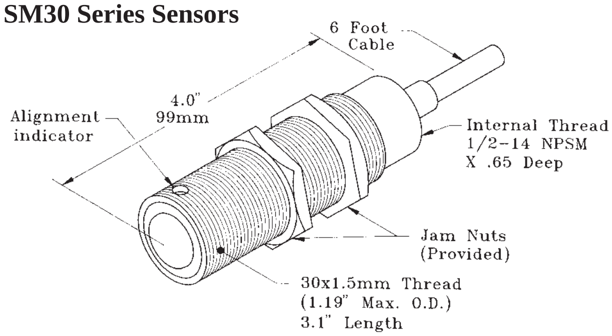
k) SM30 Series Self-contained Barrel Sensors

SM30 Series barrel sensors are extremely rugged and powerful self-contained emitter-receiver pairs. They are rated NEMA 6P and may be applied in the most demanding environments. Their 700-foot sensing range provides enough excess gain to penetrate even the heaviest contamination. SM30 Series sensors have the best immunity to electrical noise of any emitter/receiver pair, and are available with either a VALOX® or a stainless steel housing.

SM30 Series Sensors



SM30 Series Sensors

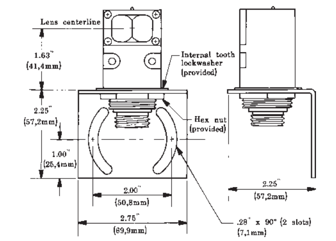


l) VALU-BEAM® Self-contained Sensors

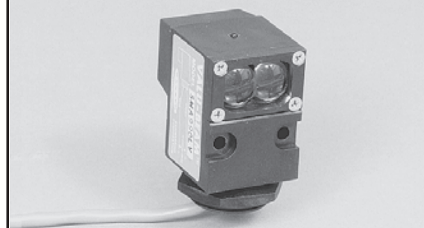
VALU-BEAM self-contained sensors offer full photoelectric sensing performance in a small, one-piece design. Mounting is accomplished using the two #10 screw clearance through-holes, or via the 30mm threaded hub and jam nut. A mounting bracket is available for mounting the sensor by its threaded base. A swivel-mount bracket, model SMB30SM, is also available.

VALU-BEAM Sensor

Shown with SMB900 Bracket

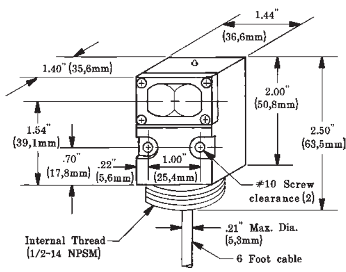


VALU-BEAM 990 Series Sensor

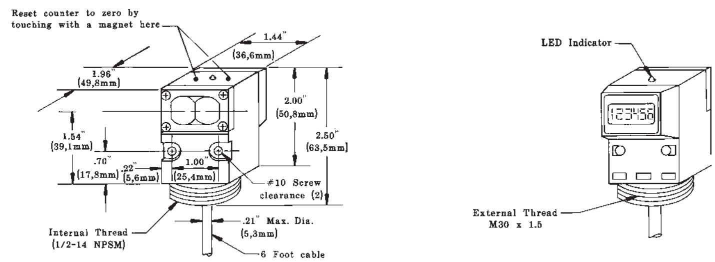


with built-in totalizing counter

VALU-BEAM Sensor



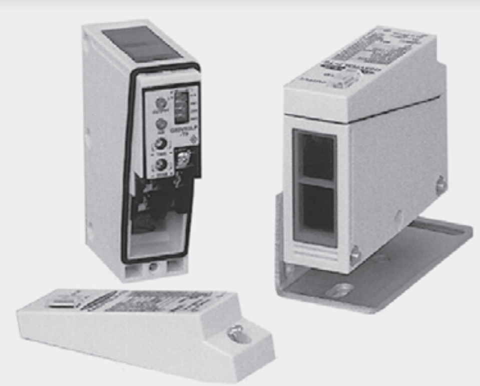
VALU-BEAM 990 Series Sensor with built-in totalizing counter



m) Q85 Series Self-contained Sensors

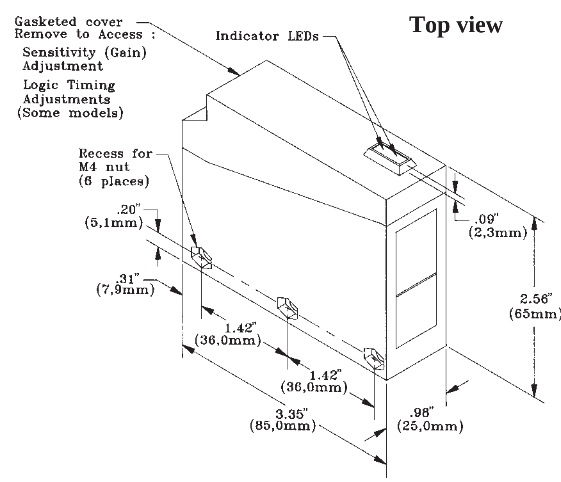
Q85 Series sensors feature a SENSITIVITY control, a light/dark operate switch, a convenient o-ring sealed wiring chamber with two conduit entrances, and optional timing logic (8 functions). The housing is Cycolac® ABS, and is rated NEMA 6P (IEC IP67). A two-axis steel mounting bracket and two mounting bolts are included.

Q85 Series Sensors

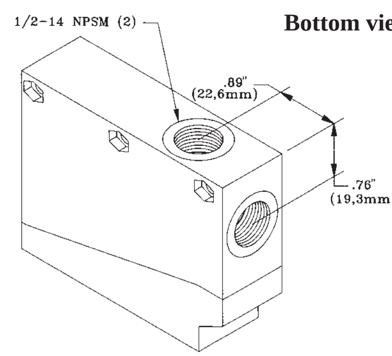


Q85 Series Sensors

Top view



Bottom view

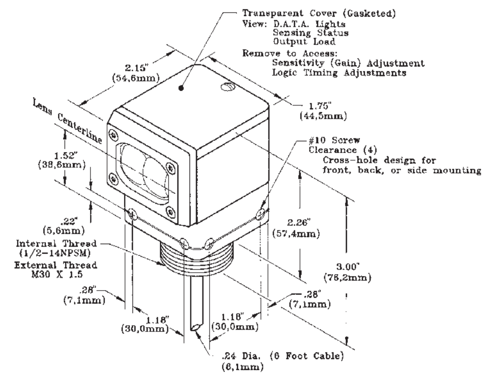


n) OMNI-BEAM™ Modular Self-contained Sensors

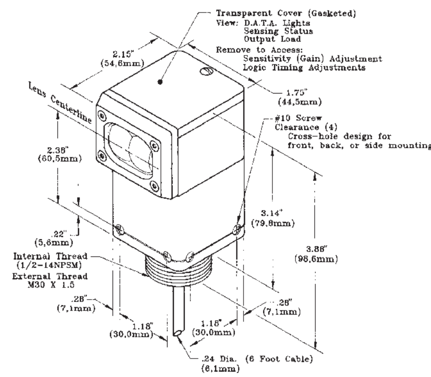
The OMNI-BEAM is the smallest of the modular self-contained sensors. Each sensor consists of a sensor head and power block. A timing logic module that slips inside the sensor head is optional. The dc power block is particularly low-profile.

The sensor mounts by using a pair of #10 clearance cross-mounting holes, or by the 30-mm threaded hub on the power block base. A stainless steel mounting bracket is available.

OMNI-BEAM Sensor with DC Power Block

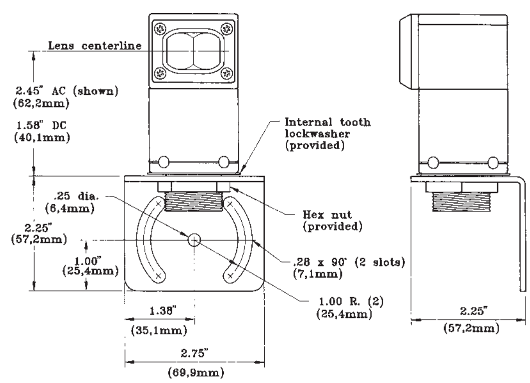


OMNI-BEAM Sensor with AC Power Block

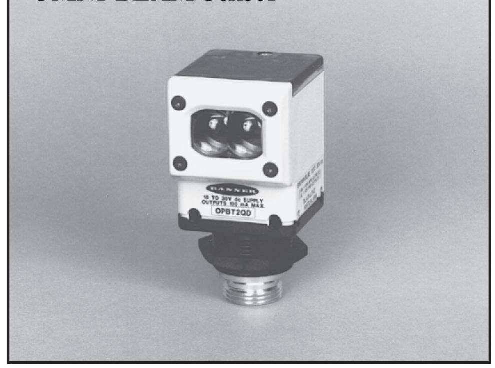


Shown with SMB30MM Bracket
(AC sensor shown)

Swivel-mount bracket model SMB30SM is also available.



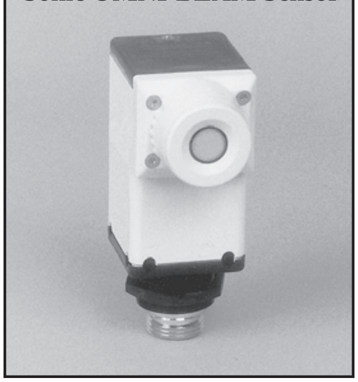
OMNI-BEAM Sensor

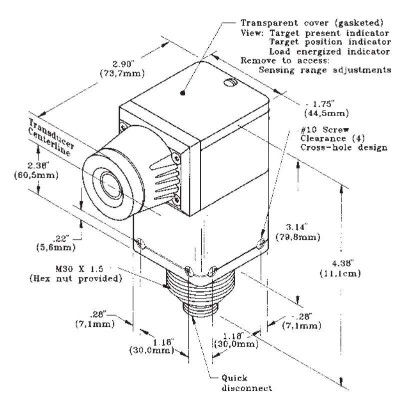


o) Sonic OMNI-BEAM™ Modular Self-contained Ultrasonic Proximity Sensor

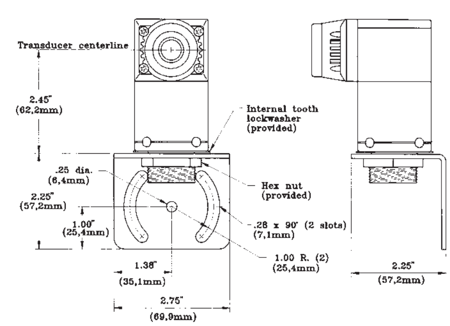
NOTE: the sonic OMNI-BEAM uses the SMB30MM mounting bracket (see OMNI-BEAM, above).

Sonic OMNI-BEAM Sensor





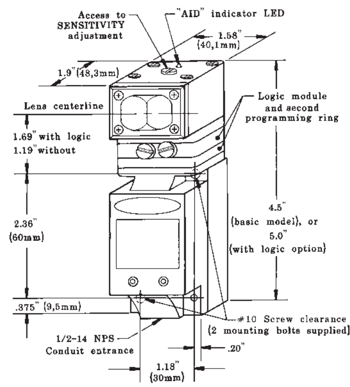
Shown with SMB30MM Bracket



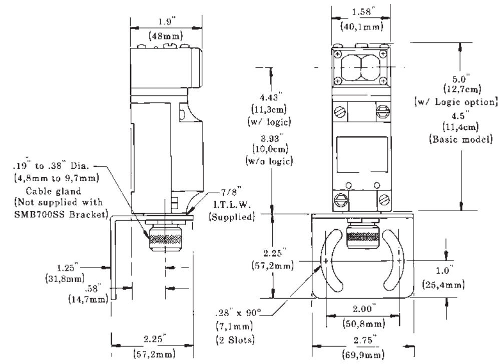
p) MAXI-BEAM® Modular Self-contained Sensor

The MAXI-BEAM is comprised of a sensor block, power block, and wiring base. The wiring base remains mounted in place (without disturbing the wiring) if either of the other components is ever removed or replaced. A timing logic module may be added if needed, and it adds 1/2 inch to the sensor height. MAXI-BEAMs feature a rotatable sensing head and logic module and many programming options. Sensor mounting is accomplished with #10 bolts using holes located on standard limit-switch 30x60mm centers, or via the 1/2 inch NPS internal thread in the wiring base.

MAXI-BEAM Sensor



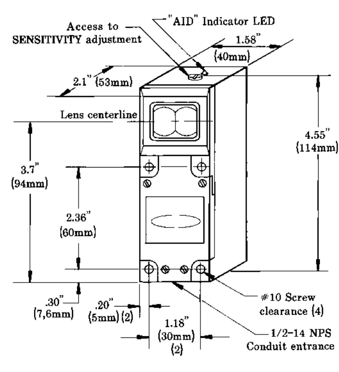
Shown with SMB700 Bracket



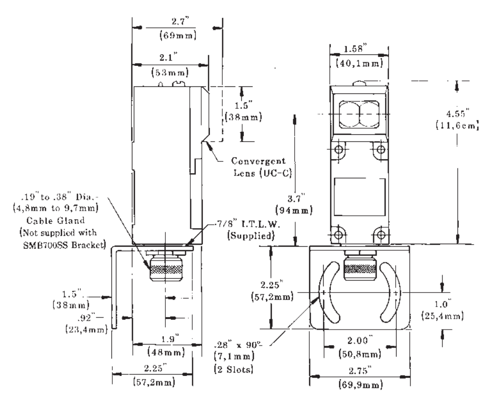
q) MULTI-BEAM® Modular Self-contained Sensor

MULTI-BEAM sensors are only slightly larger than MAXI-BEAMs, and feature the same limit-switch style design. All models require a logic module, which is contained inside the sensor. The outstanding optical performance of the MULTI-BEAM is the standard for the photoelectric industry. Sensor mounting is accomplished with #10 bolts using holes located on standard limit-switch 30x60mm centers, or via the 1/2 inch NPS internal thread in the wiring base.

MULTI-BEAM Sensor



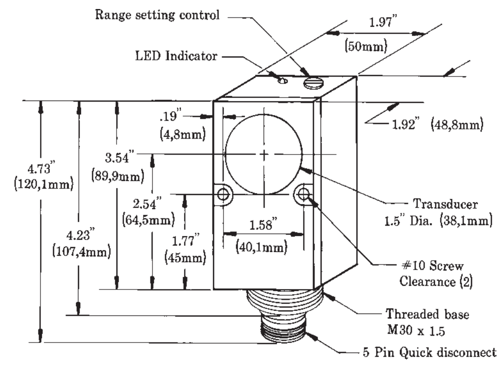
Shown with SMB700 Bracket



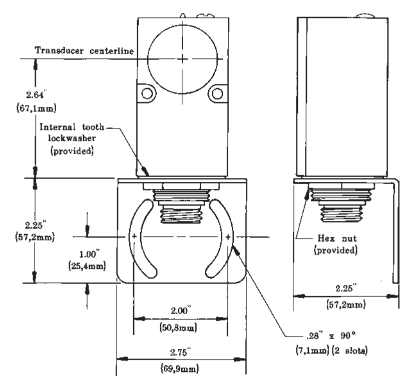
r) ULTRA-BEAM™ One-piece Self-contained Ultrasonic Proximity Sensor

The ULTRA-BEAM is the largest sensor in the Banner line. The width of the sensor is required to accomodate the electrostatic ("Polaroid-type") ultrasonic transducer. ULTRA-BEAMs may be mounted either using #10 bolts or by the 30mm threaded hub at the sensor base. A quick-disconnect fitting is standard on all ULTRA-BEAM sensors.

ULTRA-BEAM Sensor



Shown with SMB900 Bracket



3) Sensor Housing and Lens Material

Not all sensing locations are high and dry and protected from threatening elements. For some applications, sensor housing materials may be of major importance when choosing a sensor. For example, in areas with very high moisture levels it is usually best to select a non-corrosive thermoplastic housing like VALOX®. In areas where industrial solvents are used, a metal housing may be needed.

Attention to the material used for a lens or for a transducer cover may also be necessary in some environments. For example, a glass lens may be necessary in areas where there is acid or solvent splash. On the other hand, glass lenses may not be allowed in certain food processing applications. Table B-14 lists the materials that are used to construct each family of Banner sensors. The properties of the materials are compared in Table 15 in the Data Reference section (Section F) at the back of this book.

Table B-14. Materials used in Banner Sensors and Fiber Optics

NOTE 1: All integral cables are PVC-jacketed.
NOTE 2: Also see Table 15 in DATA REFERENCE.
NOTE 3: See the Banner product catalog or the individual data sheets for information on materials used for sensors and amplifiers of component systems.

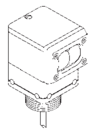
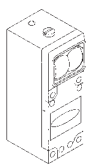
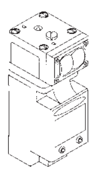
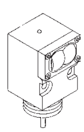
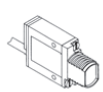
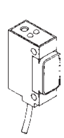
Self-contained **Sensor Family**	**Housing Materials**	**Lens Material**	**Replaceable Lens**	**Assembly Hardware**	**Mounting Hardware**
OMNI-BEAM™ 	VALOX®	Glass: convergent model. VALOX®: fiber optic models. Acrylic: all other models.	YES all models	Stainless steel	VALOX® 30-mm mounting nut; all other hardware is stainless steel.
MULTI-BEAM® 	VALOX®	Glass: convergent model. VALOX®: fiber optic models. Rigid vinyl: short-range diffuse. Acrylic: all other models.	YES all models (by changing upper cover assembly)	Stainless steel Nylon sensitivity control covers	Zinc-plated steel
MAXI-BEAM® 	VALOX®	VALOX®: fiber optic models. Acrylic: all other models.	YES all models	Stainless steel Nylon control covers	Zinc-plated steel
VALU-BEAM® 	VALOX® housing; optional Quick Disconnect fitting is nickle-chrome plated brass.	VALOX®: fiber optic models. Acrylic: all other models.	YES all models	Stainless steel Nylon control covers	VALOX® 30-mm mounting nut; all other hardware is stainless steel.
MINI-BEAM® 	VALOX® housing; acrylic control cover. Optional Quick Disconnect fitting is nickle-chrome plated brass.	VALOX®: fiber optic models. Acrylic: all other models.	YES all models	Stainless steel	VALOX® 18-mm mounting nut
ECONO-BEAM™ 	VALOX® for models SE612CV, F, FP, LV. Lexan® for all other models.	Acrylic: models SE612CV and SE612LV. VALOX®: models SE612F and SE612FP. Glass: all other models.	YES (models SE612CV, F, FP, and LV)	Stainless steel	VALOX® 18-mm mounting nut on models SE612CV, F, and LV
THIN-PAK™ 	Die-cast zinc Optional QD fitting is chrome plated brass	Polysulfone thermoplastic: opposed models Rigid vinyl: diffuse models	NO	(none)	(none)
Q19 Series 	Cycolac® ABS	Acrylic	NO	(none)	Stainless steel mounting hardware

Table B-14. Materials used in Banner Sensors and Fiber Optics (continued)

NOTE 1: All integral cables are PVC-jacketed.
NOTE 2: Also see Table 15 in DATA REFERENCE.
NOTE 3: See the Banner product catalog or the individual data sheets for information on materials used for sensors and amplifiers of component systems.

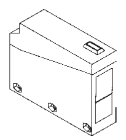
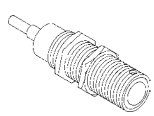
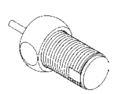
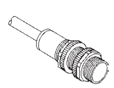
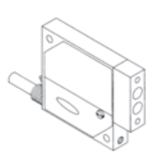
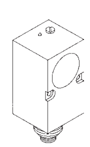
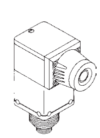
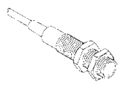
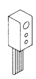
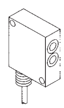
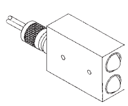
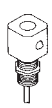
Self-contained Sensor Family	Housing Materials	Lens Material	Replaceable Lens	Assembly Hardware	Mounting Hardware
Q85 Series 	Cycolac® ABS	Acrylic	NO	Plated steel	plated steel mounting bolts and bracket included
SM3Ø Series 	VALOX® or stainless steel	Acrylic	YES all models (requires factory replacement)	(none)	VALOX® or stainless steel 30-mm jam nuts
C3Ø Series 	Lexan®	Lexan® (integral with sensor housing)	NO	(none)	30-mm VALOX® jam nuts
S18 Series (an EZ-BEAM sensor) 	VALOX®	Lexan®: most models Black acrylic: FF models	NO	(none)	18-mm VALOX® jam nuts
SM512 Series 	Epoxy powder coated zinc aluminum alloy Stainless steel cover	Glass Anodized aluminum lens block on models SM51EB6, SM51RB6, SM512C1, SM512CV1, SM512LB	YES (models SM51EB6/RB6, SM512C1, SM512CV1, SM512LB)	Black oxide steel screws Nylon sensitivity control cover	(none)
ULTRA-BEAM™ 	VALOX® housing Nickle-chrome plated quick-disconnect fitting	Anodized aluminum screen over transducer	NO	Stainless steel Nylon control covers	VALOX® 30-mm mounting nut; all other hardware is zinc plated steel
Sonic OMNI 	VALOX® housing Lexan® control cover Optional quick-disconnect fitting in nickle-chrome plated brass	KAPTON® film over transducer	Transducer is replaced by exchanging sensor head assembly	Stainless steel	VALOX® 30-mm mounting nut; all other hardware is zinc plated steel

Table B-14. Materials used in Banner Sensors and Fiber Optics (continued)

NOTE 1: All integral cables are PVC-jacketed.
NOTE 2: Also see Table 15 in DATA REFERENCE.
NOTE 3: See the Banner product catalog or the individual data sheets for information on materials used for sensors and amplifiers of component systems.

Remote **Sensor Family**	**Housing Materials**	**Lens Material**	**Replaceable Lens**	**Assembly Hardware**	**Mounting Hardware**
SP12 Series 	VALOX® or stainless steel	Acrylic	NO	none	Two jam nuts: VALOX® or stainless steel
SP100 Series 	VALOX® (except SP100DB and SP100FF are Delrin®)	Glass	NO (hermetic seal)	none	Nylon (except SP100FF is stainless steel; SP100DB is nickel-plated steel)
SP300 Series 	SP300EL, SP300L, SP300RL, and SP300D are anodized aluminum SP320D is VALOX®	Glass	NO	none	SP300D has Delrin® lens holders
SP1000 Series 	Anodized aluminum	Glass	NO	Black oxide steel capscrews	(none)
LR/PT Series 	LR/PT200 and LR/PT250 are Delrin®; LR/PT300 are VALOX®; LR/PT400 are anod. aluminum.	Glass	NO (hermetic seal)	none	LR/PT200 and LR/PT400 are supplied with nickel-plated steel mounting hardware
LP Series 	Anodized aluminum	LP510CV: glass LP400WB: acrylic	NO	none	Nickel-plated steel

Fiber Optics	**Fiber Material**	**Sensing End Tip Material**	**Sheath Material**	**Fiber Bundle Termination**	**Mounting Hardware**
Plastic Fiber Optics 	Acrylic monofilament	Threaded tips are nickel-plated brass All other tips are stainless steel	Polyethylene	N/A	Threaded end tips and nuts are nickel-plated brass
Glass Fiber Optics 	Multiple optical glass fibers; F2 core, EN1 clad	Threaded tips are brass or stainless steel Rectangular tips are plastic or aluminum All others are stainless steel	Stainless steel armor, or PVC with steel monocoil reinforcing wire	Optical grade epoxy (900-degree fibers are terminated without epoxy)	Threaded brass end tips have brass nuts Threaded stainless steel end tips have stainless steel nuts

Sensor Selection Category C - Electrical Considerations

1. Sensor supply voltage

Every sensor selection process requires an examination of the system to determine what voltage is available to power the sensor(s). Low voltage dc sensors are usually specified whenever the interface will be to a low voltage dc circuit or load. Low voltage sensors also provide a relative degree of electrical safety. High voltage ac sensors are also selected based on the sensor interface (to an ac load). However, ac sensors are often selected simply for the convenience of using readily available ac "line" voltage for sensor power. High voltage also provides a relative degree of electrical "noise" immunity.

Banner gives close attention in its sensor designs to all wiring options and offers many wiring alternatives that are not offered by competitive sensor manufacturers. These options are explained and listed in Section C ("Interfacing").

Tables B-15 through B-18 that follow group sensors and sensing systems by their supply voltage.

Table B-15. Sensors Powered by Low Voltage ac

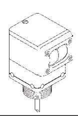
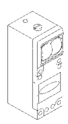
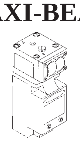
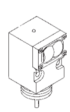
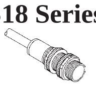
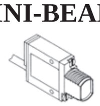
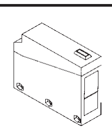
Product Family	Voltage Rating (50/60Hz)	Wiring Configuration (e/m = electromechanical relay)	Model Numbers	Notes
OMNI-BEAM™ 	24 to 250V ac	SPDT E/M relay, 5 amp max., 5-wire	Power block: **OPEJ5**	Used with OEM OMNI-BEAM sensor heads
MULTI-BEAM® 	22 to 28V ac	SPST solid-state relay, 3/4 amp max., 3- or 4-wire	Power block: **PBD**	Used with 3- & 4-wire scanner blocks and logic modules
	22 to 28V ac	SPST solid-state relay, 3/4 amp max., 2-wire	Power block: **2PBD**	Used with 2-wire scanner blocks and logic modules
	11 to 13V ac	SPST solid-state relay, 3/4 amp max., 3- or 4-wire	Power block: **PBD-2**	Used with 3- & 4-wire scanner blocks and logic modules
MAXI-BEAM® 	12 to 250V ac	Electromechanical relay, 5 amps max., 4-wire	Power block: **RPBR** (SPST) **RPBR2** (SPDT)	Used with any MAXI-BEAM sensor head; electromechanical output relay
		Optically-isolated solid-state relay, 100 ma max., 4-wire	Power block: **RPBU** (SPST)	Solid-state output relay
VALU-BEAM® 	24 to 250V ac	SPST solid-state relay, 1/2 amp max., 2-wire	**SM2A912** or **SM2A91** prefix	<1.7 mA. off-state leakage current
	12 to 28V ac	SPDT E/M relay, 5 amps max., 5-wire	**SMW915** or **SMW95** prefix	Electromechanical output relay
	10 to 250V ac	2-wire	**SMA990** or **SMA99** prefix	Built-in 6-digit LCD totalizing counter (no output)
S18 Series 	20 to 250V ac	SPST solid-state relay, 0.3 amps max., 3-wire	**S183, S18A, S18R** prefixes	<50 microamps off-state leakage current
MINI-BEAM® 	24 to 240V ac	SPST solid-state relay, 0.3 amps max., 2-wire	**SM2A312** or **SM2A31** prefix	<1.7 mA. off-state leakage current
SM30 Series 	24 to 240V ac	SPST solid-state relay, 0.5 amps max., 2-wire	**SM2A30** prefix	<1.7 mA. off-state leakage current
Q85 Series 	24 to 240V ac	SPDT e/m relay, 3 amps max., 5-wire	**Q85VR3** prefix	Electromechanical output relay

Table B-16. Sensors Powered by 110/120V ac

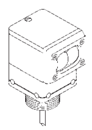
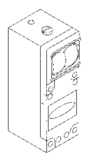
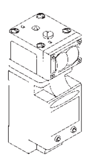
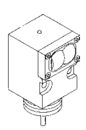
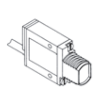
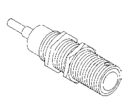
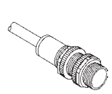
Product Family	Voltage Rating (50/60Hz)	Wiring Configuration (e/m = electromechanical relay)	Model Numbers	Notes
OMNI-BEAM™ 	105 to 130V ac	SPST solid-state relay, 1/2 amp max., 4-wire	Power block: **OPBA2**	Separate diagnostic alarm output (5th wire) **D.A.T.A.** light system
		4- or 5-wire analog	Power block: **OPBA3**	Analog output 0-10Vdc, direct or inverse
	24 to 250V ac	SPDT E/M relay, 5 amp max., 5-wire	Power block: **OPEJ5**	Used with OEM OMNI-BEAM sensor heads Electromechanical output relay
MULTI-BEAM® 	105 to 130V ac	SPST solid-state relay, 3/4 amp max., 3- or 4-wire	Power block: **PBA**	Used with 3- & 4-wire scanner blocks and logic modules
	105 to 130V ac	SPST solid-state relay, 3/4 amp max., 2-wire	Power block: **2PBA**	Used with 2-wire scanner blocks and logic modules
	105 to 130V ac	E/M relay, 5 amps max., 4-wire	Power block: **2PBR** (SPST) **2PBR2** (SPDT)	Used with 2-wire scanner blocks and logic modules; electromechanical output relay
	105 to 130V ac	SPST solid-state relay, 0.1 amp max., 3- or 4-wire	Power block: **PBAT**	Used with 3- & 4-wire scanner blocks and logic modules; switches ac or dc loads
	105 to 130V ac	SPST optically isolated solid-state relay, 0.05 amp max., 4-wire	Power block: **PBO**	Used with 3- & 4-wire scanner blocks and logic modules; switches low-voltage dc circuitry (sink or source)
MAXI-BEAM® 	105 to 130V ac	SPST solid-state relay, 3/4 amp max., 3- or 4-wire	Power block: **RPBA**	Used with any MAXI-BEAM sensor head; <0.1 mA. off-state leakage current
	105 to 130V ac	SPST solid-state relay, 3/4 amp max., 2-wire	Power block: **R2PBA**	Used with any MAXI-BEAM sensor head; <1.7 mA. off-state leakage current
	12 to 250V ac	Electromechanical relay, 5 amps max., 4-wire	Power block: **RPBR** (SPST) **RPBR2** (SPDT)	Used with any MAXI-BEAM sensor head; electromechanical relay output
		Optically-isolated solid-state relay, 100 ma max., 4-wire	Power block: **RPBU** (SPST)	Solid-state output relay
VALU-BEAM® 	24 to 250V ac	SPST solid-state relay, 1/2 amp max., 2-wire	**SM2A912** or **SM2A91** prefix	<1.7 mA. off-state leakage current
	90 to 130V ac	SPDT E/M relay, 5 amps max., 5-wire	**SMA915** or **SMA95** prefix	Electromechanical output relay
	10 to 250V ac	2-wire	**SMA990** or **SMA99** prefix	Built-in 6-digit LCD totalizing counter (no output)
MINI-BEAM® 	24 to 240V ac	SPST solid-state relay, 0.3 amps max., 2-wire	**SM2A312** or **SM2A31** prefix	<1.7 mA. off-state leakage current
SM30 Series 	24 to 240V ac	2-wire	**SM2A30** prefix	<1.7 mA. off-state leakage current
S18 Series 	20 to 250V ac	3-wire	**S183, S18A, and S18R** prefixes	<50 microamps off-state leakage current

Table B-16. Sensors Powered by 110/120V ac (continued)

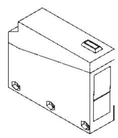
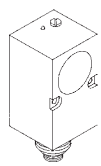
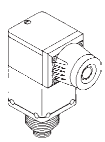
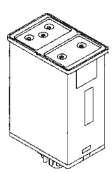
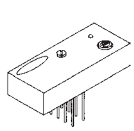
Product Family	Voltage Rating (50/60Hz)	Wiring Configuration (e/m = electromechanical relay)	Model Numbers	Notes
Q85 Series 	24 to 240V ac	SPDT E/M relay, 3 amps max., 5-wire	Models with **Q85VR3** prefix	Wiring chamber Models with -T9 suffix feature 8 selectable output timing modes
ULTRA-BEAM™ 	105 to 130V ac	SPDT E/M relay, 5 amps max., 5-wire	**SUA925QD**	Ultrasonic proximity - switched output; electromechanical output relay
		Solid-state analog voltage source or current sink, 4-wire	**SUA923QD**	Ultrasonic proximity - analog output
Sonic OMNI-BEAM™ 	105 to 130V ac	SPDT E/M relay, 5 amps max., 5-wire	Power block: **OPBA5QD**	Ultrasonic proximity - switched output Used with OSBU sensor heads Electromechanical output relay
		Isolated analog, 4-wire or 5-wire (two outputs)	**OPBA3**	0 to +10V dc analog output
MAXI-AMP™ 	105 to 130V ac	SPDT E/M relay, 5 amps max., 5-wire	**CD3RA, CD5RA**	Used with SP12 Series preamplified modulated remote sensors; electromechanical output relay
			CM3RA, CM5RA	Used with modulated remote sensors; electromechanical output relay
			CR3RA, CR5RA	Used with SP100 series miniature modulated remote sensors; electromechanical output relay
		SPST solid-state relay 30V dc, 50 mA maximum or 250V ac, 750 mA maximum	**CD3A, CD5A**	Used with SP12 Series preamplified modulated remote sensors; solid-state outputs for ac or dc
			CM3A, CM5A	Used with modulated remote sensors; solid-state outputs for ac or dc
			CR3A, CR5A	Used with SP100 series miniature modulated remote sensors; solid-state outputs for ac or dc
MICRO-AMP® 	105 to 130V ac	SPDT E/M relay, 5 amps max., 5-wire	**MPS-15**	Wiring chassis for MICRO-AMP amplifier modules and remote modulated sensors; electromechanical output relay

Table B-17. Sensors Powered by 220/240V ac

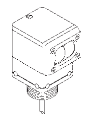
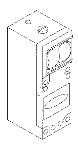
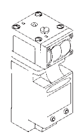
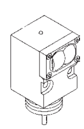
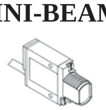
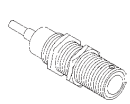
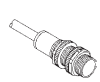
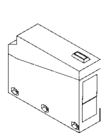
Product Family	Voltage Rating (50/60Hz)	Wiring Configuration (e/m = electromechanical relay)	Model Numbers	Notes
OMNI-BEAM™ 	210 to 250V ac	SPST solid-state relay, 1/2 amp max., 4-wire	Power block: **OPBB2**	Separate diagnostic alarm output (5th wire) **D.A.T.A.** light system
	24 to 250V ac	SPDT E/M relay, 5 amp max., 5-wire	Power block: **OPEJ5**	Used with OEM OMNI-BEAM sensor heads Electromechanical output relay
		4- or 5-wire analog	Power block: **OPBB3**	Analog output 0-10Vdc, direct or inverse
MULTI-BEAM® 	210 to 250V ac	SPST solid-state relay, 3/4 amp max., 3- or 4-wire	Power block: **PBB**	Used with 3- & 4-wire scanner blocks and logic modules
	210 to 250V ac	SPST solid-state relay, 3/4 amp max., 2-wire	Power block: **2PBB**	Used with 2-wire scanner blocks and logic modules
	210 to 250V ac	SPST solid-state relay, 0.1 amp max., 3- or 4-wire	Power block: **PBBT**	Used with 3- & 4-wire scanner blocks and logic modules; switches ac or dc loads
	210 to 250V ac	SPST optically isolated solid-state relay, 0.05 amp max., 4-wire	Power block: **PBBO**	Used with 3- & 4-wire scanner blocks and logic modules; switches low-voltage dc circuitry (sink or source)
MAXI-BEAM® 	210 to 250V ac	SPST solid-state relay, 3/4 amp max., 3- or 4-wire	Power block: **RPBB**	Used with any MAXI-BEAM sensor head; <0.1 mA. off-state leakage current
	210 to 250V ac	SPST solid-state relay, 3/4 amp max., 2-wire	Power block: **R2PBB**	Used with any MAXI-BEAM sensor head; <1.7 mA. off-state leakage current
	12 to 250V ac	Electromechanical relay, 5 amps max., 4-wire	Power block: **RPBR** (SPST) **RPBR2** (SPDT)	Used with any MAXI-BEAM sensor head; electromechanical output relay
		Optically-isolated solid-state relay, 100 ma max., 4-wire	Power block: **RPBU** (SPST)	Solid-state output relay
VALU-BEAM® 	24 to 250V ac	SPST solid-state relay, 1/2 amp max., 2-wire	**SM2A912** or **SM2A91** prefix	<1.7 mA. off-state leakage current
	210 to 250V ac	SPDT E/M relay, 5 amps max., 5-wire	**SMB915** or **SMB95** prefix	Electromechanical output relay
	10 to 250V ac	2-wire	**SMA990** or **SMA99** prefix	Built-in 6-digit LCD totalizing counter (no output)
MINI-BEAM® 	24 to 240V ac	SPST solid-state relay, 0.3 amps max., 2-wire	**SM2A312** or **SM2A31** prefix	<1.7 mA. off-state leakage current
SM30 Series 	24 to 240V ac	2-wire	**SM2A30** prefix	<1.7 mA. off-state leakage current
S18 Series 	20 to 250V ac	3-wire	**S183, S18A, and S18R** prefixes	<50 microamps off-state leakage current
Q85 Series 	24 to 240V ac	SPDT E/M relay, 0.3 amps max., 5-wire	Models with **Q85VR3** prefix	Wiring chamber Models with -T9 suffix feature 8 selectable output timing functions

Table B-17. Sensors Powered by 220/240V ac (continued)

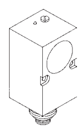
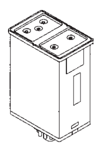
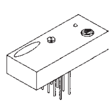
Product Family	Voltage Rating (50/60Hz)	Wiring Configuration (e/m = electromechanical relay)	Model Numbers	Notes
ULTRABEAM™ 	210 to 260V ac	SPDT E/M relay, 5 amps max., 5-wire	**SUB925QD**	Ultrasonic proximity - switched output; electromechanical output relay
		Solid-state analog voltage source or current sink, 4-wire	**SUB923QD**	Ultrasonic proximity - analog output
MAXI-AMP™ 	210 to 250V ac	SPDT E/M relay, 5 amps max., 5-wire	**CD3RB, CD5RB**	Used with SP12 Series preamplified modulated remote sensors; electromechanical output relay
			CM3RB, CM5RB	Used with modulated remote sensors; electromechanical output relay
			CR3RB, CR5RB	Used with SP100 series miniature modulated remote sensors; electromechanical output relay
		SPST solid-state relay 30V dc, 50 mA maximum or 250V ac, 750 mA maximum	**CD3A, CD5A**	Used with SP12 Series preamplified modulated remote sensors; solid-state outputs for ac or dc
			CM3A, CM5A	Used with modulated remote sensors; solid-state outputs for ac or dc
			CR3A, CR5A	Used with SP100 series miniature modulated remote sensors; solid-state outputs for ac or dc
MICRO-AMP® 	210 to 250V ac	SPDT E/M relay, 5 amps max., 5-wire	**MPS-15-230**	Wiring chassis for MICRO-AMP amplifier modules and remote modulated sensors; electromechanical output relay

Table B-18. Sensors Powered by Low Voltage dc

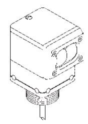
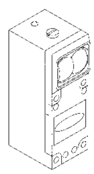
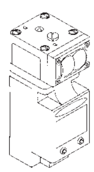
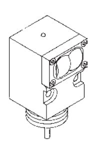
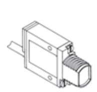
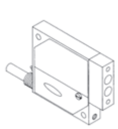
Product Family	Voltage Range	Wiring Configuration	Model Numbers	Notes
OMNI-BEAM™ 	10 to 30V dc @ <80mA	SPST solid-state relay, .1 amp max., 3-wire	Power block: **OPBT2**	Separate diagnostic alarm output (4th wire) Bi-Modal™ (sinking or sourcing) output
	24 to 36V dc @ < 50mA	SPDT E/M relay, 5 amp max., 5-wire	Power block: **OPEJ5**	Used with OEM OMNI-BEAM sensor heads; electromechanical output relay
	15 to 30V dc	4- or 5-wire analog	Power block: **OPBT3**	Analog output 0-10V dc, direct or inverse
MULTI-BEAM® 	10 to 30V dc @ <75mA	SPST solid-state relay, .25 amp max., 3-wire	Power blocks: **PBT** (sinking) **PBP** (sourcing)	Used with 3- & 4-wire scanner blocks and logic modules
	10 to 30V dc @ < 75mA	SPDT solid-state relay, .25 amp max., 3-wire	Power block: **PBT2**	Used with 3- & 4-wire scanner blocks and logic modules; complementary sinking outputs
	44 to 50V dc @ <75mA	SPST solid-state relay, .25 amp max., 3-wire	Power blocks: **PBT48** (sinking) **PBP48** (sourcing)	Used with 3- & 4-wire scanner blocks and logic modules
MAXI-BEAM® 	10 to 30V dc @ <20mA	DPST solid-state relay, .25 amp max., 3-wire	Power block: **RPBT**	Bi-polar (sourcing *and* sinking) outputs
	12 to 30V dc @ <40mA	Electromechanical relay, 5 amps max., 4-wire	Power blocks: **RPBR** (SPST) **RPBR2** (SPDT)	Used with any MAXI-BEAM sensor head; electromechanical relay output
		Optically-isolated solid-state relay, 100 ma max., 4-wire	Power block: **RPBU** (SPST)	Solid-state output relay
VALU-BEAM® 	10 to 30V dc @ <20mA	DPST solid-state relay, .25 amp max., 3-wire	**SM912** or **SM91** prefix	Bi-polar (sourcing *and* sinking) outputs
	12 to 28V dc @ <50mA	SPDT E/M relay, 5 amps max., 5-wire	**SMW915** or **SMW95** prefix	Electromechanical output relay
	12 to 115V dc @ <20mA	2-wire	**SMA990** or **SMA99** prefix	Built-in 6-digit LCD totalizing counter (no output)
MINI-BEAM® 	10 to 30V dc @ <25mA	DPST solid-state relay, 0.15 amps max., 3-wire	**SM312** or **SM31** prefix	Bi-polar (sourcing *and* sinking) outputs
ECONO-BEAM™ 	10 to 30V dc @ <20mA	DPST solid-state relay, 0.15 amps max., 3-wire	**SE612** or **SE61** prefix	Bi-polar (sourcing *and* sinking) outputs
SM512 Series 	10 to 30V dc @ <40mA	SPDT solid-state relay, .25 amp max., 3-wire	**SM512** or **SM51** prefix	Complementary sinking outputs

Table B-18. Sensors Powered by Low Voltage dc (continued)

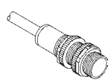
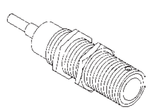
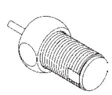
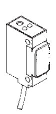
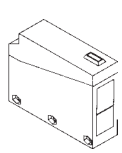
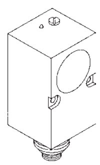
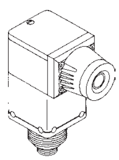
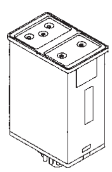
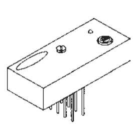
Product Family	Voltage Range	Wiring Configuration (e/m = electromechanical relay)	Model Numbers	Notes
THIN-PAK QØ8 Series 	10 to 30V dc @ < 25mA	SPST solid-state relay, .15 amp max., 3-wire	**QØ8** prefix	Four output versions, with choice of: Sourcing or sinking and Light- or dark-operate
S18 Series (an EZ-BEAM sensor) 	10 to 30V dc @ < 25mA	SPDT solid-state relay, .15 amp max., 3- or 4-wire (see notes)	**S18SN6** prefix	Complementary NPN sinking outputs: one normally open, one normally closed. Normally closed output may be wired as low-gain alarm output.
			S18SP6 prefix	Complementary PNP sourcing outputs: one normally open, one normally closed. Normally closed output may be wired as low-gain alarm output.
SM30 Series 	10 to 30V dc @ < 30mA (per pair)	SPST solid-state relay, .25 amp max., 4-wire	**SM30** prefix	Bi-Modal™ (sinking or sourcing) output
C3Ø Series 	10 to 30V dc @ < 30mA	SPST solid-state relay, .15 amp max., 3-wire	**C3Ø** prefix	Four output versions, with choice of: Sourcing or sinking and Light- or dark-operate
Q19 Series 	10 to 30V dc @ < 25mA	SPDT solid-state relay, .15 amp max., 3- or 4-wire (see notes)	**Q19SN6** prefix	Complementary NPN sinking outputs: one normally open, one normally closed. Normally closed output may be wired as low-gain alarm output.
			Q19SP6 prefix	Complementary PNP sourcing outputs: one normally open, one normally closed. Normally closed output may be wired as low-gain alarm output.
Q85 Series 	12 to 240V dc (2 watts max.)	SPDT E/M relay, 3 amp max., 30V dc max., 5-wire	**Q85VR3** prefix	Wiring chamber Models with -T9 suffix feature 8 selectable output timing functions

Table B-18. Sensors Powered by Low Voltage dc (continued)

Product Family	Voltage Range	Wiring Configuration (e/m = electromechanical relay)	Model Numbers	Notes
ULTRABEAM™ 	18 to 30V dc @ < 300mA	Solid-state analog voltage source or current sink, 4-wire	**SU923QD**	Ultrasonic proximity - analog output
Sonic OMNI-BEAM™ 	15 to 30V dc 3VA	Solid-state analog voltage source, 4-wire or 5-wire (two outputs)	**OSBUSR sensor head with OPBT3 power block**	Ultrasonic proximity - dual analog outputs
	15 to 30V dc @ <80 mA	SPDT solid-state relay, .1 amp maximum, 3- or 4-wire	**OSBUSR sensor head with OPBT2U power block**	Bi-Modal™ complementary sinking or sourcing outputs
MAXI-AMP™ 	12 to 28V dc @ < 70mA	SPDT E/M relay, 5 amps max., 5-wire	**CD3RA, CD5RA**	Used with SP12 Series preamplified modulated remote sensors; electromechanical output relay
			CM3RA, CM5RA	Used with modulated remote sensors; electromechanical output relay
			CR3RA, CR5RA	Used with SP100 Series miniature modulated remote sensors; electromechanical output relay
		SPST solid-state relay 30V dc, 50 mA maximum or 250V ac, 750 mA maximum	**CD3A, CD5A**	Used with SP12 Series preamplified modulated remote sensors; solid-state outputs for ac or dc
			CM3A, CM5A	Used with modulated remote sensors; solid-state outputs for ac or dc
			CR3A, CR5A	Used with SP100 series miniature modulated remote sensors; solid-state outputs for ac or dc
MICRO-AMP® 	10 to 30V dc @ < 20mA	SPDT solid-state relay, .15 amps max., 3-wire	**MA3-4** - sink **MA3-4P** - source	Used with remote modulated sensors; complementary outputs
	10 to 30V dc @ < 20mA	SPDT solid-state relay, .15 amps max., 3-wire	**MA3** - sink **MA3P** - source	Used with SP100 Series miniature modulated remote sensors; complementary outputs
	5V dc @ < 20mA	Buffered CMOS outputs for 5V dc interface	**MPC3**	Used with SP100 Series miniature modulated remote sensors; complementary outputs

2. Sensor interface

There are a few general questions that must be answered during the sensor selection process that concern interfacing of the sensor to its load. The *load* may be an electro-mechanical device (e.g. a solenoid, clutch, brake, contactor, etc.), or it may be an input to a circuit (e.g. a counter, programmable logic controller, electronic speed control, Banner logic module, etc.).

First, it must be determined whether the interface is analog or digital (switched). Examples of devices that require an analog signal from a sensor include: meters, data recorders, speed controls, and analog inputs to programmable logic controllers.

Switched outputs are typical of most sensing situations, including: presence/absence, go/no-go, limit control, and counting applications. There are two basic types of contacts for switched sensor outputs: *electro-mechanical (hard)* and *solid-state* contacts. Both types of contacts have their advantages and disadvantages (see Table C-1).

Solid-state contacts are designed to switch ac voltage or dc voltage, but usually not both. However, a few solid-state contact designs will switch either ac *or* dc loads. Some self-contained sensors with solid-state output are designed for two-wire operation (see Section C). Two-wire design is necessary for some applications, including those where existing mechanical limit switches are to be directly replaced with a sensor. Also, two-wire ac sensors help minimize mis-connection of the sensor into a circuit, since they are usually not polarity-sensitive and connect without regard to wire color or connector pin number. However, two-wire sensors carry with them a few application warnings that are outlined in Section C.

The following tables indicate which sensor families offer analog outputs and which offer switched outputs. In addition, Tables C-2 through C-5 in the "Interfacing" section list specific model numbers of power blocks, sensors, and amplifiers, plus detailed comparative specifications for the output contacts.

Table B-19. Sensors with Analog Output

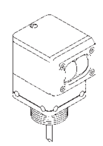
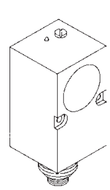
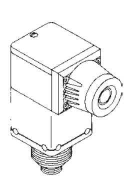
Sensor Family	Sensor Type	Operating Voltage	Output: Voltage Source	Output: Current Sink	Comments
Analog OMNI-BEAM™ 	Modular, self contained: sensor head and power block	210 to 250V ac or 105 to 130V ac or 15 to 30V dc (depending on power block)	0 to +10V dc and +10 to 0V dc	No	Offers all photoelectric sensing modes (except retro) by selection of sensor head. NOTE: opposed sensing is accomplished using glass fiber optics. Dual sourcing outputs (useable simultaneously). Non-interactive NULL and SPAN controls.
ULTRABEAM™ 	One-piece, self-contained	210 to 260V ac or 105 to 130V ac or 18 to 30V dc (depending on model used)	0 to +10V dc	0 to 20mA	Ultrasonic proximity sensing mode. Both voltage source or current sink outputs in same unit. Programmable for positive or negative slope.
Sonic OMNI-BEAM™ 	Modular, self contained: scanner block & power block	210 to 250V ac or 105 to 130V ac or 15 to 30V dc (depending on power block)	0 to +10V dc or +10 to 0V dc	No	Ultrasonic proximity sensing mode. Dual sourcing outputs.

Table B-20. Sensors with Electromechanical Output Relay*

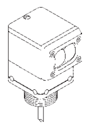
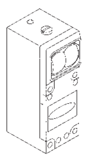
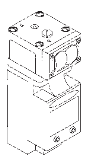
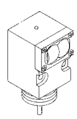
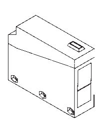
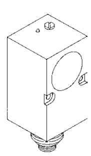
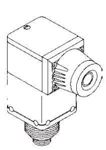
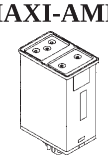
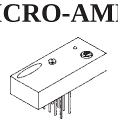
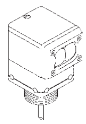
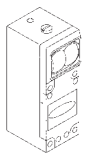
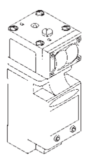
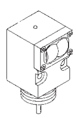
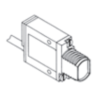
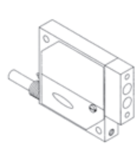
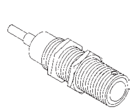
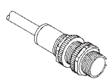
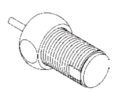
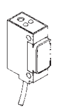
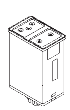
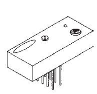
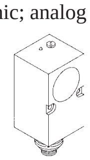
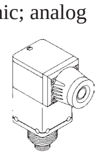
Product Family	Sensor Type	Sensor Operating Voltage	Contact Configuration	Comments *See Table C-2 for relay specifications.
OMNI-BEAM™ 	Modular, self-contained: sensor head and power block	24 to 250V ac or 24 to 36V dc	SPDT	All photoelectric sensing modes. Designed for OEM use. Sensor head accepts optional timing logic modules
MULTI-BEAM® 	Modular, self-contained: scanner block, power block, and logic module	105 to 130V ac	SPST or SPDT (depending on power block)	Power blocks with electromechanical relay work with 2-wire scanner blocks and logic modules. Power block models are 2PBR and 2PBR2. Timing logic may be added.
MAXI-BEAM® 	Modular, self-contained: sensor head and power block	12 to 30V dc or 12 to 250V ac	SPST or SPDT (depending on power block)	Power blocks with electromechanical relay work with all MAXI-BEAM sensor heads. Power block models are RPBR and RPBR2. Timing logic may be added.
VALU-BEAM® 	One piece, self-contained	12 to 28V ac or dc, 90 to 130V ac, or 210 to 250V ac (depending on sensor model)	SPDT	Models for all photoelectric sensing modes.
Q85 Series 	One piece, self-contained	24 to 240V ac or 12 to 240V dc	SPDT	Opposed, short and long range diffuse, and polarized retroreflective modes. Wiring chamber. Optional selectable output timing logic.
ULTRA-BEAM™ 	One piece, self-contained	105 to 130V ac or 210 to 260V ac (depending on sensor model)	SPDT	Ultrasonic proximity sensor. Long range (2 to 20 feet)
Sonic OMNI-BEAM™ 	One piece, self-contained	105 to 130V ac	SPDT	Ultrasonic proximity sensing with adjustable ranging. Programmable for high/low limit logic.
MAXI-AMP™ 	Component system	12 to 28V dc (all models) plus 105 to 130V ac or 210 to 250V ac (depending on amplifier model)	SPDT	Amplifier modules (e.g. CM3RA) contain power supply and output relay. No wiring chassis is required.
MICRO-AMP® 	Component system	105 to 130V ac or 210 to 260V ac (depending on chassis model)	SPDT	Relay is on MPS-15 or MPS-15-230 wiring chassis. Amplifier modules (e.g. MA3-4) stand alone as dc powered units with solid-state output relay.

Table B-21. Sensors with Solid-state Output Relay*

Sensor Family	Sensor Type	Sensor Operating Voltage	Contact Configuration for ac Loads (ac models)	Contact Configuration for dc Loads (dc models)	Comments
OMNI-BEAM™ 	Modular, self-contained: sensor head and power block	210 to 250V ac, 105 to 130V ac, or 10 to 30V dc (depending on power block)	SPST Loads up to 1/2 amp 3-wire	Bi-Modal™ SPST, sourcing or sinking Loads up to 0.1 amp; 3-wire	Separate output for alarm function of **D.A.T.A.** system. Sensor head accepts optional timing logic module. Sensor heads for all photoelectric sensing modes.
MULTI-BEAM® 	Modular, self-contained: scanner block, power block, and logic module	210 to 250V ac, 105 to 130V ac, 22 to 28V ac, 11 to 13V ac, 44 to 52V dc,or 10 to 30V dc (depending on power block)	SPST Loads up to 3/4 amp 2, 3, or 4-wire	SPST or SPDT sourcing or sinking (depending on power block) Loads up to .25 amp; 3-wire	Power block models also available for ac input with dc output. Timing logic may be added. Scanner blocks for all photoelectric sensing modes.
MAXI-BEAM® 	Modular, self-contained: sensor head and power block	210 to 250V ac, 105 to 130V ac, or 10 to 30V dc (depending on power block)	SPST Loads up to 3/4 amp 2, 3, or 4-wire	Bi-polar DPST, sourcing and sinking Loads up to .25 amp; 3-wire	Timing logic module may be added. Sensor heads for all photoelectric sensing modes.
VALU-BEAM® 	One piece, self-contained	24 to 250V ac or 10 to 30V dc (depending on sensor model)	SPST Loads up to 1/2 amp 2-wire	Bi-polar DPST, sourcing and sinking Loads up to .25 amp; 3-wire	Models for all photoelectric sensing modes.
MINI-BEAM® 	One piece, self-contained	24 to 240V ac or 10 to 30V dc (depending on sensor model)	SPST Loads up to 0.3 amp 2-wire	Bi-polar DPST, sourcing and sinking Loads up to 0.15 amp; 3-wire	Miniature self-contained. Models for all photoelectric sensing modes
ECONO-BEAM™ 	One piece, self-contained	10 to 30V dc	N/A	Bi-polar DPST, sourcing and sinking Loads up to 0.15 amp; 3-wire	Designed for OEM applications. Models for all photoelectric sensing modes.
SM512 Series 	One piece, self-contained	10 to 30V dc	N/A	SPDT (complementary sinking) Loads up to .25 amp; 3-wire	Thin (1/2 inch wide) metal housing. All photoelectric sensing modes available.
SM3Ø Series 	One piece, self-contained	10 to 30V dc and 24 to 240V ac	SPST Loads up to 1/2 amp 2-wire	Bi-Modal™ SPST, sourcing or sinking Loads up to .25 amp; 4-wire	30mm threaded VALOX® or metal barrel Opposed mode only NEMA 6P; designed for demanding environments

***See Tables C-4, C-4, and C-5 for relay specifications.**

Table B-21. Sensors with Solid-state Output Relay (continued)*

Product Family	Sensor Type	Sensor Operating Voltage	Contact Configuration for ac Loads (ac models)	Contact Configuration for dc Loads (dc models)	Comments
THIN-PAK QØ8 Series 	One piece, self-contained	10 to 30V dc	N/A	SPST Loads up to 0.15 amp; 3-wire	8-mm deep metal housing Opposed and diffuse modes only Choice of sourcing or sinking, light- or dark-operate
S18 Series (an EZ-BEAM sensor) 	One piece, self-contained	20 to 250V ac or 10 to 30V (depending upon model)	SPST Loads up to .3 amp 3-wire	SPDT Loads up to 0.15 amp; 3- or 4-wire	18 mm threaded barrel DC models: Choose NPN sinking or PNP sourcing complementary outputs Normally closed output may be wired as low-gain alarm output
C3Ø Series 	One piece, self-contained	10 to 30V dc	N/A	SPST Loads up to 0.15 amp; 3-wire	30 mm threaded LEXAN® barrel Choice of sourcing or sinking, light- or dark-operate
Q19 Series 	One piece, self-contained	10 to 30V dc	N/A	SPDT Loads up to 0.15 amp 3- or 4-wire	Miniature self-contained DC models: Choose NPN sinking or PNP sourcing complementary outputs Normally-closed output may be wired as low-gain alarm output
MAXI-AMP™ 	Component system	12 to 28V dc (all models) plus 105 to 130V ac or 210 to 250V ac (depending on amplifier model)	SPST Loads up to 3/4 amp 3- or 4-wire	SPST Loads up to 50 mA 3- or 4-wire	Models CD3A, CD3B, CD5A, CD5B, CM3A, CM3B, CM5A, and CM5B with solid-state output
MICRO-AMP® 	Component system	10 to 30V dc	N/A	Bi-polar DPST, sourcing and sinking Loads up to .25 amp; 3-wire	Sinking outputs: models MA3 and MA3-4. Sourcing outputs: models MA3P and MA3-4P.
ULTRA-BEAM™ 923 Series (ultrasonic; analog output) 	Ultrasonic, one piece, self-contained	18 to 30V dc, 105 to 130V ac, or 210 to 260V ac	None	Two analog outputs: 0 to +10V dc sourcing (minimum 500 ohm load) 0 to 20mA dc sinking (4V dc maximum voltage drop)	Ultrasonic proximity sensor Sinking and sourcing analog outputs Output selectable for positive or negative slope
Sonic OMNI-BEAM™ (ultrasonic; analog output) 	Ultrasonic: modular, self-contained: sensor head (model OSBUSR) and analog power block	10 to 30V dc, 105 to 130V ac, or 210 to 250V ac (depending on power block)	None	Two analog sourcing outputs: 0 to +10V dc (10mA) +10 to 0V dc (10mA)	Ultrasonic proximity sensor Two sourcing analog outputs Requires analog power block

***See Tables C-3, C-4, and C-5 for relay specifications.**

3. Sensor Switching Speed

Whenever small parts are sensed and/or when sensing events occur at high speed, the response times of the load and of the sensor require close examination. The sensor must have a response time that is fast enough to react to the sensing event. The load has its own response time specification. The response of the load must be fast enough to follow the output of the sensor.

Electromechanical loads (solenoids, contactors, etc.) generally have slower response as compared to solid-state loads (programmable logic controllers, counters, etc.). Also, ac loads generally have slower response than dc loads. Even the ac inputs of solid-state circuits, like PLCs, are slower to respond than dc inputs because ac loads require up to one-half cycle of ac current before they turn "off". At 60Hz, this delay is up to 8.3 milliseconds. As a result, a dc interface is usually preferred in applications such as high-speed counting, where the repetition rate ("rep rate") of the sensor output is very fast.

There are sensing applications where the rep rate is slow, but where each sensing event occurs very quickly. An example is a die protection application, where a part must be sensed as it exits a press at high speed, but where there is a relatively long time between ejected parts. If, in applications like these, the duration of the sensor's output signal is too short for the load to react, a *one-shot* timer may be added in the sensor or between the sensor and the load to stretch the duration of the sensor's output.

The discussion of required sensor response time at the end of Section A explains how a response time requirement is determined. It also suggests a few ways to ease the response time requirement for a sensor and its load. There are, however, many high-speed counting and inspection applications that demand very fast sensor response.

Ultrasonic proximity sensors cannot be used for high speed response requirements. Ultrasonic proximity mode sensors require time to "listen" for the echo of their emitted signal. This amount of time can range from about 25 milliseconds up to about one-half second. Also, sensors with electromechanical output relays cannot be used for high speed switching. Electromechanical relays require several milliseconds to energize and (especially) to de-energize, in addition to the actual sensor response time. Finally, ac loads are usually not involved in very high speed sensing applications, due to their slower response (see above). Sensors used for very high speed requirements are typically those with solid-state interfaces to dc loads.

The speed of response of a modulated photoelectric sensor is limited by its frequency of modulation. Modulation frequencies range from about 2kHz to about 30kHz, depending on the sensor design. There is a direct trade-off of fast sensor response time for sensing range (excess gain). If an LED is pulsed less often, it can be pulsed with a higher current, thereby producing more light energy.

A modulated receiver is designed to recognize several pulses of light before it responds to its emitter. Demodulation schemes can account for receiver reponse times of several hundred microseconds, even at modulation frequencies of 30kHz. When required response times are faster than about 300 microseconds (0.3 milliseconds), we need to consider non-modulated schemes. With a high sensing contrast ratio, non-modulated remote sensors (e.g. model LP510CV) working with modified non-modulated amplifiers (e.g. model B3-4MVHS) are able to respond to sensing events as short as 50 microseconds (0.05 milliseconds).

Non-modulated amplifiers with very fast response times are susceptible to false response from quick ambient light changes (such as from ac room lighting) and from electrical "noise" pulses. The required sensor response time should be eased, whenever possible, to permit the use of a modulated system and to increase the "noise" immunity of the sensing system (see "Required Sensor Response Time" in Section A). Table B-22 lists the fastest of the modulated sensors and component systems.

4. Sensor Diagnostic Feedback

Increasingly sophisticated automation is creating a frequent requirement for sensor self- diagnostics. With computers, microprocessors, and programmable logic controllers integrating all aspects of automated manufacturing and material handling, a sensor that is able to provide an early warning of impending sensing problems can prevent expensive downtime.

The OMNI-BEAM's D.A.T.A. (Display and Trouble Alert) is a sensor self-diagnostics system that monitors all of the following sensing parameters:

Condensation or moisture inside the sensor	Output (load) demand
Operating temperature	Gain setting
Supply voltage	Sensing contrast

Whenever any of these sensing parameters goes beyond its predefined limit, the sensor's dedicated alarm output changes state to signal the system controller or operations personnel that sensing conditions have become marginal. LEDs built into the sensor identify the problem cause (see Figure B.52). The trend is for an increase in requirements for sensor self-diagnostics. The OMNI-BEAM is the first sensor design to provide *complete* sensor self-diagnostics.

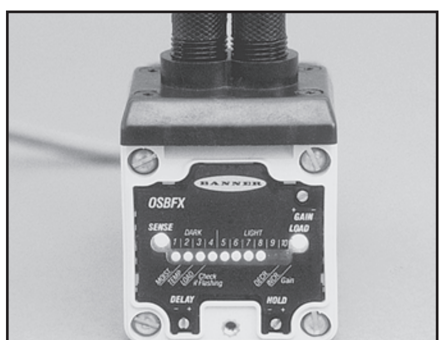
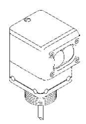
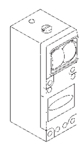
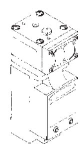
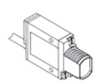
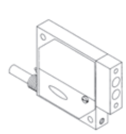


Figure B.52. The OMNI-BEAM's D.A.T.A.™ light system flashes an early warning of an impending sensing problem.

Table B-22. Sensors for High-speed Sensing Requirements

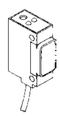
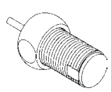
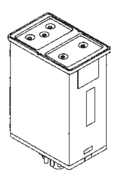
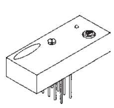
Self-contained Sensor Family	Models	Sensing Mode	"on" & "off" Response (milliseconds)	NOTES
OMNI-BEAM™ 	**OSBE & OSBR**	Opposed	2	Use a dc power block (e.g. model OPBT2)
	OSBD	Diffuse	2	
	OSBF, OSBFV	Glass fiber optic	2	
	OSBFP	Plastic fiber optic	2	
	OSBFAC	AC-coupled, glass fiber optic	1	
MULTI-BEAM® 	**SBE & SBR1**	Long-range opposed	1	Use a dc power block (e.g. model PBT) These scanner blocks may be ordered modified for 0.3 millisecond response. Add suffix "MHS" to model number.
	SBED & SBRD1	Short-range opposed	1	
	SBLV, SBLV1, SBLVAG1	Retroreflective	1	
	SBD1, SBDL1	Diffuse	1	
	SBC1, SBCV1, SBCVG1	Convergent	1	
	SBEF & SBRF1	Opposed glass fiber optic	1	
	SBF1, SBFV1, SBFVG1	Glass fiber optic	1	
MAXI-BEAM® 	**RSBE & RSBR**	Opposed	0.3	Use dc power block (e.g. model RPBT) Sensor heads may be programmed for slower response times (except models RSBFV and RSBFP)
	RSBLV, RSBLVAG	Retroreflective	1	
	RSBD, RSBDSR	Diffuse	0.3	
	RSBC, RSBCV	Convergent	1	
	RSBF	Glass fiber optic	0.3	
	RSBFV	Glass fiber optic	1	
	RSBFP	Plastic fiber optic	1	
MINI-BEAM® 	**SM31E & SM31R**	Short-range opposed	1	All models may be ordered modified for 0.3 millisecond response. Add suffix "MHS" to model number.
	SM31EL & SM31RL	Long-range opposed	1	
	SM312LV, SM312LVAG	Retroreflective	1	
	SM312D, SM312DBZ	Diffuse	1	
	SM312W	Divergent	1	
	SM312CV, SM312CV2	Convergent	1	
	SM312CVG	Convergent	1	
	SM312C, SM312C2	Convergent	1	
	SM312F, SM312FV	Glass fiber optic	1	
	SM312FP	Plastic fiber optic	1	
SM512 Series 	**SM51EB & SM51RB**	Opposed	1	SM53E & R are used with an ac-coupled amplifier. The amplifier determines the sensor "on" response time: B4-6 for 1 millisecond response, B4-1500A for 0.2ms response. Output pulse time determines the "off" response time.
	SM53E & SM53R	Opposed	(see note)	
	SM512LB, SM502A	Retroreflective	1	
	SM512DB	Diffuse	1	
	SM512C1, SM512CV1	Convergent	1	
	SM512DBCV	Precise-focus convergent	1	
	SM512LBFO	Glass fiber optic	1	
THIN-PAK QØ8 	**SO6Ø-QØ8 and EO6Ø-QØ8-AN6X (or -RN6X, -AP6X, or -RP6X)**	Opposed	1	-AN models: NPN, light operate -RN models: NPN, dark operate -AP models: PNP, light operate -RP models: PNP, dark operate
	NO5-QØ8-AN7 (or -RN7, -AP7, or -RP7)	Diffuse	1	

The dual-LED indicator system on S18 and Q19 Series sensors, while not as comprehensive as the D.A.T.A. system just described, provides extremely useful indications of sensing conditions beyond what is available on most other sensors. Two LED indicators (yellow and green), indicate as follows:

GREEN glowing steadily = power to the sensor is "on"
GREEN flashing (dc models only) = sensor output is overloaded
YELLOW glowing steadily (dc models) = normally open sensor output is "on"
YELLOW glowing steadily (ac models) = the sensor is seeing its own modulated light source
YELLOW flashing = marginal excess gain (less than 1.5x) in the light condition; flashing YELLOW coincides with the "on" state of the alarm output (dc models only).

These sensors are ideal for use in demanding environments. Q19 sensors are rated NEMA 6; S18s are rated NEMA 6P.

Table B-22. Sensors for High-speed Sensing Requirements (continued)

Component Systems	Models	Sensing Mode	"on" & "off" Response (milliseconds)	NOTES
Q19 Series 	**Q19SN6LP, Q19SP6LP**	Polarized retroreflective	1	-SN6 models: NPN (sinking)
	Q19SN6D, Q19SP6D	Diffuse	1	-SP6 models: PNP (sourcing)
	Q19SN6DL, Q19SP6DL	Diffuse	1	
	Q196E and Q19SN6R or Q19SP6R	Opposed	1	
C3Ø Series 	**C3ØAN7L, C3ØRN7L, C3ØAP7L and C3ØRP7L**	Retroreflective	1	-AN models: NPN, light operate -RN models: NPN, dark operate
	C3ØAN7D, C3ØRN7D, C3ØAP7D, and C3ØRP7D	Diffuse	1	-AP models: PNP, light operate -RP models: PNP, dark operate
MAXI-AMP™ 	**CM3A**	(Remote sensors for all sensing modes)	0.3	Amplifiers also programmable for 2 or 10 millisecond response.
	CM3B		0.3	
	CM5A		(see note)	Response of CM5A and CM5B is determined by the programmed timing function.
	CM5B		(see note)	
MICRO-AMP® 	**MA3, MA3P**	(SP100 Series remote sensors)	1	MPC3 response time is adjustable from about 0.5 to 10 milliseconds
	MA3-4, MA3-4P		1	
	MPC3		(see note)	
	MA3A	SP100FF	2	
	MPC3A	SP100FF	1.5	

Sensor Selection Category D - Environmental Considerations

1) Temperature

The operating temperature range of any self-contained sensor or of any remote amplifier or logic module is determined by the temperature range of its electronic circuit components. The narrowest temperature range for any type of sensor is 0 to +50°C (+32 to +122°F). This temperature range is typical of remote amplifiers, remote logic modules, ultrasonic sensors, and a few self-contained photoelectric sensors (see Table B-23).

Remote photoelectric sensors have higher operating temperature maximums because they contain only optoelements, which are usually rated for -40 to +100°C (-40 to +212°F). However, the practical operating temperature maximum for a remote photoelectric sensor is often limited by the type of insulation used on the connecting cable.

Glass fiberoptic assemblies must be used to "pipe" photoelectric sensing energy into and out of sensing areas where ambient temperatures are below -40°C (F) or above 100°C (212°F). Fiber optic assemblies that are used beyond these temperatures must be constructed using metal sheathing (vs. plastic sheathing - see Table B-23). Glass fiber optic assemblies that use standard flexible stainless steel armored sheath are rated for use in -140 to +249°C (-220 to +480°F) environments.

The high temperature limit of this type of fiber optic assembly is determined by the epoxy used to terminate the glass bundle in the end tips. An optically-clear epoxy is wicked into the first 1/2 inch of the bundle at each termination. This keeps the bundle rigid to allow optical polishing of the fiber ends. (The quality of the optical polishing of the bundle ends is the most important factor in determining the efficiency of a glass fiber optic assembly.)

Fiber optic assemblies that use stainless steel sheathing may be used up to 600°F if a special epoxy is used to terminate the sensing end. This option is available by designating "M600" as a model number suffix. The special epoxy adds significant time to the fiber optic manufacturing process, and as a result, its use increases the cost of a fiber optic assembly.

Fiber optic assemblies that have straight metal sensing ends (e.g. those with threads or ferrules) may be built without epoxy in the sensing end. In these specially-made fiber optic assemblies, the bundle is kept rigid during and after polishing by using a shrink-fit ring at the sensing end. This metal ring is heated while the bundle is carefully inserted. The ring shrinks as it cools, and compresses the bundle. The bundle, with the ring attached, is then press-fit into a ferrule or a threaded stainless steel end tip. Finally, the end tip is carefully polished. This type of fiber optic assembly is rated at 900°F and is ordered by adding the suffix "M900" to a model number. The Banner product catalog indicates those models which may be modified for 900°F operation.

Plastic fiber optics are *not* a choice for temperature extremes. Temperatures below -30°C (-20°F) cause embrittlement of the plastic materials, but will not cause transmission loss. Temperatures above +70°C (+158°F) will cause both transmission loss and fiber shrinkage.

Table B-23. Operating Temperature Range of Sensors and Modules

Self-contained Sensors	Operating Temperature Range
OMNI-BEAM	-40 to +70°C (-40 to +158°F)
MULTI-BEAM	-40 to +70°C (-40 to +158°F)
(except LS10E & LS10R)	0 to +50°C (+32 to +122°F)
MAXI-BEAM	-40 to +70°C (-40 to +158°F)
VALU-BEAM (912 Series)	-20 to +70°C (-4 to +158°F)
(915 and 990 Series)	0 to +50°C (+32 to +122°F)
MINI-BEAM	-20 to +70°C (-4 to +158°F)
ECONO-BEAM	0 to +50°C (+32 to +122°F)
S18 Series	-40 to +70°C (-40 to +158°F)
SM500 Series	-40 to +70°C (-40 to +158°F)
SM30 Series	-40 to +70°C (-40 to +158°F)
THIN-PAK QØ8 Series	0 to +50°C (+32 to +122°F)
Q19 Series	-20 to +55°C (-5 to +131°F)
C30 Series	0 to +50°C (+32 to +122°F)
Q85 Series	-25 to +55°C (-13 to +131°F)
BEAM-ARRAY Systems	-20 to +50°C (-4 to +122°F)
Sonic OMNI-BEAM	0 to +50°C (+32 to +122°F)
ULTRA-BEAM	0 to +50°C (+32 to +122°F)
OPTO-TOUCH	-20 to +50°C (-4 to +122°F)
Remote Sensors	**Operating Temperature Range**
SP12 Series	-40 to +70°C (-40 to +158°F)
SP100 Series	0 to +70°C (+32 to +158°F)
SP300 Series	-40 to +80°C (-40 to +176°F)
(except SP300EL & SP300RL)	-40 to +100°C (-40 to +212°F)
SP1000 Series	-40 to +80°C (-40 to +176°F)
LR/PT Series	-40 to +100°C (-40 to +212°F)
(except LR/PT300)	-40 to +80°C (-40 to +176°F)
LP Series	-40 to +80°C (-40 to +176°F)
Remote Amplifiers & Logic Modules	**Operating Temperature Range**
MAXI-AMP	0 to +50°C (+32 to +122°F)
MICRO-AMP	0 to +70°C (+32 to +158°F)
Plug Logic	0 to +50°C (+32 to +122°F)
Fiber Optic Assemblies	**Operating Temperature Range**
Plastic fiber optic assemblies	-30 to +70°C (-20 to +158°F)
Glass fiber optic assemblies	
(standard w/stainless steel sheath)	-140 to +249°C (-220 to +480°F)
(standard w/PVC sheath)	-40 to +105°C (-40 to +220°F)
("M600" special epoxy)	-140 to +315°C (-220 to +600°F)
("M900" special - no epoxy)	-140 to +480°C (-220 to +900°F)

2) Moisture

Much of the circuitry contained in sensors and sensing systems can be affected by even small amounts of moisture. This is especially true of amplifier and timing circuits. Moisture can cause changes in circuit impedance that may result in symptoms ranging from a slight change in sensing performance to catastrophic failure of the circuit. For this reason, it becomes very important to protect any sensing circuitry that is placed directly in moist environments. This is best accomplished by epoxy encapsulation of sensing components that contain circuitry.

Most Banner sensors are epoxy encapsulated. Exceptions include OMNI-BEAM sensor heads (OMNI-BEAM power blocks are epoxy potted), C3Ø Series, and Q85 Series sensors. Component MICRO-AMP amplifier and logic modules are also epoxy encapsulated. However, all other component amplifier and logic modules are not potted, and are not suitable for mounting outside of an additional enclosure when used in a moist environment. NOTE: Model BENC-4 is a NEMA 4X rated enclosure that is designed to house one or two MAXI-AMP modules or other control device.

Standards Publication #250 of the National Electrical Manufacturers Association (NEMA) establishes guidelines for specifying the degree of sealing offered by any particular electrical enclosure design. These ratings may be applied to the housings of sensors and component modules to predict their relative resistance to infiltration of dirt, dust, moisture, and corrosive agents (see Table 13 in Section F, "Data Reference"). In the case of moisture, NEMA standards make reference to degrees of relative exposure, such as: "falling liquid, light splash, heavy splash, and hosedown".

NEMA 6 designs represent the best seals against moisture, and are able to resist occasional (NEMA 6) or prolonged (NEMA 6P) submersion. NEMA 4 and NEMA 6 designs are able to withstand pressure hosedowns (e.g. those typical in car washes). However, the NEMA tests do not take into account the elevated temperatures (195 to 212°F) of solutions used to wash equipment in food processing applications. The thermal shock to sensors that is produced by a high temperature spray (especially in a refrigerated food process) can challenge many NEMA 4 gasketing designs. Sensor selection for these types of hosedown environments should always include evaluation of sensors with NEMA 6P sealing, which is offered by the SM30, SP12, Q85, and S18 Series and by fiber optics.

Moisture can form inside a sensor or component module from *condensation* of the water vapor that is contained within an air space. Condensation occurs whenever the air is cooled below its dew point or whenever the air becomes saturated with water vapor. Condensation can form within a perfectly-sealed sensor housing. Condensation is most prevalent in photoelectric sensors where an air space exists between the lens and the optoelement(s), or in self-contained sensors that have a wiring chamber.

Sensors that are used for outdoor applications are prone to problems caused by condensation whenever the air is near saturation. A quick rise in air temperature outside of the sensor (e.g during morning hours) can precipitate water vapor inside the sensor. This is also a common problem when sensors are hit with high temperature water spray, as routinely occurs in food processing applications.

One way to minimize condensation in these situations is to violate the seal of the sensor. This might be accomplished by simply drilling a hole from the outside of the sensor into the air space. This will allow faster equalization of outside to inside temperature, minimizing condensation potential. Of course, the hole should be drilled at a location or at an angle that will not invite direct entry of water.

Internal condensation can be eliminated completely by using unlensed fiber optics (with the sensor mounted in a dry location) or by using an epoxy-encapsulated photoelectric sensor with *hermetically sealed* lenses. These include most opposed mode remote sensors, plus opposed mode models within the ECONO-BEAM and SM512 Series of self-contained sensors. There are also diffuse, divergent, and convergent mode sensors that have hermetically sealed optics. However, these sensing modes are usually not recommended for use in areas with the potential for fog, mist, or splash.

Another major problem results from attenuation of sensing energy from moisture on the lens of a photoelectric emitter or receiver or on the transducer of an ultrasonic sensor. Fog on the surface of a lens (from condensation) can severely attenuate light energy. A droplet of liquid on a small lens can send a light beam in the wrong direction. Moisture on the face of an ultrasonic transducer will dampen its movement. Whenever these conditions cannot be avoided, the best chance for reliable operation is with the sensor that offers the highest excess gain. This usually dictates the need for opposed mode photoelectric sensors. When conditions are severe, consider the SMA30SEL and SM30SRL opposed sensor pair for general and long range use. For short range sensing where "burn through" power is needed, consider the opposed pair models SP12SEL and SP12SRL.

3) Corrosive agents

All materials that are commonly used to house sensors and sensing components are vulnerable to one or more types of corrosive agents. Table 15 in the Data Reference section indicates relative degrees of resistance that each housing material has to general categories of potentially corrosive materials. Corrosive materials are grouped into the general categories of: solvents, acids, alkalis (bases), and sunlight/weathering. Sunlight contributes ultraviolet radiation (UV), which weakens some materials. Other damaging effects of weathering include corrosion due to industrial pollutants that are dissolved in rain water and the effects of hot/cold cycling.

Within each group of corrosive agents there may be particular compounds that very rapidly attack a housing material. For example, isopropyl alcohol contacting the surface of a molded acrylic lens releases stresses within the lens, quickly resulting in hundreds of micro-cracks. Some of these specific warnings are noted in Table 15.

Table 15 indicates that glass lenses are far superior to acrylic lenses in terms of chemical resistance, yet most sensor lenses are acrylic. There are several reasons for standardizing on plastic lenses. Molded acrylic lenses are less expensive than glass lenses. (Acrylic lenses can, nevertheless, be highly consistent in their optical geometry.) Also, it is easier to mold complex shapes to facilitate lens mounting or special optical response. In addition, glass lenses are generally *not* allowed in food processing sensing applications. Where the properties of glass are required, the MULTI-BEAM offers an upper cover, model UC-LG, that provides a plane glass window (e.g. a flashlight lens) to protect most models with acrylic lenses from attack by solvents, acids, or stong bases. Also, the acrylic lenses used on many Banner sensors are replaceable.

For particularly corrosive environments, glass fiber optic assemblies offer exceptional resistance to attack. Standard fiber optic assemblies offer the choice between stainless steel armored cable or PVC jacket. The grade of stainless steel that is used for the sheathing (#302) has good to excellent resistance to attack by solvents and alkalis, but the epoxy that is used to terminate the bundles is attacked by many solvents. Use of special M900 fiber assemblies (built without epoxy; see "Temperature", previous page) is recommended for areas where the sensing tip(s) will be in direct contact with any industrial solvent.

Standard fiber optic assemblies with PVC jackets provide excellent resistance to the caustic bases typically used in hose washdown solutions found in food processing applications. Special fiber optic assemblies with Teflon® sheathing are an excellent choice for acid environments; however, it is important to protect the sensing tip from direct contact with concentrated acids. The polyethylene jacket of plastic fiberoptics has excellent resistance to acids but the jacket is thin, and prolonged contact may result in migration of the acid (or any corrosive material) through the jacket to the acrylic fiber. Test samples of plastic fiber optic cable material are available for evaluation from your Banner sales engineer.

The SM30 Series is also designed to stand up to corrosive sensing environments. It is available in either a stainless steel housing or a molded VALOX® housing. Stainless steel is the best choice for all applications except those involving contact with acids. VALOX® offers good to excellent resistance to all acids. The SM30 Series also offers very high excess gain to penetrate mist, dirt or dust, or fogging of its acrylic lens due to chemical attack. The lens of the SM30 Series is factory replaceable.

Acids and bases are rarely encountered at full concentration, and are usually a component of a water-based solution that contacts a sensing device by way of splash or vapor. The concentration of an acid or base is important to consider when estimating the resistance of a sensor housing material to attack. Table B-14 lists the materials used in the construction of each family of self-contained sensor. You can call upon your Banner sales engineer for assistance in researching the resistance of these materials to the corrosive agents present in your particular sensing environment.

4) Dirt, Dust, Fog

Dirt, dust, smoke, or fog in the sensing path plus dirt, dust, fog, oil, grease, or soot build-up on the face of a sensor can all contribute to attenuation of the light energy available for sensing. It is in these very dirty sensing environments that inductive metal proximity detectors become a first choice. An inductive metal proximity sensor can ignore buildup of contaminants on its sensing face unless the buildup contains metal, as might be the case in a machine tool monitoring application. There are many sensing applications, though, where the target is not metal and/or where the sensing distance is too great to use an inductive proximity sensor.

Ultrasonic sensors offer a fixed amount of sensing energy. Proximity mode ultrasonic sensors depend on receiving an echo of an emitted signal. The echo can be quickly dampened by contaminants on the transducer or in the sensing path. This leaves photoelectric sensors as the only cost-effective non-contact sensing choice.

In environments where contamination is particularly thick, close attention must be given to excess gain data for any sensor under consideration. Very high excess gain is available only from some opposed mode sensors. Excess gain of opposed mode sensors is inversely proportional to the *square* of the sensing range. At close range, excess gains of several thousand times are common, as indicated in Table B-24.

In general, the more excess gain that is available from a sensor pair, the more reliable the sensing system will be in a dirt-filled environment. The only warning is that the target that is to interrupt the beam must be opaque to light. Opposed pairs with excess gain above 1,000x will survive in extremely dirty areas, but may also begin to penetrate paper, thin cardboard, and materials of similar density.

The greatest amount of "burn-through" (penetrating) ability is offered by high power opposed mode sensors with a small effective beam (i. e. small lenses). Large lenses yield longer range, but also spread the available sensing energy over a larger area. A 1/8-inch diameter beam with very high burn-through power may be created by removing the lens blocks from an SM51EB6/SM51RB6 opposed mode pair. This pair will function reliably in extremely dirty conditions at up to about one foot range (see Table B-24).

5) Air Turbulence

The sensing signal or the echo of an ultrasonic proximity sensor can literally be blown off course by wind that crosses the sensing path. Air flow along an ultrasonic proximity sensing *axis* can cause instability of response that is especially noticeable in analog measurement applications. For these reasons, use of ultrasonic sensors in outdoor applications is not recommended.

Air turbulence caused by heating of air (i.e. upward convection currents) can cause severe scattering of photoelectric (as well as ultrasonic) sensing energy. Sensing material flowing through a heat treating oven is an example of an application where convective air turbulence is encountered. In these situations, only opposed mode sensors with very high excess gain should be considered (Table B-24). When fiber optics are required, consider the addition of a lens on the sensing end tip of the emitter and receiver fiber optic assemblies to maximize excess gain (see Table B-7 and Figure B.16).

Table B-24
Sensors with Very High Optical Energy for use in Areas of Dirt, Dust, or Fog

Sensor Family	Minimum Guaranteed Excess Gain at (Range):			Models	Notes
	6 inches	1 foot	10 feet		
OMNI-BEAM™	40,000x	10,000x	100x	**OSBE & OSBR**	D.A.T.A. self-diagnostic system with alarm output. 10-element signal strength indicator.
MULTI-BEAM®	2,000,000x	500,000x	5,000x	**SBEX & SBRX1**	Highest excess gain available
	90,000x	22,500x	225x	**SBE & SBR1**	Very fast (1ms) response
	40,000x	10,000x	100x	**SBEV & SBRX1**	Visible (red) sensing beam
	90,000x	22,500x	225x	**SBE & 2SBR1**	2-wire hookup
MAXI-BEAM®	360,000x	90,000x	900x	**RSBE & RSBR**	Excess gain figures are with sensors programmed for 10 millisecond response
VALU-BEAM®	160,000x	40,000x	400x	**SMA91E & SM91R or SM2A91R**	Visible tracer beam Solid-state output
				SMA91E & SMW95R, SMA95R, or SMB95R	Visible tracer beam Electromechanical relay output
MINI-BEAM®	40,000x	10,000x	100x	**SM31EL & SM31RL, SMA31EL & SM2A31RL**	Apertures are available Miniature size
SM512 Series	10,000x	2,500x	25x	**SM51EB6 & SM51RB6**	Very small effective beam for highest available penetrating power (remove lens blocks for best penetration)
SM30 Series	2,000,000x	500,000x	5,000x	**SMA30SEL & SM30SRL or SM2A30SRL** **SMA30PEL & SM30PRL or SM2A30PRL**	Highest excess gain available
SP12 Series	160,000x	40,000x	400x	**SP12SEL & SP12SRL, SP12PEL & SP12PRL**	12-mm threaded barrel design Use with MAXI-AMP CD Series

6) Vibration and Shock

Vibration is generally regarded as an oscillating force, whereas *shock* refers to a transient force of short duration. The difference between these two potentially destructive forces can be blurred in some situations. For example, a cycling punch press can induce a force to a sensing component at a predictable frequency, but such press strokes are generally regarded as producers of shock because of the short time duration of each impulse. In contrast, a motor running the press flywheel might produce destructive vibration that could affect a sensing component that is bolted to the press frame.

Vibration and shock can be expressed in terms of variations in displacement, velocity, or acceleration with time. Acceleration is used most frequently to indicate the shock tolerance of sensing components, since the destructive force is equal to the weight of the component times its acceleration:

$$F_{destructive} = WG$$

where:

W = weight of the sensing component

G = the maximum acceleration in gravity units, that is, the maximum acceleration of the sensing component due to an impulse divided by the acceleration due to gravity.

From this basic relationship, it follows that a lightweight sensing component will survive more "Gs" of acceleration from shock or vibration than will a heavy sensing component. *This means that the best sensor choice for areas of shock and vibration is a glass fiber optic assembly*. The majority of a glass fiber optic assembly's weight is in the sheathing. The sheath is typically constructed from a flexible stainless steel conduit or spiral wire that naturally dampens much of any induced shock. The delicate parts of a glass fiber optic assembly are the optical glass fibers themselves, which individually present very little mass. The second best choice for sensing in areas of shock or vibration is a plastic fiber optic assembly. Its overall low mass is a plastic fiber optic assembly's main advantage in the presence of heavy shock or vibration. Fiber optics, in general, are able to survive hundreds of Gs of acceleration.

The next best category of sensors for shock resistance is the SP100 Series remote sensors, followed by the rest of the remote sensors (the smaller the better).

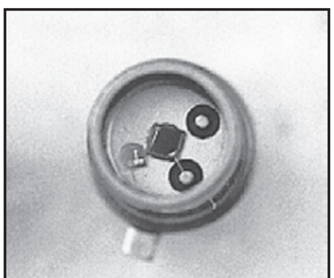


Figure B.53. Optoelectronic device.

The most fragile element of any photoelectric sensor is its LED or phototransistor. Within each opto device there is one or more "bond wires" that connect the active element(s) to the lead wires of the device (Figure B.53). The bond wire itself is very low in mass, but the two components that each bond wire connects together may move relative to each other when subjected to enough mechanical shock, causing the delicate electrical bonds to fracture or shear. Most of the opto devices that are used in industrial photoelectric sensors are rated for up to 15 Gs.

Following remote sensors, one-piece self-contained sensors are a good choice for areas of shock or vibration. Most tolerant of vibration are those which have epoxy-encapsulated circuitry. For the reason explained above, the smallest and lightest-weight models are best. *Unpotted* one-piece self-contained sensors, such as C3Ø and Q85 Series sensors, may fail from fractured circuit connections whenever shock levels exceed 10G, or when the vibration frequency is at resonance (see explanation, next page).

Modular self-contained sensors usually should not be mounted directly in areas of heavy shock or vibration. However, the MAXI-BEAM® is able to withstand forces up to 10 Gs, due to the fact that all of its components (except for the wiring base) are epoxy encapsulated, plus the fact that all of the components are bolted together.

Even if the components of a modular self-contained sensor bolt together, the heavy vibration that is typical of vibratory feeder bowl

Table B-25. Sensor Shock and Vibration Resistance
(best to worst*)

Sensing Component	Shock or Vibration Tolerance
Fiber optic assemblies:	
Glass fiber optics	(more than) 100G
Plastic fiber optics	
Remote Sensors:	
SP100 Series	15G (limited by opto device)
LR/PT Series	
LP Series	
SP12 Series	
SP300 Series	
One-piece self-contained sensors:	
Q19 Series	10G
QØ8 Series	
ECONO-BEAM	
MINI-BEAM	
S18 Series	
SM512 Series	
SM30 Series	
VALU-BEAM	
C3Ø Series	
Q85 Series	
ULTRA-BEAM	
Modular self-contained sensors:	
MAXI-BEAM	10G (shock only)

*NOTE: Sensing components not listed should be isolated from heavy vibration or shock.

equipment, sawmill equipment, and similar sensing environments *can* cause surprise failures. Every sensor or sensing component has its own unique *natural frequency*, the frequency at which *resonance* occurs. At resonance, a sensing component under vibration will, itself, vibrate at its highest amplitude. If the vibration (or a component of complex vibration) happens to coincide with the natural frequency of a modular self-contained sensor, it is possibile that the sensor could disassemble itself.

MAXI-AMP™ component amplifier modules are not recommended for mounting without isolation in areas of high vibration or shock. MICRO-AMP® modules, on the other hand, are epoxy encapsulated and are usually suitable for mounting directly to a machine frame if they are properly bolted to an RS-8 wiring socket.

Again, as a general rule, whenever it is known that a sensor will be subjected to high levels of shock or vibration, fiber optics are usually a safe choice. But remember that, although they can withstand hundreds of Gs of force from shock or vibration, *glass* fibers cannot tolerate repeated *flexing*. Tolerance to flexing *is* a strong point for *plastic* fiber optic assemblies, especially for those that are pre-coiled.

7) Hazardous Environments

The term *hazardous environment* is used here to describe a sensing location where combustible materials are present in dangerous quantities. In these environments, sensing equipment must be installed using special measures to avoid sources of ignition. Hazardous environments are defined and classified by several agencies and codes, including the IEC (International Electrotechnical Commission), and in the U.S.A. by the NEC (National Electrical Code). Table 12 in the Data Reference section at the back of this book outlines the NEC classifications for hazardous areas. Data Reference Table 14 correlates a NEMA standard to each hazardous location classification.

To avoid a source of ignition, sensors that are used inside hazardous areas may be treated in several ways. There are three common approaches to sensor use. One way is to "pipe" photoelectric sensing light into and out of the hazardous area using fiber optics. This is usually costly, because very long fiber optic assemblies are needed in most sensing situations. Also, long fiber optic runs result in very little sensing energy, making their use impractical in many applications.

The biggest obstacle to using glass fiber optics is the difficulty of sealing around the fiber bundle at the barrier between the hazardous and safe environments. Left unsealed, it is theoretically possible for a spark that originates in the safe area to propagate along the fiber optic assembly and into the explosive environment. As a result, plastic fiber optic assemblies are usually the only practical type for carrying sensing energy into and out of a hazardous area.

Another way to accomplish sensing in hazardous areas is to place (or build) a standard sensor into an explosion-proof enclosure (Figure B.54). An explosion-proof enclosure can withstand the pressure developed during an internal explosion and prevent the transmission of the explosion to the atmosphere that surrounds the enclosure. This solution is always expensive, and places limitations on the types of sensors that may be used. Also, the wiring that supplies power to and transmits data from the sensor must be treated specially so that a spark originating in the safe area cannot follow along the cable into the hazardous environment.

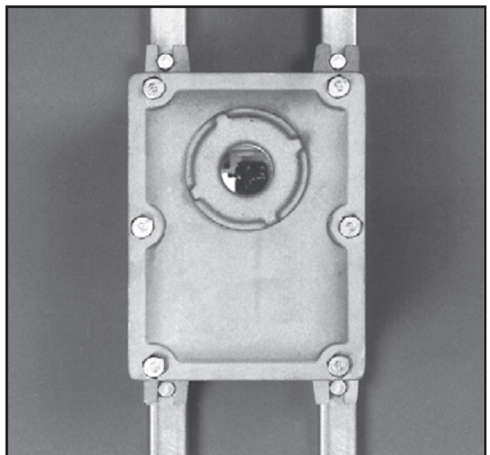


Figure B.54. Standard photoelectric sensor inside an explosion-proof housing.

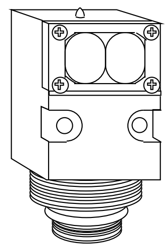
A third way to accomplish sensing in hazardous environments is to limit the electrical energy that can enter the hazardous environment by selecting sensors that require very low levels of energy for operation, and also by limiting the energy that can enter the hazardous area due to any fault condition. A sensing system that meets this criteria is referred to as *intrinsically safe*. Intrinsically-safe sensors are specially designed to require less than a specified maximum current and voltage, and to exhibit less than a specified maximum capacitance and inductance. Intrinsically-safe sensors *must* carry agency certification.

Energy limiting is provided by a safety *barrier*. Most barriers use zener diodes that limit voltage by shunting current to ground. The barrier protects against several fault conditions that could produce a spark, including shorting of the wires in the hazardous area, breaking of the wires in the hazardous area, grounding of the wires in the hazardous area, and failure of the power supply in the safe area. Intrinsically-safe barriers must also carry agency certification.

The SMI912 Series VALU-BEAM® sensors are certified by Factory Mutual as intrinsically safe for use in the most volatile areas. This includes NEC Division 1, Classes I, II, and III, groups A,B,C,D,E, F, and G (see Table 12 in the Data Reference Section). SMI912 Series sensors are also certified for use, without safety barriers, in Division 2 locations. SMI912 Series sensors have optical performance and features comparable to standard VALU-BEAM sensors (see Table B-26).

Use of SMI912 series sensors in Division 1 locations requires the use of safety barriers. Installation may be made using either a single barrier (2-wire hookup) or two barriers (or one double barrier, 3-wire hookup). In the 2-wire configuration, the sensor will act as a current sink, drawing less than 10mA in the OFF state and more than 20mA in the ON state (Figure B.55). A *current sensor* is used to convert this current change to a logic level switch. MAXI-AMP™ model CI3RC is a current sensor module that is powered by 115Vac line voltage and provides an electromechanical SPDT relay, plus a dc solid-state contact as output switches (Figure B.56).

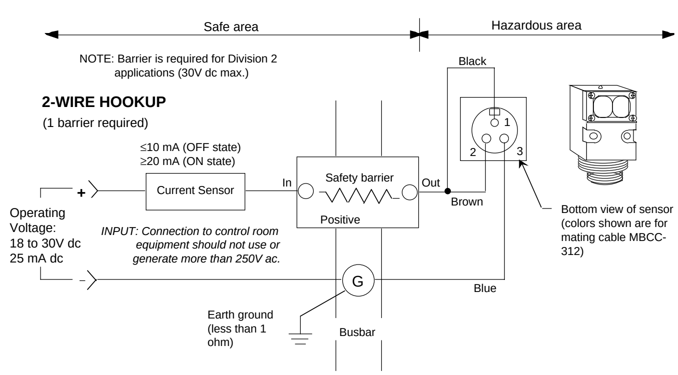
Table B-26. Sensors for Use in Hazardous Environments: Intrinsically-safe Sensors for Use with Safety Barriers

Sensor Family	Photoelectric Sensing Mode	Range	Sensor Model
VALU-BEAM® SMI912 Series 	Opposed	200 feet	**SMI91EQD & SMI91RQD**
	Opposed	10 feet	**SMI91ESRQD & SMI91RSRQD**
	Opposed fiber optic	(see catalog)	**SMI91EFQD & SMI91RFQD**
	Retroreflective	30 feet	**SMI912LVQD**
	Retroreflective (anti-glare)	15 feet	**SMI912LVAGQD**
	Diffuse	15 inches	**SMI912DSRQD**
	Diffuse	30 inches	**SMI912DQD**
	Visible Convergent	Focus at 1.5 inch	**SMI912CVQD**
	Glass fiber optic	(see catalog)	**SMI912FQD**
	Plastic fiber optic	(see catalog)	**SMI912FPQD**

An SMI912 Series sensor may also be configured in a 3-wire mode for directly switching a load up to 15 milliamps. The 3-wire mode requires two safety barriers (Figure B.57). Note that, in the 3-wire hookup, the positive load barrier is in series with the load. This results in an apparent saturation voltage of the output that is higher than the sensor output and is equal to the current multiplied by the voltage drop across the barrier.

Barriers are classified as either "positive input" or "negative input". SMI912 sensors require positive input barriers. When selecting a barrier, it is also important to consider the barrier's resistance. The SMI912 sensor must have at least 10 volts across the brown and blue wires for operation. The formula that determines how much barrier resistance is allowed is:

Figure B.55. SMI912 Series 2-wire hookup.

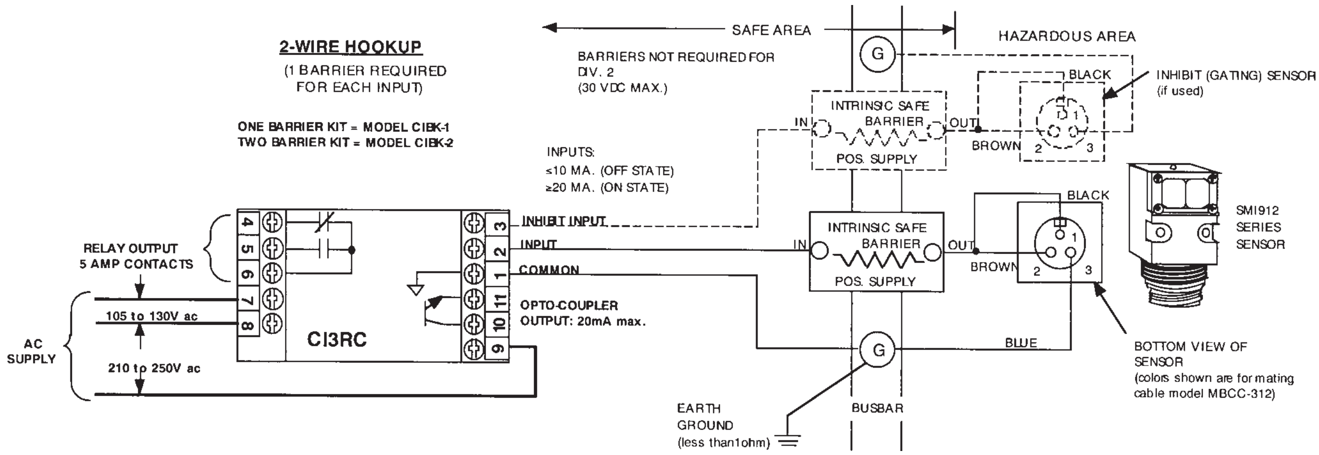


$R_{Barrier}$ = 40 (Supply voltage - 10 volts).

In the 2-wire configuration this amount of maximum resistance must include the resistance due to the current sensing device, so the barrier resistance must be further reduced by the resistance of the current sensor. For assistance when selecting a barrier, contact your Banner sales engineer.

The CI3RC current sensing module is available with a properly sized safety barrier in a kit which also includes a busbar, module socket, and DIN rail mounting track. Model CIBK-1 includes one barrier. Model CIBK-2 includes two barriers for applications where an auxiliary sensor is used or where an opposed emitter/receiver pair is used (Figures B.56 and B.58).

Figure B.56. Hookup of SMI912 Series sensors to a Banner model CI3RC current amplifier module.



Intrinsically-safe sensors offer many advantages over explosion-proof sensing design, including:

1) Significant reduction in costs of hardware and installation;

2) Ease of sensor installation and alignment (sensors can be adjusted with power applied);

3) Suitability for all Classes, Groups, and Divisions of hazardous locations (see Table 12);

4) Explosions are prevented, not simply contained;

5) No shock hazards exist because circuits are low voltage and very low current;

6) Intrinsic safety approach is recognized internationally.

The SMI912 Series offers exceptionally high optical performance. It is *the* best choice for sensing in hazardous environments.

Figure B.57. SMI912 Series 3-wire hookup.

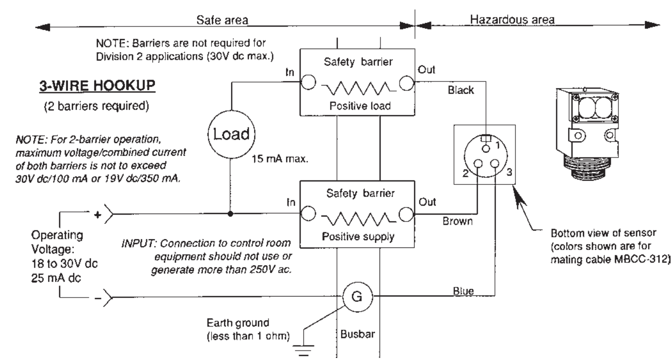
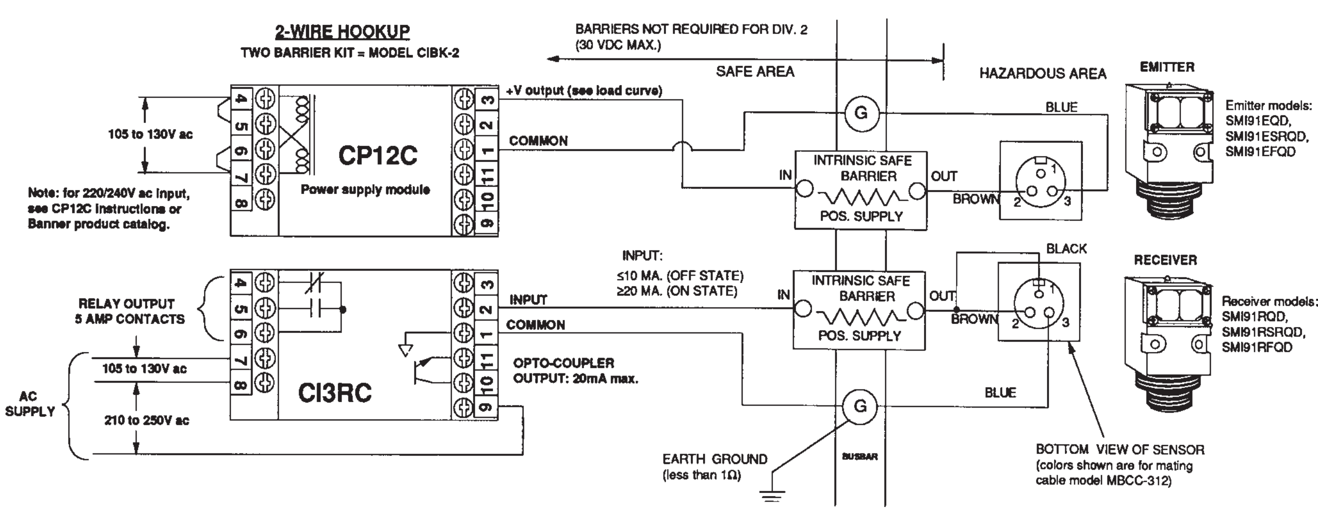


Figure B.58. Hookup of SMI912 Series emitter-receiver pair.

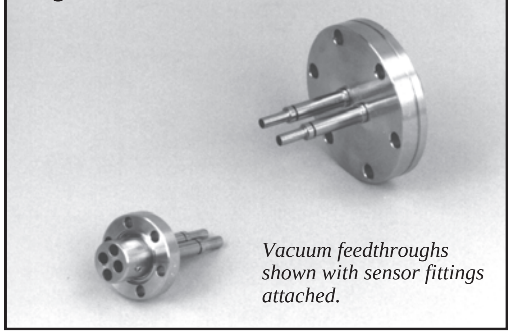


8) Vacuum Feedthroughs

Banner vacuum fiber optic feedthroughs allow photoelectric sensing in vacuum chambers. These feedthroughs allow both emitted and recieved light through one flange, thereby reducing the size and cost of each sensing point. See Figure B.60.

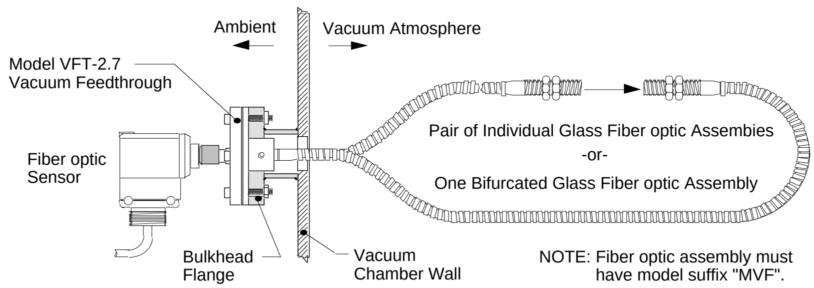
A photoelectric sensor is installed in the ambient environment and is connected to the feedthrough either directly or via fiber optic cables. Figure B.60 shows direct connection, the method which results in the least amount of sensing energy loss. The feedthrough mounts to a bulkhead flange, and fiber optics connect (via setscrews) to the other side of the feedthrough inside the vacuum chamber. Banner vacuum feedthroughs (examples, Figure B.59) are constructed from a modified Varian Conflat® flange, and use solid-glass feedthrough media. Two types are available, based on sealing ability. High vacuum models, for use in vacuum environments to 10^{-7} torr, use a Teflon® o-ring seal and are available in either stainless steel or aluminum. Ultra-high vacuum models, which use a copper gasket seal and are available in stainless steel only, may be used in vacuum environments to 10^{-10} torr. Operating temperature range of all feedthroughs is -60 to +180°C (-76 to +356°F).

Figure B.59.



Vacuum feedthroughs shown with sensor fittings attached.

Figure B.60. A vacuum feedthrough sensing sytem in place.



VFT-2.7xx models offer maximum fiber optic sensing range by accomodating .156" fiber optic bundles. VFT-1.3xx models use fibers with up to .125" bundle size. The fibers used with vacuum feedthroughs are specially modified for use in vacuum environments. Special fiber optic cables, constructed without epoxy to prevent outgassing, are available. Mounting bolts are supplied. Sensor fittings (for mounting the sensor directly to the feedthrough) and fiber adaptors (for connecting fiber optics to the ambient side of the feedthrough) are sold separately.

Banner OMNI-BEAM, MAXI-BEAM, MULTI-BEAM, and VALU-BEAM sensors mount directly to VFT-2.7xx models via sensor fittings. VFT-1.3xx models mount directly (via fittings) to MINI-BEAM sensors.

9) Electrical Noise

Electrical noise is a catch-all term that includes the interference caused by both EMI (electromagnetic interference) and RFI (radio frequency interference). Common sources of continuous EMI include lighting fixtures and lighting controls, motors, and generators. The most common source of intermittent EMI is the arcing produced by contacts of electromechanical relays or contactors that switch inductive or large resistive loads. EMI emissions are distributed uniformly across the radio frequency spectrum. Their presence is recognized (between stations on an AM band radio) as a "buzzing" or "frying" noise (from a continuous source) or as a loud "popping" noise (from an intermittent source).

Continuous RFI interference is commonly caused by computers and data terminals. Intermittent RFI sources include stepper motor controls and two-way radio systems. RFI most often occurs at a specific frequency or within a relatively narrow band of frequencies (although devices such as stepper motor controls and computers can produce many strong *spurious emissions* throughout the radio frequency spectrum). As a result, one electronic instrument may be radically affected by the presence of RFI, while another similar instrument in the same area may appear completely immune.

The Banner BEAM TRACKER™ is designed to respond to a high level of emission that falls anywhere within the (LF, HF, VHF, or UHF) RF spectrum. This makes the BEAM TRACKER a valuable tool for locating any strong source of RFI *or* EMI. The BEAM TRACKER includes a signal strength measurement circuit that flashes an indicating LED at a rate that is proportional to the strength of the noise source. Intermittent noise sources will light the LED for the duration of each emission burst. RFI may be tracked by moving the BEAM TRACKER in all directions, while observing the indicating LED. EMI is readily coupled to and conducted along cables, so the source of EMI emission is often discovered by tracking along wireways. It is normal in these situations for the interference to alternately rise and fall along the length of a long cable or wireway.

When noise is present in levels that begin to affect electronic circuits including sensors and/or their loads, it is best to locate the source of the noise and take steps to minimize the emission. Some commonly-encountered noise sources and cures are discussed in Section E , "Troubleshooting". However, there are some very potent sources of EMI and/or RFI, such as arc welders or inductive heaters, that cannot be controlled; and, instead, require careful sensor selection, sensor mounting, and sensor wiring to avoid the effects of the interference.

Airborne RFI decreases in intensity by the *square* of the distance moved away from the source. *When sensing needs to be performed near a known noise source, fiber optics are always the best choice.* Either glass or plastic fiber assemblies may be used to "pipe" sensing light energy into and out of high noise areas. If glass fiber optics are used, the first choice is an assembly with an insulating sheathing material to avoid the possibility of conducting noise back to the photoelectric sensor.

All Banner sensors and remote amplifiers are designed for high noise immunity. However, there are some designs that are inherently more immune than others. There are three general comparison statements that hold true under most circumstances.

First, photoelectric sensors have higher noise immunity than ultrasonic sensors. Ultrasonic receivers must amplify much lower-level signals as compared to photoelectrics (microvolt vs. millivolt level). It follows that the gain of an ultrasonic sensor is usually higher than that of a photoelectric sensor. For this reason alone, an ultrasonic sensor is more likely to amplify unwanted signals. However, ultrasonic proximity sensors have relatively slow response times (25 milliseconds and up), and so are very unlikely to give a false output from short pulses of intermittent noise.

Second, with the exception of model SP12 preamplified remote sensors, self-contained sensors are less susceptible to noise compared with component systems. Remote sensors of a component system send the received signal along a cable to their amplifier. These signals are generally very small (typically millivolt levels) and must be highly amplified. The sensor cable can act as an antenna, and pick up some portion of the noise and route it to the amplifier.

In order to minimize noise pickup, it is very important to route the cables of remote sensors away from power-carrying wires, and to keep sensor leads as short as possible. With the exception of SP12 Series receivers, remote receiver cables always require a shield (drain) wire, connected to ground at the amplifier, to minimize the possibility of noise coupling into the receiver lead wires. Wire routing requirements for SP12 Series sensors are much less stringent. These sensors gain exceptional noise immunity by amplifying the light signal *before* sending it down the line to a component amplifier (MAXI-AMP CD Series) which further amplifies the signal.

Third, it is generally true that self-contained sensors containing both the emitter and the receiver (i.e. retroreflective, proximity, and fiberoptic mode sensors) are more immune to noise as compared to self-contained opposed mode pairs. This is because an emitter and receiver together in the same circuit can be synchronized, resulting in a relatively narrow band of frequency response for the receiver amplifier. A self-contained receiver (only) that is designed to work with any emitter within its sensor family group must have a wider frequency response. For this reason, self-contained receivers are less able to discriminate against unwanted signals.

There is one definite exception to this rule. The SM30 Series barrel sensor receiver is specially engineered to discriminate against noise. An SM30 emitter/receiver pair will demonstrate as good or better noise immunity compared with a self-contained sensor where both the emitter and receiver are together in the same unit. Another exception is the SM51EB6/SM51RB6 emitter/receiver pair, which uses "sync" wires that connect together *externally* to lock the pair on a common frequency.

Table B-27.
Ranking of Sensor Types by Relative Electrical Noise Immunity (highest to lowest noise immunity)

Plastic fiber optics or glass fiber optics with insulating sheath
Glass fiber optics with metal sheath
SM30 Series self-contained photoelectric sensors
***Self-contained photoelectric sensors** with emitter and receiver in the same housing (retroreflective, proximity, and fiber optic mode models)
***SP12 Series preamplified remote sensors**
***Separate emitter and receiver** (opposed mode) self-contained sensors
****Ultrasonic sensors**
***Remote photoelectric sensors** (except SP12 Series; see above)

*****Note: add ON-DELAY timer for increased immunity to intermittent noise.

******Note: ultrasonic sensors have good to excellent immunity to intermittent noise.

When it is known that strong intermittent interference must be dealt with, and when fast response is not a requirement, it is good insurance to select a sensor or component system that allows the addition of an ON-DELAY timer (see Section D). A small amount of ON-DELAY time (e.g. 0.1 second) can prevent false sensor outputs that are triggered by short bursts of intermittent noise. For this same reason, sensors with long response times, such as those with an electromechanical output relay, may be preferable over those with fast response in areas with intermittent noise pulses. OMNI-BEAM, MULTI-BEAM, MAXI-BEAM, and the Q85 Series all offer ON-DELAY timers, as do the component amplifiers of the MAXI-AMP family. On the other hand, use ONE-SHOT and OFF-DELAY (only) timers with caution in areas of high noise, because they are triggered by any false sensor response that is longer than the specified amplifier response time.

There are also situations where a sensor will operate normally until it is mounted in place on a machine. Improperly grounded electric motors and generators are notorious for generating EMI that can be coupled to a machine frame. An earth ground connected directly to the motor frame is the usual cure. However, when grounding is impractical or when the noise source is not controllable, sensors may need to be insulated from the machine frame. When the sensor housing is plastic, noise may be reaching the sensor's amplifier through capacitive coupling. When this occurs, insulating shims or standoffs may be required to increase the spacing between the sensor and the machine frame.

Again, the best way to deal with electrical noise is to locate the source of the noise and take steps to minimize the emissions. However, whenever high noise levels are an accepted environmental factor, then selection of a sensor with sufficient noise immunity becomes an important consideration. Table B-27 lists sensor types by their relative noise immunity (highest immunity to lowest immunity).

Sensor Selection Category E - Sensor Cost

1) Sensing Mode

Ultrasonic sensors are among the most expensive industrial presence sensing devices. The high cost per sensor is due largely to the cost of the transducer and to the cost of the circuitry required for sensing. However, for long-range reflective sensing or for linear analog distance measurement, ultrasonic proximity sensors are a very cost-effective alternative to laser or microwave sensing devices.

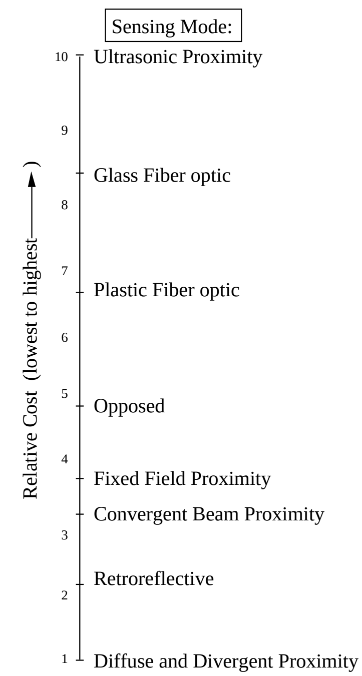
Fiber optic assemblies represent cost *in addition to* actual sensor cost. Glass fiber optic assemblies are significantly more expensive than plastic fiber optic assemblies. Specially-manufactured glass fiber optic assemblies can add considerable expense to a sensing system. However, multiple-channel fiber optics that require only one sensor for several sensing locations (see Multiple Sensor Logic, Section D) can actually *save* sensing system cost. In addition, fiber optics are the solution to many otherwise difficult or impossible sensing requirements (see pages B-17 through B-19 in Category A - Sensing Mode).

The opposed mode is the next most expensive sensing mode, due to the need for two sensing units. The cost associated with the installation of two units (versus one) is also an important consideration, especially in systems that require multiple sensing points.

Diffuse, divergent, and retroreflective sensors all have the same cost within most sensor families. However, retroreflective sensors require a retro target that adds a small additional cost per sensing point. More important, a retroreflective sensing system requires additional expense for *installation* of the target. Convergent beam and fixed-field proximity mode sensors are usually more expensive than retro sensors because of the additional costs associated with their optical systems.

Figure B.61 ranks the relative cost of the sensing modes. Of course, there are many exceptions to the comparisons shown. This ranking is the relative cost averaged from seven sensor product groups. The glass fiber optic assembly price used for this comparison was the average cost of the four most popular bifurcated assemblies and the four most popular individual glass fiber optic pairs. The average cost of a standard plastic fiber assembly (or pair) was also used. *NOTE: The numbers (1 to 10) along the scale in Figure B.61 are not multiplicative factors; they represent only a relative ranking.*

Figure B.61. Relative cost comparison of sensing modes



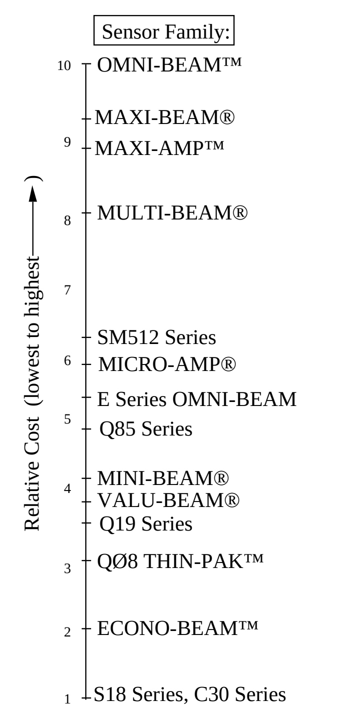
2) Sensor Supply Voltage

Sensors and component sensing systems that are powered by low voltage dc average about 10 percent less in cost than those powered by 120V ac. Of course, this savings is only possible if dc power is already available in the system. Also, 220/240V ac sensors average about 5 percent more in cost than 120V ac models.

3) Sensor Family

It is no surprise that sensor designs offering the most features are also the most expensive (see Figure B.62). This relative cost comparison between sensor families assumes a diffuse proximity mode sensor with basic ON/OFF operation (i.e. no timing logic). Figure B.62 also reflects the higher costs that are associated with component sensing systems (MAXI-AMP™ and MICRO-AMP®). *NOTE: The numbers (1 to 10) along the the scale in Figure B.62 are not multipicitive factors; they represent only a relative ranking.*

Figure B.62. Relative cost comparison of sensor families



Section G
Glossary of Sensing Terms

Glossary of Sensing Terms

ac-coupled amplifier

ac-coupled amplifiers may sometimes be used reliably in close differential sensing applications, since they amplify only quick signal changes and ignore slow signal changes. As a result, very small changes in light level can be highly amplified. The output of ac-coupled amplifiers is a one-shot pulse. (See also "dc-coupled amplifier".)

In photoelectric sensing, ac-coupled amplifiers are most often used to amplify the analog signal from a non-modulated remote sensor, such as model FO2BG. However, ac-coupled amplifiers may also be used with specially-designed modulated sensors which have an analog output, like model SM53R. OMNI-BEAM sensor model OSBFAC is an example of a self-contained sensor with a built-in ac-coupled amplifier.

Use of ac-coupled amplifiers should be avoided, except when they are the only solution to a close differential sensing situation. Because ac-coupled amplifiers are sensitive to very small signal changes, they may respond to unwanted conditions like sensor vibration or electrical "noise".

AID™

"AID" (Alignment Indicating Device, US patent #4356393) is an exclusive Banner built-in feature that permits optimum alignment and continuous monitoring of a photoelectric sensing system. The AID system lights an indicator LED whenever the receiver "sees" its modulated light source.

In addition, a low frequency pulse rate is superimposed on the indicator LED. As alignment is improved, the pulse rate increases, indicating increased excess gain. Optimum sensor alignment is indicated by the fastest pulse rate.

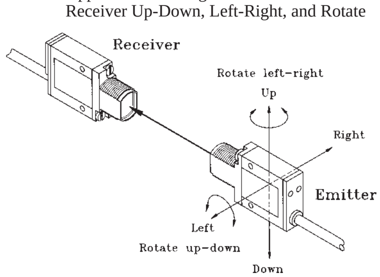
The AID feature also signals when maintenance is needed. Whenever the pulse rate is slow, the lenses should be cleaned and/or the alignment checked. Table E-1 identifies those sensors and amplifiers that feature AID™.

alignment

Positioning of a sensor so that the maximum amount of the emitted energy reaches the receive sensing element (below).

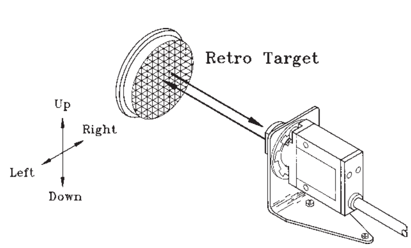
Opposed Mode Alignment

Opposed Mode Alignment: Move Emitter or Receiver Up-Down, Left-Right, and Rotate



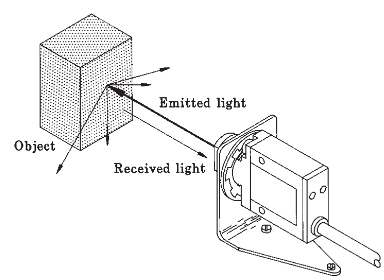
Retroreflective Mode Alignment

Retroreflective Mode Alignment: Move Target Up-Down, Left-Right



Proximity (Diffuse) Mode Alignment

Diffuse Mode Alignment: Rotate Up-Down, Left-Right



alternate action (see "**flip-flop**")

alternating current (ac)

A sinusoidal current rated at a given frequency, usually 50Hz or 60Hz.

ambient

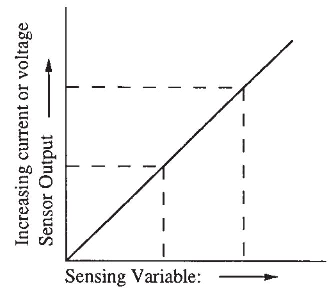
The environmental conditons in a sensing area (e.g. - temperature, light level, humidity, air speed).

ambient light receiver

A non-modulated photoelectric receiver that is used to detect differences in ambient light level (using sunlight or incandescent, fluorescent, infrared, or laser light sources). Used for outdoor lighting control, sensing of hot objects (infrared), and for some indoor applications using existing factory lighting. MULTI-BEAM scanner block model SBAR1 is a good example of an ambient light receiver.

ampere (amp)
A unit of measurement of electric current. One volt across one ohm of resistance causes a current flow of one amp. One ampere is equal to 6.28×10^{18} electrons passing a point in one second.

Analog Output



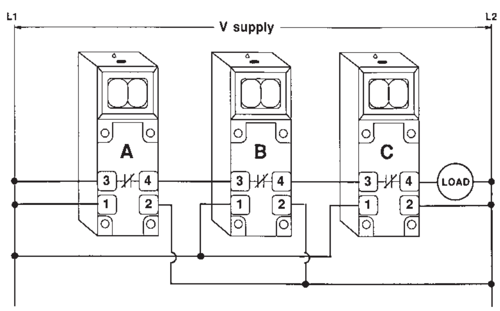
Photoelectric: Increase (or decrease) in received light level
-or-
Ultrasonic: Movement of object toward (or away from) sensor

analog output
A sensor output that varies over a range of voltage (or current) and is *proportional* to some sensing parameter (as opposed to a digital output). The output of an analog photoelectric sensor is proportional to the strength of the received light signal (e.g.- OMNI-BEAM analog sensors). The output of an analog ultrasonic proximity sensor is proportional to the distance from the sensor to the object that is returning the sound echo (e.g.- ULTRA-BEAM 923 Series sensors).

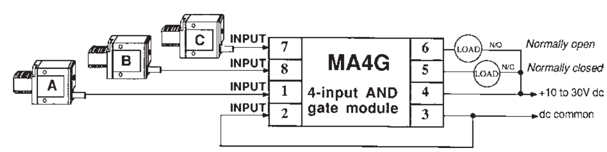
AND logic
A logic function in which all of two or more defined input conditions must exist simultaneously before a load is energized (A *and* B *and* C = output).

Examples of "AND" Logic

A. Using Sensor Outputs in Series



B. Using "AND" Gate Logic Module



angle of acceptance
The included angle of the field of view of a sensor. See **"field of view"**.

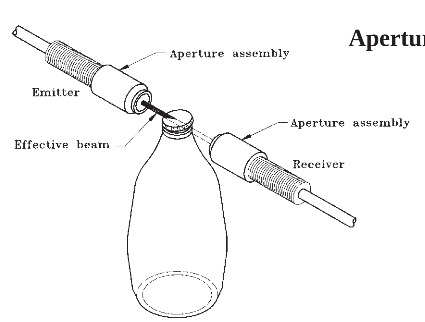
anode
A positive electrode of a device. See **"diode"**.

anti-glare filter
A lens attachment consisting of a pair of polarizing filters that are oriented so that planes of polarization are at 90° to one another. Used to enable a photoelectric receiver to "see" only light of the desired polarization (from its modulated emitter), while blocking unwanted light. Used with retroreflective sensors for minimizing "proxing" effects from shiny objects.

artificial load
A resistor connected in parallel with a load to lower the load's effective resistance. Usually encountered when interfacing 2-wire sensors to high-impedance inputs in order to lower the off-state voltage at the input.

aperture
The size of a lens opening. A mechanical part attached to a lens used to restrict the size of a lens opening. Apertures are used to limit the amount of light reaching a photoelectric receiver. Apertures are used in opposed photoelectric sensing to shape the size of the effective beam to match the profile of the object to be sensed (e.g. a "line" or slit-type aperture is used on the receiver and/or emitter to sense small diameter wire or thread).

Aperture



attenuation
Lessening of sensing energy caused by environmental elements such as dirt, dust, moisture, or other contaminants in the sensing area.

B Series

Banner's original product line of non-modulated solid-state amplifier and logic modules. Features aluminum construction with relay-style octal base for plug-in operation with Banner MRB or BRB control chassis. B Series modules offer complete selection of timing logic functions. Inputs are derived from non-modulated remote photoelectric sensors, contact closures, or any dc self-contained sensor or sensing system with NPN (sinking) output.

background suppression (see **"fixed-field sensing mode"**)

barrier (see **"intrinsic safety barrier"**)

beam-break (see **"opposed sensing mode"**)

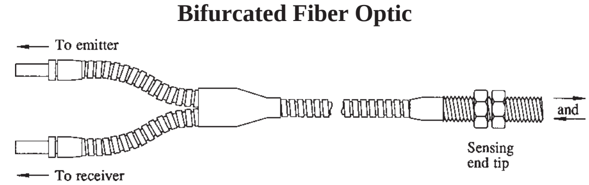
beam pattern

A two-dimensional graph of a sensor's response. (Beam patterns are assumed to have the same shape in all sensing planes.) Beam patterns are plotted for perfectly clean sensing conditions, optimum angular sensor alignment, and the sensitivity (gain) setting for the specified range. Beam patterns are included as part of the description of each sensor. The dimensions of the plot are typical, and should not be considered exact specifications. Beam pattern information and assumptions are slightly different for each sensing mode. Beam patterns are helpful in predicting the performance of the sensor.

BEAM TRACKER™

A portable hand-held sensor that provides a means for troubleshooting any modulated photoelectric system. It is used to check the functioning of a modulated emitter and/or receiver, to locate the center of sensing beams during alignment, and to track down sources of severe EMI and RFI "noise". (Photo above, right.)

Bifurcated Fiber Optic



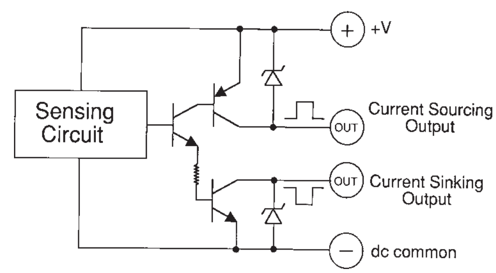
bifurcated fiber(optic)

A fiber optic assembly that is branched to combine emitted light with received light in the same assembly. Bifurcated fibers are used for diffuse (divergent) mode proximity sensing, or they may be equipped with a lens for use in the retroreflective mode.

Bi-Modal™ output

An exclusive Banner output circuit design that offers either sinking (NPN) or sourcing (PNP) output, depending upon the polarity with which the two dc supply leads are connected. Used in Banner OMNI-BEAM™ dc power blocks & SM30 sensors.

Bipolar Output

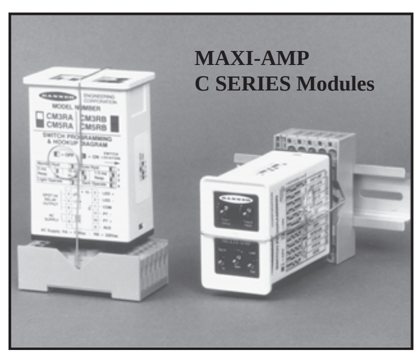


bipolar output

The dual output configuration of a dc sensing device, where one output switch is a sinking device (NPN transistor) and the other output switch is a sourcing device (PNP transistor). The solid-state equivalent of a DPST relay (for most loads).

burn-through

Describes the ability of high-powered modulated opposed mode sensors to "see" through paper, thin cardboard, opaque plastics, and materials of similar optical density. Burn-through may be used to advantage in some sensing situations, such as when looking through an opaque walled container (like a cereal box) to sense the presence or absence of product inside.



MAXI-AMP
C SERIES Modules

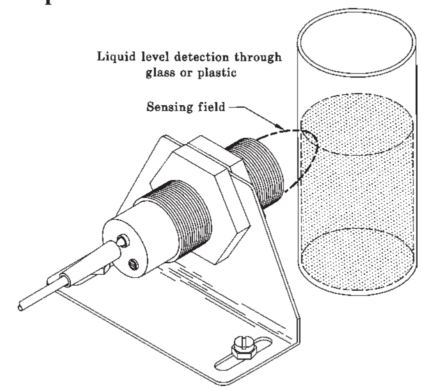
C Series

An alternate name for the MAXI-AMP family of stand-alone photoelectric sensor control modules and power supplies. MAXI-AMP modules combine power supply, photoelectric amplifier (some models), timing logic (some models), and output switching device into a single compact plug-in module. (Photo at right.)

capacitive sensor

Capacitive proximity sensors are triggered by a change in the surrounding dielectric. The transducer of a capacitive sensor is configured to act as the plate of a capacitor. The dielectric property of any object present in the sensing field increases the capacitance of the transducer circuit and, in turn, changes the frequency of an oscillator circuit. A detector circuit senses this change in frequency, and signals the output to change state.

Capacitive Sensor



cathode

A negative electrode of a device. See **"diode"**.

CCD array

CCD = Charge Coupled Device. A self-scanning imaging device arrayed so that the electrical charge at the output of one semiconductor element provides the input to the next. The CCD array is used as the sensing element of CCTV and inspection cameras.

CENELEC

Acronym for the European Committee for Electrotechnical Standardization. Responsible for the development of standards covering dimensional and operating characteristics of control components.

close differential sensing

Sensing situations with low optical contrast (less than 3 to 1). Includes most color registration sensing applications. Also, breaking of a large effective beam with a small profile, as in ejected part detection or thread break detection. Close differential sensing often requires the use of an ac-coupled amplifier.

CMOS

CMOS = Complementary Metal Oxide Semiconductor (device). Highly efficient semiconductors used in custom monolithic photoelectric circuit designs.

collimation

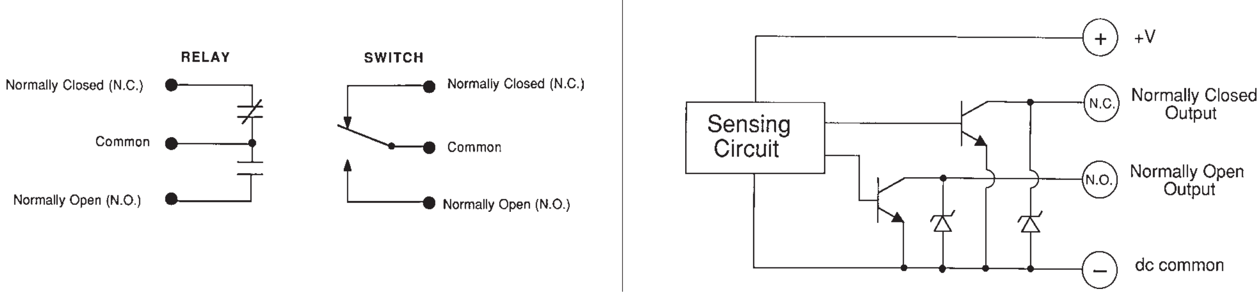
Optical collimation is the process by which a lens converts a divergent beam into a parallel beam of light.

complementary output

The dual output configuration of a sensing device, where one output is normally open and the other is normally closed. An example is a SPDT form 1C relay contact. Solid-state complementary outputs are offered in SM512, Q19, and S18 Series sensors and MICRO-AMP modules.

Complementary Outputs
Using Electromechanical SPDT Relay Contacts

Complementary Outputs
Using Solid-state Device



component system

A system in which sensors are remote from power supply, amplifier, logic device, and output switching device. MAXI-AMP CD, CM, or CR Series modules used with modulated remote sensors comprise component systems.

contact bounce

Occurs on the closure of a mechanical contact pair. When the contact pair closes, the contacts make and break several times before a stable closed condition is established. Contact bounce is *not* a characteristic of solid-state switch contacts.

continuous scanning

A mode of scan control in light-curtain type systems in which each scan through a beam array is followed automatically by another scan, and so on, for as long as a clock signal is present. Used in the BEAM-ARRAY Measuring Light Curtain system.

contrast (optical)

The ratio of the amount of light falling on the receiver in the "light" state as compared to the "dark" state. Contrast is also referred to as the "light-to-dark-ratio" as expressed by the equation:

$$\text{Contrast} = \frac{\text{Light level at receiver (light condition)}}{\text{Light level at receiver (dark condition)}} = \frac{\text{Excess gain (light condition)}}{\text{Excess gain (dark condition)}}$$

Optimizing the contrast in any sensing situation will increase the reliability of the sensing system.

control end

Refers to the end of a fiber optic assembly that attaches to the photoelectric sensor. An individual fiber optic assembly has one control end; a bifurcated fiber has two. See **"fiber optic"**.

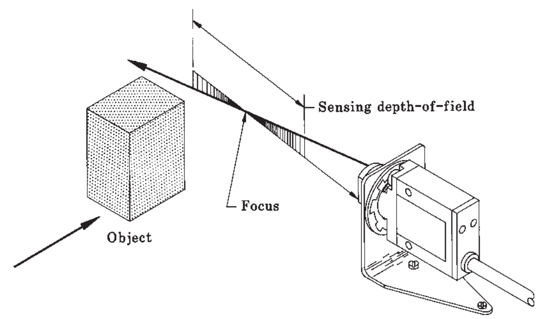
conventional current (flow)

The concept of current flow from positive to negative.

convergent beam sensing mode

A special variation of diffuse mode photoelectric proximity sensing which uses additional optics to create a small, intense, and well-defined image at a fixed distance from the front surface of the sensor lens. Convergent beam sensing is the first choice for photoelectric sensing of transparent materials that remain within the sensor's depth-of-field. Also called "fixed-focus proximity mode".

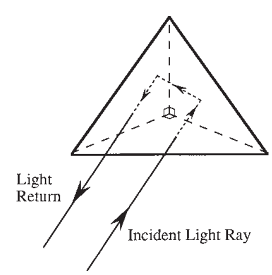
Convergent Beam Sensing Mode



corner-cube reflector

Also called a corner-cube prism. A prism having three mutually perpendicular surfaces and a hypotenuse face. Light entering through the hypotenuse face is reflected by the three surfaces and emerges back through the hypotenuse face parallel to the entering beam. The light beam is returned to its source. May also be constructed from three first-surface mirrors. Corner-cube geometry is used for retroreflective materials. See **"retroreflector"**.

Corner-cube Reflector



crosstalk (electrical)

Electrical crosstalk occurs in modulated photoelectric component systems when the modulated emitter signal (which is a high-current pulsed signal) couples directly onto the receiver lead wires. This results in a "lock-on" condition of the amplifier (i.e. the amplifier recognizes a light condition regardless of the sensor's status). Crosstalk is usually a result of improper splicing of additional remote sensor lead length. In component systems, remote sensors require separate shielded cables for emitter and receiver lead extension, even if the original cable length contained wires for both the emitter and the receiver.

crosstalk (optical)

Optical crosstalk occurs when a photoelectric receiver responds to light from an adjacent emitter. This is often an unwanted situation. If crosstalk cannot be resolved by repositioning of sensors, it can often be eliminated using sensor multiplexing, as with the MP-8 multiplexer module.

crosstalk (acoustical)

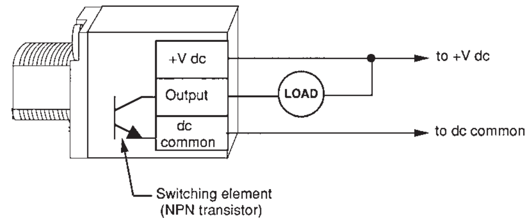
Acoustical crosstalk occurs when an ultrasonic sensor responds to the signal from an adjacent ultrasonic sensor. If crosstalk cannot be resolved by repositioning of the sensors, it can often be minimized by installing baffles between the sensors and/or wave guides (i.e. extension tubes) ahead of the transducers.

CSA

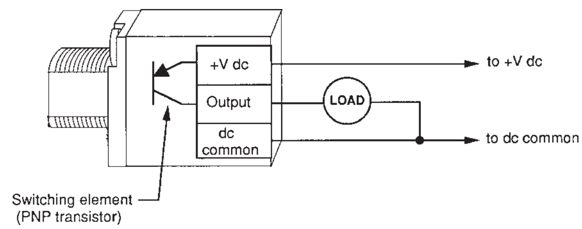
Abbreviation for Canadian Standards Association. A testing agency analogous to Underwriters Laboratories, Inc. (UL) in the United States. A product that is "CSA certified" has been type-tested and approved by the Canadian Standards Association as meeting electrical and safety codes. See logo at right.

current trip point amplifier
An amplifier that converts the current output signal of analog sensing devices to a trip point switch. An example is model CI3RC which converts the current loop output of SMI912-Series intrinsically safe sensors to a digital (switched) output.

Current Sinking Output



Current Sourcing Output



current sinking output
The output of a dc device that switches ground (dc common) to a load. The load is connected between the output of the device and the positive side of the power supply. The switching component is usually an open collector NPN transistor, with its emitter tied to the negative side of the supply voltage.

current sourcing output
The output of a dc device that switches positive dc to a load. The load is connected between the output of the device and the ground (dc common) side of the power supply. The switching component is usually an open collector PNP transistor, with its emitter tied to the positive side of the supply voltage.

curtain of light (see **"light curtain"**)

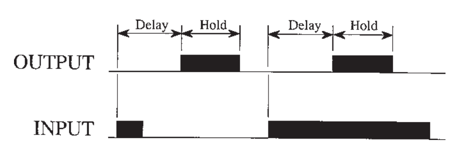
dark operate mode (D.O. or D/O)
The initiation of a photoelectric sensor's output (or of timing logic) when the receiver goes sufficiently dark. Most photoelectric sensors (or sensing systems) can be programmed for either dark operate or light operate.

D.A.T.A.™
Data **a**nd **T**rouble **A**lert system, an exclusive (U.S. patent 4965548) Banner sensing aid system consisting of an LED array which indicates light signal strength and sensor output state, and warns the operator of marginal sensing or failure conditions including: too high or too low gain setting, inadequate sensing contrast, too low voltage, too high internal temperature, excessive moisture inside sensor, and overloaded output. Used on Banner standard OMNI-BEAM™ photoelectric sensors (as seen in photo at right).

dc-coupled amplifier
An amplifier in which all signal changes, slow or fast, are amplified. The amplifier's sensitivity control is actually a threshold adjustment, setting the point (in received signal intensity) at which the output will change state from "off" to "on". See also **"ac-coupled amplifier"**.

delayed one-shot (delayed one-shot logic)
Timing logic in which an input signal initiates an adjustable delay period, at the end of which the output pulses for an adjustable pulse ("hold") time. The input signal may be either momentary or maintained. No further action occurs until the input signal is removed and then reapplied, at which time the sequence begins again. An auxiliary inhibit signal (e.g. from an inspection sensor) during the delay period will cancel the output pulse. Useful for inspection/rejection control applications. See also **"on-delayed one shot"**.

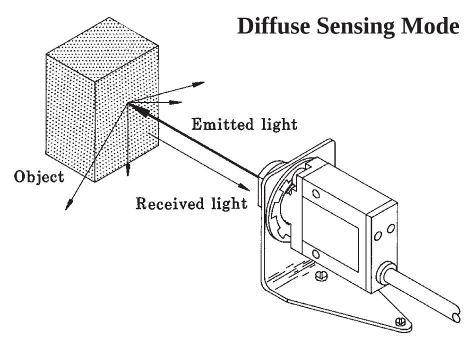
"DELAYED ONE-SHOT" Logic



demodulate (demodulator) (see **"modulation"**)

depth-of-field
The range of distance within which a sensor has response. Used to define the response pattern of proximity-mode sensors, especially ultrasonic and photoelectric convergent beam and fixed-field mode sensors. See **"convergent beam sensing mode"**.

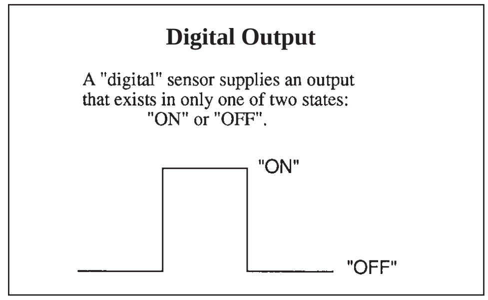
Diffuse Sensing Mode



diffuse sensing mode
A photoelectric proximity sensing mode in which light from the emitter strikes a surface of an object at some arbitrary angle and is detected when the receiver captures some small percentage of the diffused light. Also called the "direct reflection mode" or simply the photoelectric "proximity mode".

digital output
A sensor output that exists in only one of two states: "on" or "off". The output of most sensors and sensing systems is digital.

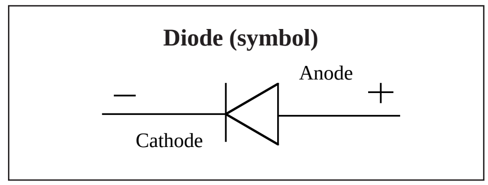
DIN standard
Abbreviation for “Deutsches Institut fur Normung". A collection of German industry standards that are recognized throughout the world.



diode
A two-layer semiconductor that allows current to flow in only one direction.

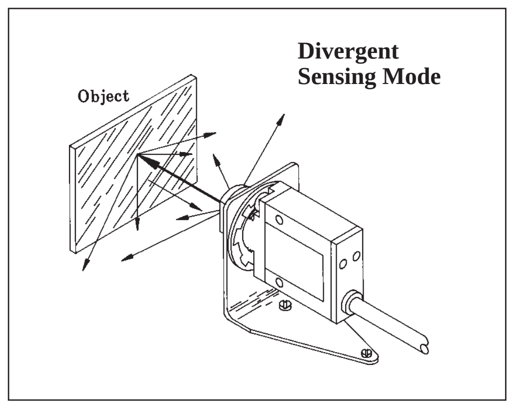
direct current (dc)
A current that flows only in one direction through a circuit. May or may not have a dc ripple component. DC sources that are unfiltered should be referred to as *full-wave* or *half-wave rectified ac.*

direct scan mode (see **"opposed sensing mode"**)



disable
To prevent an output from occurring, despite the input signal status. See **"inhibit"**.

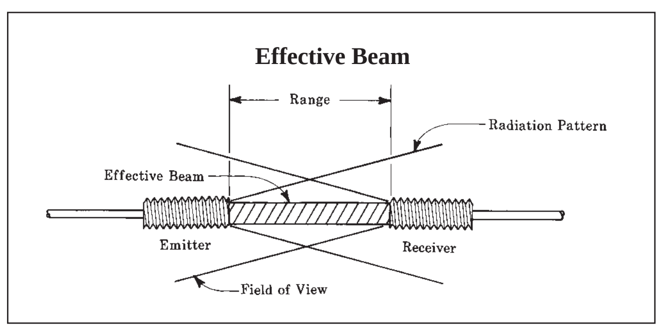
divergent sensing mode
A variation of the diffuse photoelectric sensing mode in which the emitted beam and the receiver’s field of view are both very wide. Divergent mode sensors have very forgiving alignment requirements, but have shorter sensing range as compared to diffuse mode sensors of the same basic design. Divergent sensors are particularly useful for sensing transparent or translucent materials or for sensing objects with irregular surfaces (e.g. webs with "flutter"). They are also used to reflectively sense objects with very small profiles, like small diameter thread or wire, at close range.



Examples of divergent sensors include MINI-BEAM model SM312W and remote sensor model LP400WB. All unlensed bifurcated fiber optics are divergent. The divergent mode is sometimes called the "wide beam diffuse (or proximity) mode".

DPDT relay
Abbreviation for "Double-Pole Double-Throw". A relay with two sets of single-pole double-throw form 1C contacts that are operated simultaneously by a single action. See **"SPDT relay"**.

effective beam
The "working" part of a photoelectric beam. The portion of a beam that must be completely interrupted in order for an object to be reliably sensed. Not to be confused with the actual radiation pattern of the emitter, or with the field of view of the receiver.



electromechanical relay
Conventional switching relays consisting of "hard" contacts (metal-to-metal), switched to opened or closed position by applying voltage to an electromagnetic coil. Can be constructed to reliably switch loads which demand much higher power levels than can be switched by most solid-state relays. Limited by relatively slow switching speeds and finite mechanical life.

electromagnetic interference (EMI)
Electrical "noise" which may interfere with proper operation of sensors, programmable logic controllers, counters, data recorders, and other sensitive electronic equipment. Common sources of EMI include lighting fixtures and controls, motors, generators, and contactors. EMI emissions are distributed evenly across the radio frequency spectrum. Emissions are readily conducted along cables, so EMI sources can often be found by following along wireways with a portable radio or with model BT-1 BEAM TRACKER.

emitter (photoelectric)

1. The sensor containing the light source in an opposed mode photoelectric sensing pair (see **"opposed sensing mode"**).
2. The light emitting device within any photoelectric sensor (e.g. LED, incandescent bulb, laser diode, etc.).

enable

To allow an output to occur in response to an input signal. Synonomous with "interrogate" when used to describe the gating function in an inspection scheme. See **"inspection logic"**.

excess gain

A measurement of the amount of light energy falling on the receiver of a sensing system over and above the minimum amount of light required to just operate the sensor's amplifier. In equation form:

$$\text{EXCESS GAIN} = \frac{\text{Light energy falling on receiver}}{\text{Amplifier threshold}}$$

Excess gain is a specification of every photoelectric sensor. It is plotted versus sensing distance. Excess gain values are used in the sensor selection process to predict the reliability of a photoelectric sensor in a known sensing environment.

Excess Gain Guidelines

OPERATING ENVIRONMENT	EXCESS GAIN REQUIRED
Clean air. No dirt buildup on lenses or reflectors	1.5
Slightly dirty. Slight buildup of lint, paper, dust, moisture, or film on lenses or reflectors; lenses cleaned regularly	5
Moderately dirty. Obvious contamination of lenses and reflector, but not obscured; Lenses cleaned occasionally or when necessary	10
Very dirty. Heavy contamination of lenses; fog, mist, or dust. Minimal cleaning of lenses.	50 or more

Factory Mutual Research (FM)

Tests and approves products for use in hazardous areas. See logo at right.

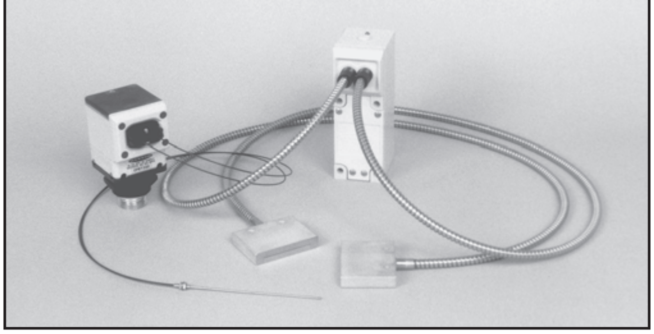
false pulse protection

Circuitry designed to disable the output of a sensor or sensing system until the power supply circuit has time to stabilize at the proper voltage level. Typically 100 - 300 milliseconds (this time is always specified).

FET (Field Effect Transistor)

Bilateral FETs are semiconductors used as the output switch of some sensing devices for their ability to switch either ac or dc, their low on-state voltage drop, and their low off-state leakage current. Not tolerant of inrush current, typical of inductive loads.

Banner Glass and Plastic Fiber Optics



fiber optics

Transparent fibers of glass or plastic used for conducting and guiding light energy. Used in photoelectrics as "light pipes" to conduct sensing light into and out of a sensing area.

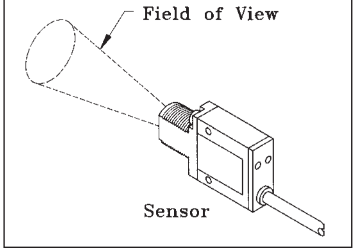
Glass fiber optic assemblies consist of a "bundle" of small (about .002" diameter), discrete, glass optical fibers housed within a flexible sheath. Glass fiber optics are able to withstand hostile sensing environments. Plastic fiber optic assemblies are made up of either one or two acrylic monofilaments in a flexible sheath. Plastic fiber optics comprise the smallest group of photoelectric sensors.

There are two basic styles of fiber optic assemblies: individual and bifurcated. Individual fiber optic assemblies guide light from an emitter to a sensing location, or to a receiver from a sensing location. Bifurcated fibers use half of their fiber area to transmit light and the other half to receive light. See **"individual fiber"** and **"bifurcated fiber"**. (Photo above.)

field of view

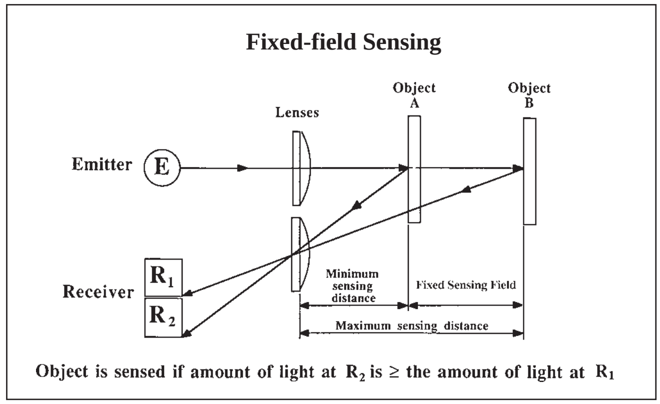
Refers to the area of response of a photoelectric sensor (receiver).

Field of View



fixed-field sensing mode

A photoelectric proximity sensing mode with response that is similar to a diffuse sensor, but with a defined range limit. The amount of reflected light received by each of two optoelements is compared. An object is recognized as long as the amount of light reaching receiver R_2 is equal to or greater than the amount seen by R_1. The sensor's output switches as soon as the amount of light at R_1 becomes greater than at R_2 .



flip-flop

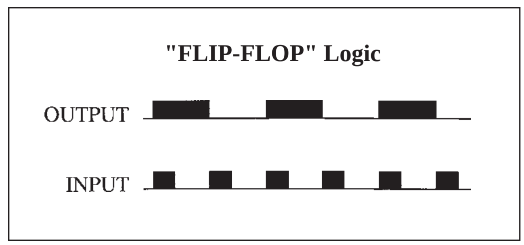
An electronic circuit with two stable states (Hi and Low, On and Off, etc.). The circuit remains in one of the states until application of an external signal causes it to change to the opposite state. See timing diagram below.

In sensing logic schemes, a flip-flop is a function that switches a load from "off" to "on" and back again with each sequential input. Also known as "alternate action logic", "ratchet logic", or "divide-by-two logic". Used to split production lines into two lanes.

fluorescence

The emission by a material of light radiation at a longer wavelength as a result of the absorption of some other radiation of shorter wavelengths. For example, the emission of visible light as a result of excitation by ultraviolet light.

gain adjustment (see **"sensitivity adjustment"**)



gate

1. A combinational logic circuit having one or more input channels.
2. Used as shorthand for "interrogate". See **"inspection logic"**.

glass fibers

Single glass optical fibers are small strands (typically .002 inch diameter) of glass with an outer cladding of glass of a different index of refraction (used to contain light energy as it is conducted along the fiber's length).

Glass fiber assemblies are constructed of a bundle of individual glass fibers, contained and protected by a sheath (typically a flexible armored cable). See **"fiber optics"**.

ground

An often misused term. In power distribution systems it refers to earth ground. It is important at high power levels mainly for safety reasons.

Within a manufacturing plant, it generally refers to conduit or machine frame ground.

In electronic systems, it refers to the electronic chassis or enclosure ground or to dc common (voltage reference to the negative side of a dc power supply).

hermetic seal

An air-tight seal. In photoelectrics, the lens assemblies of some sensors have hermetic seals to exclude the entrance of air and water behind the lens, thereby preventing fogging of the inner surface of the lens.

Hertz (Hz)

The international unit of frequency, equal to one cycle per second. Named after the German physicist Heinrich Rudolph Hertz.

holding current

1) A specification of a load, especially an electromechanical load. The current that is drawn by a load while it is energized. Also called "sealed current" of a load. See **"inrush current"**.
2) The current necessary to maintain a thyristor in the "on" state.

hysteresis, switching

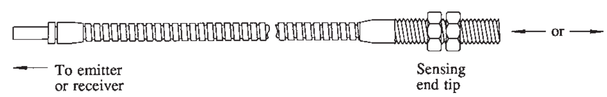
Meaning "to lag behind". An electronic design consideration for sensors such that the operate point (received light level, etc.) is not the same as the release point of the sensor output. This differential prevents the output of a sensor or sensing system from "buzzing" or "chattering" when a signal at or near the threshold level is detected.

IEC
The International Electrotechnical Commission, headquartered in Geneva, Switzerland. This organization writes and distributes recommended safety and performance standards for electrical products and components. See **"IP rating"**.

impedance
The opposition in an electric circuit to the flow of alternating current (ac) at a given frequency. Impedance consists of resistance, inductive reactance, and capacitive reactance. It is measured in ohms.

individual fiber (optic)
A fiber optic assembly having one control end and one sensing end. Used for piping photoelectric light from an emitter to the sensing location or from the sensing location back to a receiver. Usually used in in pairs in the opposed sensing mode, but can also be used side-by-side in the diffuse proximity mode or angled for the specular reflection or mechanical convergent mode.

Individual Fiber Optic

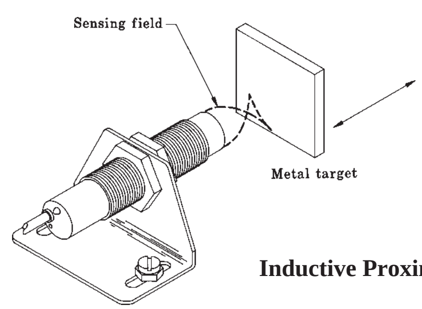


inductance
The property of an electric circuit whereby an electromotive force (emf) is induced in it by a change of current in itself or in a neighboring circuit. When a current changing at the rate of one ampere per second induces a voltage of 1 volt, the inductance of the circuit is 1 *henry*.

inductive load
Electrical devices generally made of wire that is coiled to create a magnetic field to, in turn, produce mechanical work when energized. Examples of inductive loads include motors, solenoids, and relays.

Inductive loads exhibit *inrush* of current when energized that can be many times the steady state *holding* current. When de-energized, the magnetic field collapses, generating a high voltage transient. This transient can cause arcing across mechanical switching contacts or can cause damage to solid-state contacts. See **"transient"**.

inductive proximity sensor
Sensors with an oscillator and coil which radiate an electromagnetic field that induces eddy currents on the surface of metallic objects approaching the sensor face. The eddy currents dampen the oscillator energy. This energy loss is sensed as a voltage drop, which causes a change in the sensor's output state. Often called simply a "proximity sensor".



Inductive Proximity Sensor

infrared (IR)
Light with wavelengths generally greater than 800 nanometers (8000 Angstroms). Invisible to the eye and safe to most photographic films. Infrared LEDs used as the emitter source in photoelectric sensors offer the highest amount of excess gain. See **"LED"**.

inhibit
In sensing logic schemes, an inhibit signal (e.g. from an inspection sensor) cancels a timing function and/or output. See **"inspection logic"**.

input
1. The signal (voltage or current) applied to a circuit to cause the output of that circuit to change state.
2. The terminals, jack, or receptacle provided for reception of the input signal.

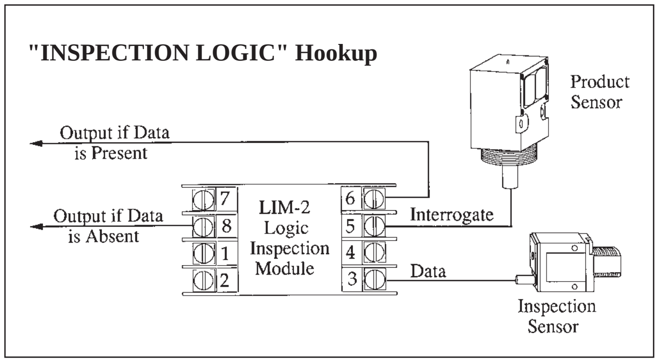
input voltage
The power source required by an electric or electronic device (e.g. a self-contained sensor) in order for the device to operate properly.

inrush current
The initial surge of current through a load when power is first applied. An important specification to consider whenever evaluating an interface. Inrush current to an inductive load (solenoid, contactor, etc.) is up to ten times the holding current.

inspection logic

A logic scheme used in high-speed inspection applications that generally uses two sensors as inputs. One sensor, called the "product sensor" senses the product's presence and "interrogates" the "inspection sensor". If the inspection sensor "sees" a good product, it "inhibits" the inspection logic from rejecting the product.

The output of the inspection logic can be a pulse to reject or a latch to divert. The output might also be used as the input to a shift register for downstream reject control. Module model LIM-2 provides programmable parameters for various inspection logic schemes.



interrogate

In sensing logic schemes, an *interrogate* signal (e.g. from a product sensor) allows the information from one or more other inputs (e.g. an inspection sensor) to be recognized by the inspection or control logic. Also called "gate" or "enable". See **"inspection logic"**.

intrinsic safety

A design technique applied to electrical equipment (e.g. sensors and switches) and wiring for hazardous locations. The technique involves limiting electrical and thermal energy to a level below that required to ignite a specific hazardous atmosphere. Intrinsic safety design often eliminates the requirement for expensive and awkward explosion-proof enclosures.

intrinsic safety barrier

A protective component designed to limit the voltage and current in a hazardous area. The barrier functions outside of the hazardous location to divert abnormal energy to ground. A barrier that is used in conjunction with an SMI912 Series sensor and a CI3RC control module makes a complete intrinsically-safe sensing system.

inverter (circuit)

A circuit whose output is always in the opposite state (or phase) from the input. Also called a "NOT" circuit.

IP rating

A rating system established by IEC Publications 144 and 529 which defines the suitability of sensor and sensor system enclosures for various environments. Similar to NEMA ratings for enclosures.

kilohm (k)

One thousand ohms. 1kΩ = 1,000Ω

laser

An active electron device that converts input power into a narrow, intense beam of coherent visible or infrared light. The input power excites the atoms of an optical resonator to a higher energy level, and the resonator forces the excited atoms to radiate in phase. Term derived from "Light Amplification by Stimulated Emission of Radiation".

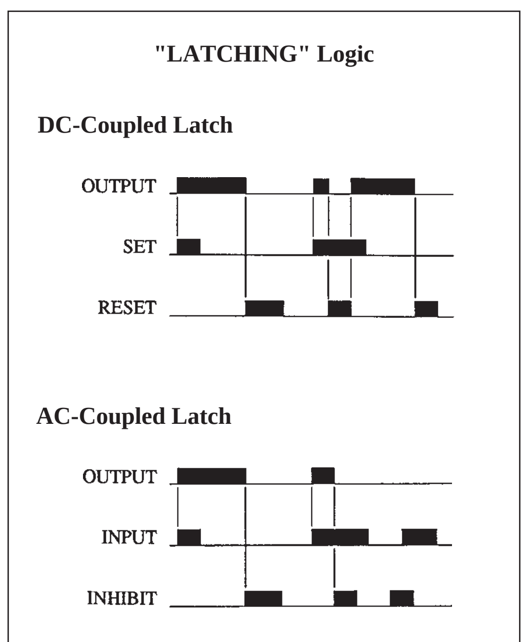
laser diode

A laser employing a forward-biased semiconductor junction as the active medium. Also called "diode laser" or "semiconductor laser".

latch (latching logic)

A logic function in which an input signal (e.g. from a sensor) locks "on" the output. The output remains "on" until a signal is applied to a second input to reset the latch.

The output of a "dc latch" will immediately latch "on" again if the input signal is present when the reset signal is removed. The reset signal of an "ac latch" will cancel the output, even if the input signal remains when the reset is removed. The output will not re-latch until the reset signal is removed and then the input signal is removed and then reapplied.



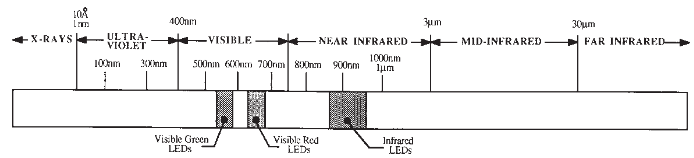
leakage current

The small amount of (undesirable) current that is inherent in solid-state switches when they are in the "off" state. Most commonly encountered with 2-wire sensors that require leakage current in order to remain powered in the "off" state. High leakage current values are also inherent in some triac switches. Becomes important if the resultant "off" state voltage across the load being switched is too high for the load to de-energize. (The "off" state voltage across the load is equal to the leakage current of the switch multiplied by the resistance of the load.)

LED (Light Emitting Diode)

A semiconductor that emits a small amount of light when current flows through it in the forward direction. In Banner photoelectric sensors, LEDs are used both as emitters for sensing beams and as visual indicators of alignment or output status (see **"AID"**). Banner sensors use visible red, visible green, or infrared (invisible) LEDs.

Wavelengths of Commonly-used Light Emitting Diodes (LEDs)



lens

The optical component of a photoelectric sensor that collimates or focuses emitted light rays and/or focuses incident light rays upon the receiver optoelement.

light curtain (light screen)

An array of photoelectric sensing beams configured to sense objects passing anywhere through an area (sensing plane). Some light curtains process the data from the array to measure the profile of the object or track its movement within the array. "Safety light curtains" are used to detect personnel who move into an unsafe area of a machine.

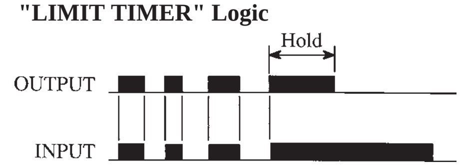
light operate mode (L.O. or L/O)

The program mode for a photoelectric sensor in which the output energizes (or the timing logic begins) when the receiver becomes sufficiently light.

limit timer

Also called a "time-limited on-off" function. A timing logic function where the output follows the input ("on-off" operation). However, an input signal that is longer than the adjustable "LIMIT" time will turn the output "off". This function is useful for conserving energy during times of machine inactivity.

"LIMIT TIMER" Logic



linear output

Refers to the output of an analog sensor that has a "straight-line" relationship to a sensing parameter (e.g. sensing distance). A linear output is characteristic of analog ultrasonic sensors.

line-scan camera

A camera whose light-sensing element consists of a linear array of photodiodes, providing a high degree of resolution for precision measurement in one dimension. Also provides an economical means of detecting the presence or size (or feature or defect) of an object anywhere within a wide area of scan.

line voltage

The normal in-plant power line supply voltage which is usually 120 or 220/240V ac.

load

A general term for a device (or a circuit) that draws power when switched by another device (or circuit).

logic high

The higher of two voltage levels in a digital circuit.

logic level

Refers to the state of an input to or an output from a digital circuit (not applicable to analog circuits). It is always at one of only two possible voltages: "low" being a voltage usually less than 2 volts measured with respect to ground; and "high" being a voltage of some nominal level, usually within 2 volts of the positive supply.

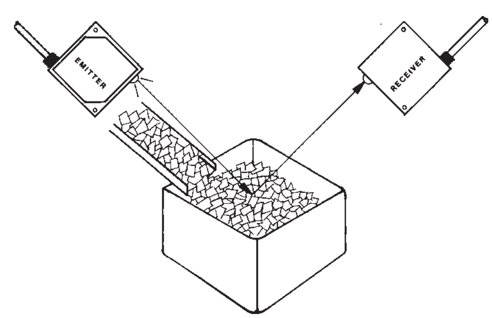
logic low
The lower of two voltage levels in a digital circuit.

logic module
A sensing system accessory that interprets one or more input signals (e.g. from sensors, limit switches, or other logic modules) and modifies and/or combines those input signals for control of a process. A logic module is sometimes an integral part of a sensor assembly, as in OMNI-BEAM, MULTI-BEAM, MAXI-BEAM, and Q85 Series sensors with timing logic modules.

M Series
Banner's original product line of solid-state modulated photoelectric amplifier modules. Features aluminum construction with relay-style octal base for plug-in operation with Banner MRB control chassis. M Series modules offer complete selection of timing logic functions. Inputs are derived from Banner's line of modulated remote sensors. M Series modules have been superseded by the MAXI-AMP CM Series of stand alone modulated amplifier modules.

mechanical convergence
A less precise form of convergent sensing as compared to the optical convergent beam sensing mode. In mechanical convergence, an emitter and a receiver are simply angled toward a common point, ahead of the sensor(s). This approach to reflective sensing results in more efficient use of light energy as compared to diffuse mode sensing, and a greater depth-of-field than realized with true optical convergence. Sensor model SE612C is an example of mechanical convergent design. Mechanical convergence may also be customized for an application by mounting the emitter and receiver of an opposed sensing pair to mechanically converge at the desired distance. Depth-of-field is controlled by adjusting the angle between the emitter and the receiver.

Mechanical Convergence



megohm (meg)
One million ohms. 1megΩ = 1,000,000Ω

"MHS"
A model number suffix designating **M**odified for **H**igh **S**peed. Most often used to increase the response of modulated dc sensors with design response speed of 1 millisecond to 300 microseconds (0.3 millisecond). When this modification is made to most modulated amplifiers there is a loss of available gain of about 50 percent.

microsecond
One millionth of a second. 1 microsecond = 0.000001 second or 0.001 millisecond. Abbreviated: **µs**

millisecond
One thousandth of a second. 1 millisecond = 0.001 second or 1000 microseconds. Abbreviated: **ms**

modulation
In photoelectrics, modulation of an LED simply means to turn it on and off at a high frequency (typically several kilohertz). The secret of a modulated photoelectric sensor's superior performance is that the sensor's phototransistor and amplifier are *tuned* to the frequency of modulation. Only the modulated light is amplified, and all other light which reaches the receiver is ignored. This is analogous to a radio receiver which tunes solidly to one station, while ignoring all of the other radio waves that are present in the room. In fact, a modulated sensor's LED is most often referred to as the *transmitter* or *emitter* and its phototransistor as the *receiver*.

MOV (metal oxide varistor)
A component designed to protect solid-state output devices and other sensitive electronic equipment from damaging effects of transient voltage spikes. When voltage spikes occur across an MOV, its impedance changes from very high to very low, clamping the transient voltage to a protective level. The excess energy of the high voltage pulse is absorbed by the MOV (or conducted to ground). MOVs are rated by their clamping voltage and by their peak pulse current capacity.

multiplexing
A scheme in which an electronic control circuit interrogates each sensor of an array in sequence. "True" photoelectric multiplexing enables each modulated emitter only during the time that it samples the output of the associated receiver. In this way, the chance of false response of any receiver to the wrong light source is eliminated. Model MP-8 is an example of a "true" photoelectric multiplexer.

nanometer (nm)

Unit of length used to specify the wavelength of light energy. 1 nm = 0.000000001 meter (10^{-9} meter). 1 nm = 10 Angstroms. 1 nm = .001 microns. Some typical wavelengths: red LEDs are 650 nm, green LEDs are 560 nm, infrared LEDs are 880 or 940 nm. See **"LED"**.

NEMA

National Electrical Manufacturers Association. NEMA standards are used to specify suitability of sensor and sensing system enclosures for various sensing environments.

NEMA 1	Indoor use	Protects against accidental contact by personnel & falling dirt
NEMA 2	Indoor use	Protects against falling dirt & liquid & light splash
NEMA 3	Outdoor use	Protects against rain, sleet, snow, dirt, & dust
NEMA 3S	Outdoor use	Protects against rain, sleet, snow, dirt, dust & ice buildup
NEMA 4	In- or outdoor	Protects against dirt, dust, hosedown (and heavy splash)
NEMA 4X	In- or outdoor	Protects against dirt, dust, hosedown, & corrosion
NEMA 6	In- or outdoor	Protects against dirt, dust, hosedown, & occasional submersion
NEMA 6P	In- or outdoor	Protects against dirt, dust, hosedown, & prolonged submersion
NEMA 7	Indoor use	For use in areas of explosive gases or vapors or combustible dust
NEMA 9	Indoor use	For use in areas of atmospheres containing combustible dust
NEMA 12	Indoor use	Protects against dirt, dust, light splash, & oil or coolant seepage
NEMA 13	Indoor use	Protects against dirt, dust, light splash, & oil or coolant spray

noise (electrical)

Term used to collectively describe undesirable energy that may cause false response of sensing system logic or may be falsely recognized as a received signal by a sensor amplifier. Includes EMI (electromagnetic interference) and RFI (radio frequency interference).

Common sources of EMI are lighting fixtures and controls, motors, generators, and contactors. EMI is readily coupled to and conducted along wireways.

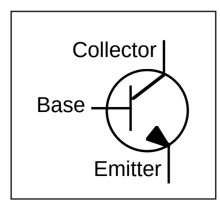
RFI generators include in-plant two-way radios, stepper motor controls, computers, and CRTs. RFI occurs most often within a narrow band of frequencies. As a result, one electronic instrument may be radically affected by presence of RF interference, while another similar instrument in the same area may appear completely immune.

Not all sources of noise are continuous. For example, an arcing relay may emit a burst of EMI *and* RFI when its contacts open. The Banner model BT-1 BEAM TRACKER is a valuable tool used in tracking the source of interfering noise.

NPN output

A transistor available as an output switch in most dc sensors and logic modules. Usually configured with its collector open and its emitter connected to ground (dc common). In this configuration, a load is connected between the output (collector) and the positive of the dc supply. This output configuration is also called a "sinking" output. See **"current sinking output"**.

Isolated NPN transistors are sometimes offered as output switches, and can be used to either sink *or* source current to a circuit input. The drawing at the right shows the electronic symbol for an NPN transistor.



NPS thread

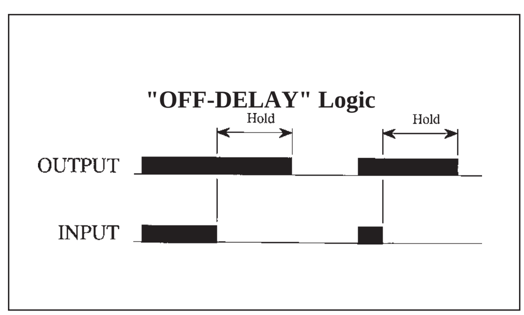
"NPS" is used as shorthand for "NPSM" which designates thread form according to the American National Standard Straight Pipe Thread for Free-fitting Mechanical Joints (ANSI $B_{2.2}$). This thread form is similar to the more widely recognized ANSI Standard Taper Pipe Thread (NPT), except that thread diameters remain constant along the length of the threads. NPSM threads are popular for electrical conduit assemblies where there is no requirement for sealing against internal pressure.

null

This term is used in analog sensing and control to desribe the minimum voltage (or current) in an analog output range. Analog sensors have an adjustment for setting the null value.

off delay (off delay logic)

Timing logic in which the output energizes immmediately when an input signal is received, and remains energized as long as the input signal is present. The off-delay timing begins at the trailing edge of the input signal, keeping the output energized. If a new input signal is received during the off-delay timing, the timer is reset, and the off-delay period begins again at the trailing edge of

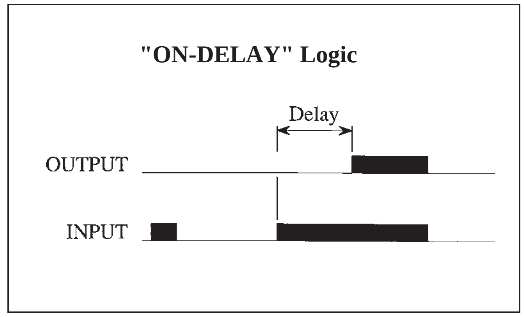


the new input signal. Off-delay timers allow sensing controls to ignore intermittent signal losses in tracking or flow control applications.

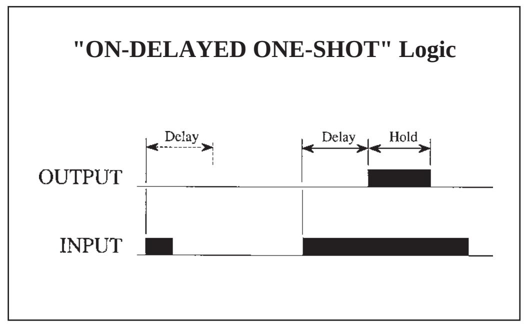
ohm
Unit of measurement for resistance and impedance. The resistance through which a current of one ampere will flow when one volt is applied.

Ohm's law
E = I x R. Current (I) is directly proportional to voltage (E) and inversely proportional to total resistance (R) of a circuit.

on delay (on delay logic)
Timing logic in which timing begins at the leading edge of an input signal, but the output is energized only after the preset on-delay time has elapsed. The output ceases immediately at the trailing edge of the input signal. If the input signal is not present for the on-delay time period, no output occurs. If the input signal is removed momentarily and the reestablished, the on-delay timing starts over again from the beginning. Used to allow sensing controls to ignore short interruptions of the light beam, such as the normal flow of products past a sensor in fill-level or flow control applications.

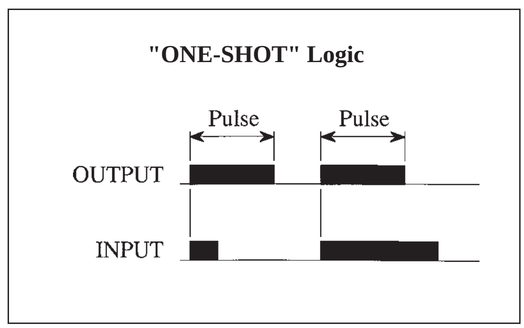


on-delayed one-shot (logic)
Timing logic which combines on delay and one-shot timing into a single function. The input signal must be present for at least the time of the on-delay in order for a timed one-shot pulse to occur. (Contrast this to "delayed one-shot" timing logic, where a timed one-shot pulse occurs for any input signal, momentary or maintained.) No subsequent output can occur until the input is removed and then reapplied, at which time the delay period begins again. Useful for jam detection applications.

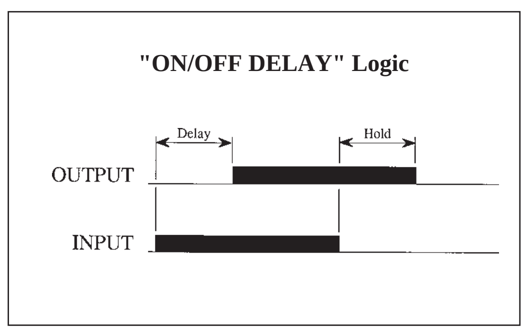


on-demand scanning (see also **"continuous scanning"**)
A mode of scan control in light-curtain type systems in which each scan through a beam array is individually initiated when required. Used in the BEAM-ARRAY Measuring Light Curtain system.

one-shot (one-shot logic)
Timing logic in which a timed output pulse begins at the leading edge of an input signal . The pulse is always of the same duration, regardless of the length of the input signal. The output cannot reenergize until the input signal is removed and then reapplied. A one-shot timer is useful for initiating a control function keyed to the passing of either the leading or trailing edge of a product. It is also used in "on-the-fly" inspection applications (see **"inspection logic"**). Also called "single-shot logic", "pulse timer", or "pulse stretcher".



on/off delay (on/off delay logic)
Timing logic which combines on delay and off delay timing into a single function. On/off delay logic is often used in jam and void control, high/low level control, and edgeguiding applications.

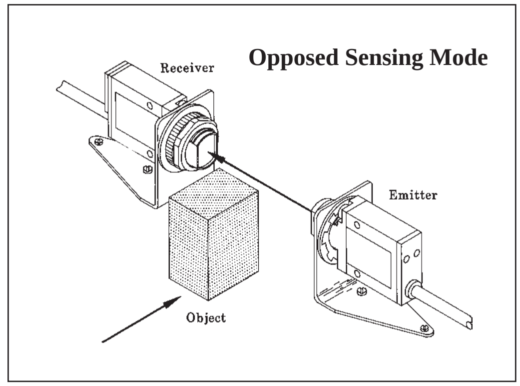


opaque
A term used to describe a material that blocks the passage of light energy. "Opacity" is the relative ability of a material to obstruct the passage of light.

open-collector
A term used to describe the NPN or PNP output of a dc device, where the collector of the output transistor is not connected to any other part of the output circuit (except through a diode for protection). Analogous to a SPST relay contact. See **"NPN"** and **"PNP"**.

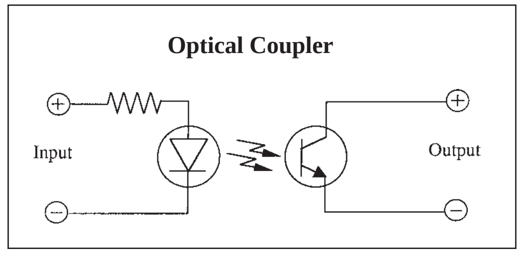
opposed sensing mode

A photoelectric sensing mode in which the emitter and receiver are positioned opposite each other so that the light from the emitter shines directly at the receiver. An object then breaks the light beam that is is established between the two. Opposed sensing will always result in the most reliable photoelectric sensing system, as long as the item to be detected is opaque to light. Opposed sensing is the most efficient photoelectric sensing mode and offers the highest level of optical energy to overcome lens contamination, sensor misalignment, or long scanning ranges. Also often referred to as "direct scanning" and sometimes called the "beam-break" mode.



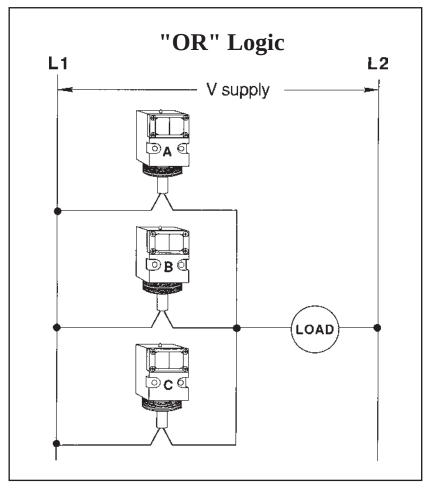
optical coupler (optical isolator)

A solid-state photoelectric device combining a light-emitting diode (LED) and a phototransistor in a single package, so that when power is applied to the LED, the phototransistor conducts. This is the equivalent of a solid-state relay contact (SPST normally open) except that normally only currents of a few milliamps can flow through the phototransistor. The advantage of this type of coupling is total electrical isolation of the output from the input. Since the input and output communicate only by light, the main use is to interface two systems without the use of interconnecting lines. The result is exceptional noise immunity. Optical couplers are of great benefit when interfacing systems which include programmable logic controllers, computers, microprocessors, and instrumentation equipment.



OR logic

A logic function in which the presence of *any* of two or more defined input conditions will cause a load to energize (A *or* B *or* C = output). Usually created by wiring all outputs in parallel to a load.



output

1. The section of a sensor or control circuit that energizes and/or de-energizes the attached load (or input).
2. The useful energy delivered by a circuit or device.

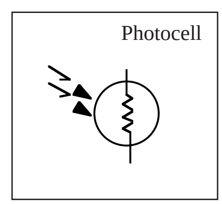
parallel operation

Refers to the interconnection of two or more output devices (e.g. several sensor outputs) in parallel to a single input or load. See **"OR logic"**.

passive pullup (see **"pullup resistor"**)

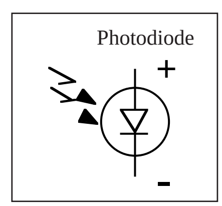
photocell

A resistive photosensitive device in which the resistance varies in inverse proportion to the amount of incident light. The most common light-sensitive materials used are cadmium sulfide and cadmium selenide. Such devices are characterized by resistances of from 1000 ohms to 1 megohm, response speed of several milliseconds, and color response roughly equivalent to that of the human eye. Also called "photoresistor". (See electronic symbol at right.)



photodiode

A semiconductor diode in which the reverse current varies with illumination. Characterized by linearity of its output over several magnitudes of light intensity, very fast response time, and wide range of color response. (See electronic symbol at right.)

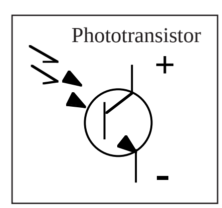


photoelectric sensor

A device which detects a visible or invisible beam of light and responds to a change in received light intensity.

phototransistor

A photojunction device in which current flow is directly proportional to the amount of incident light. The phototransistor is characterized by impedances of from 1000 ohms to 1 megohm in most low level DC circuits. Response times are inversely proportional to incident light, but moderately high light levels yield response well under 1 millisecond. Color response is poor to greens and blues but good to reds and near infrareds. Phototransistors are well matched spectrally to infrared LEDs. (See symbol at right.)

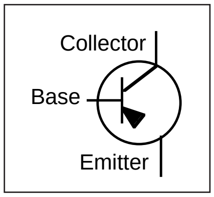


pixel
Contraction of "picture element". An individual element in a digitized image array.

plastic fiber optics (see **"fiber optics"**)

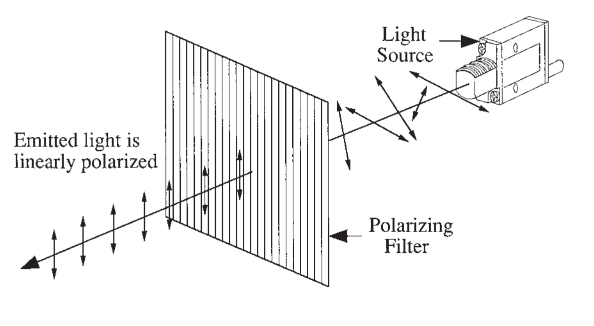
plug logic
A family of Banner octal-base plug-in logic modules. They operate on low voltage dc , and accept inputs from sensors and devices with NPN transistor (current sinking or isolated) or hard contact closure outputs. Popular Plug Logic modules include: model BN2-2 dual NAND gate, model LIM-2 logic inspection module, and model LSR64 shift register.

PNP output
A transistor available as an output switch in most dc sensors. Usually configured with its collector open and its emitter connected to the positive of the sensor supply voltage. In this configuration, a load is connected between the output (collector) and ground (dc common). This output configuration is also called a "sourcing" output. See **"current sourcing output"**. The drawing at the right shows the electronic symbol for a PNP transistor.



polarized light
Light which has all component waves in the same direction of displacement. Natural light is made up of waves having a variety of displacements. Photoelectric sensors with polarizing filters emit and detect only light waves of a specific polarization, while rejecting unwanted light of other polarizations. Also, various materials "bend" light waves (alter polarization) by known amounts. This may be used to advantage to photoelectrically detect certain materials while ignoring others.

Polarized Light



polarizing filter
A filter that polarizes light passing through it. It is possible to fabricate sheets of plastic or gelatin that contain birefringent crystals so oriented as to pass only polarized light. Also called "anti-glare filters" when used on retroreflective mode sensors.

power block
The component of a modular self-contained sensor (e.g. OMNI-BEAM, MULTI-BEAM, or MAXI-BEAM) that provides the power to run the sensor and also provides the output circuitry to interface with the external load or circuit being controlled. See **"scanner block"** and **"sensor head"**.

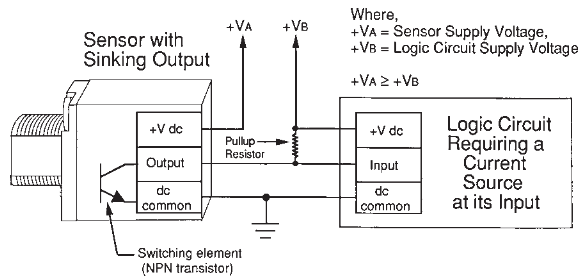
programmable logic controller (PLC)
A control device, usually used in industrial control applications, that employs the hardware architecture of a computer and relay ladder diagram language. Inputs to PLCs can originate from many sources including sensors and the outputs of other logic devices. Banner sensors and logic devices are all designed for ease of interfacing to PLCs. Also called "programmable controller".

proximity sensing mode
Direct sensing of an object by its presence in front of a sensor. For example, an object is sensed when its surface reflects a sound wave back to an ultrasonic proximity sensor. Also see **"diffuse mode** (photoelectric) **sensing"**.

proxing
In retroreflective sensing, "proxing" is used to describe undesirable reflection of the sensing beam directly back from an object that is supposed to *break* the beam. When sufficient light is reflected from the object back to the sensor, the sensor thinks it is seeing the retroreflective target, and the object may pass undetected. This is a common problem encountered when attempting to retroreflectively sense highly reflective objects. There are a number of cures for proxing, including use of anti-glare (polarizing) filters, angling of the retroreflective sensor and its target, and substitution of opposed mode sensors.

pullup resistor
A resistor connected to the output of a device to hold that output voltage higher than the input transition level of a digital circuit. Usually a resistor connected between the output of a current sinking (NPN) device and the positive supply voltage of a logic gate.

Pullup Resistor



Hookup of a current sinking output to a logic input requiring a current source, using a pullup resistor.

pulse modulated (see **"modulation"**)

pulse stretcher (see **"one-shot"**)

PVC (polyvinyl chloride)
A member of the vinyl plastic resin family, with many applications, including jacketing of wire and fiberoptic cables. Characterized by its high degree of flexibility and good chemical resistance.

QD (quick disconnect)
A cable attachment scheme used on some Banner sensors, in which a male connector in the base of the sensor mates with the female connector of an industrial-grade cable. The QD feature is standard on ULTRA-BEAM ultrasonic sensors and on VALU-BEAM SMI912 Series intrinsically-safe sensors. A built-in QD connector is available as an option on other sensors. A QD fitting can also be installed in the wiring base of any OMNI-BEAM, MULTI-BEAM, MAXI-BEAM, or Q85 Series sensor. This feature is indicated by the letters "Q" or "QD" in the model number suffix.

radiation pattern (see **"effective beam"**)

radio frequency interference (RFI)
Interference caused by electromagnetic radiation at radio frequencies to sensors or to other sensitive electronic circuitry. RFI may originate from radio control equipment, stepper motor controls, CRTs, computers, walkie-talkies, public service communications, commercial broadcast stations, or a variety of other sources. RFI occurs most often at a specific frequency or within a specific range of frequencies. As a result, one electronic instrument may be radically affected by the presence of RF interference, while another similar instrument in the same area may apppear completely immune.

In reference to photoelectric sensing, the usual effect of RFI is the generation of false signals and the random "triggering" of equipment or processes that are controlled by the sensors. Usual curative measures include proper shielding and grounding of the affected device and also of the source, if it can be located. The Banner model BT-1 BEAM TRACKER is an invaluable aid for tracking down sources of RFI and EMI, and allows the tracking of RFI across open areas.

range (sensing range)
The specified maximum operating distance of a sensor or sensing system:

Opposed sensing mode: the distance from the emitter to the receiver
Retroreflective sensing mode: the distance from the sensor to the retro target
Proximity sensing modes: the distance from the sensor to the object being sensed

ranging (see **"sensing window"**)

rate sensor
Timing logic in which overspeed or underspeed conditions are sensed by a circuit that continuously monitors and calculates the time between input signals, and compares that time with a preset reference. In Banner rate sensing logic the output *drops out* if the preset rate is not met (underspeed) or is exceeded (overspeed).

receiver
The transducer element that responds to the sensing energy. Also the name for the half of an opposed pair of photoelectric or ultrasonic sensors that receives the sensing energy from the emitter.

reflectivity (relative)

A measure of the efficiency of any material surface as a reflector of light, as compared to a Kodak white test card which is arbitrarily rated at 90% reflectivity. Relative reflectivity is of great importance in photoelectric proximity modes (diffuse, divergent, convergent, and fixed-field), where the more reflective an object is, the easier it is to sense.

RELATIVE REFLECTIVITY TABLE

Material	Reflectivity (%)	Excess Gain Required
Kodak white test card	90%	1
White paper	80%	1.1
Masking tape	75%	1.2
Beer foam	70%	1.3
Clear Plastic*	40%	2.3
Rough wood pallet (clean)	20%	4.5
Black neoprene	4%	22.5
Natural aluminum, unfinished*	140%	0.6
Stainless steel, microfinish	400%	0.2
Black anodized aluminum*	50%	1.8

*NOTE: For materials with shiny or glossy surfaces, the reflectivity figure represents the maximum light return, with the sensor beam *exactly perpendicular* to the material surface

reflex sensing mode

(see **"retroreflective sensing mode"**)

refraction

The "bending" of light rays as they pass through the boundary from a medium having one refractive index into a medium with a different refractive index. For example, as from air into water or from air into glass or plastic.

registration mark

A mark printed on a material using a color that provides optical contrast to the material color. The mark is sensed as it moves past a photoelectric color sensor. Registration marks are used for cutoff control as in a wrapping or bagging operation, or for product positioning as in a tube end crimping process.

relay

A switching device, operated by variations in the conditions of one circuit, which serves to make or break one or more connections in the same or another circuit. May be mechanical, as in the common electromechanical relay having an electromagnetic coil and metal contacts. Or, may be solid-state, in which switching is accomplished by a solid-state element such as a transistor or SCR. Relays are used as output switching devices for sensors and control modules, and serve to interface the sensor or module to the circuit under control.

remote sensor

The remote photoelectric sensor of a *component system* contains only the optical elements. The circuitry for system power, amplification, logic, and output switching are all located at a central location, typically in a control cabinet. As a result, remote sensors are generally the smallest and the most tolerant of hostile sensing environments. Remote sensors include those which are used with the Banner MAXI-AMP & MICRO-AMP modules.

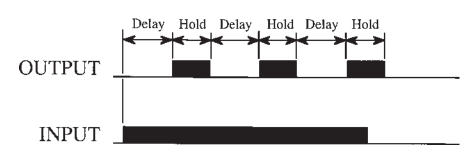
rep rate (scan rate)

In photoelectrics, this term is used to describe the time taken to interrogate each optoelement in a scanned array of receivers (e.g. for a line-scan camera, a multiplexed array of emitters and receivers, or a light curtain). It is the time from the start of one complete scan until the start of the next scan. The rep rate is one parameter that determines the system response speed. In general, higher light level is required for faster rep rates.

repeat-cycle timer (repeat cycler)

Timing logic in which an input signal begins a delay period, during which there is no output. If the signal remains, the delay period is followed by a hold period, during which the output is energized. If the input signal remains after the first hold period, a new delay period is started, followed by the hold period, etc. This sequence continues indefinitely until the output signal is removed. One application is in edgeguide and other guidance control applications where it is desireable to pulse the correction mechanism to avoid overcorrection that might occur with a continuous output.

"REPEAT CYCLER" Logic



repeatability

A measure of the repeat accuracy of a sensor and/or timer and/or control mechanism (e.g. motor, brake, solenoid, etc.). Usually expressed as a distance or time.

resistance

The opposition to the flow of electric current. That property of a material which impedes electrical current and results in the dissipation of power in the form of heat. Resistance is measured in ohms.

Resistor (symbol)

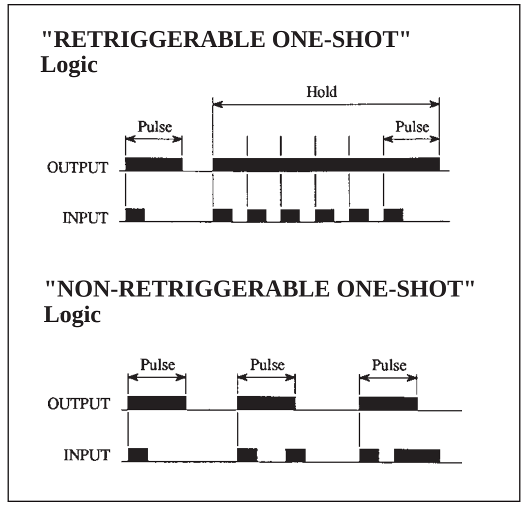
resolution

In presence sensing: the smallest part profile dimension that will be reliably sensed.
In position sensing applications: the smallest increment of distance that can be repeatably sensed.
In line-scanning: the projected distance between two adjacent pixels, i.e. the size of the field-of-view divided by the number of pixels in the CCD array.

response time (response speed)

The time required for the output of a sensor or sensing system to respond to a change of the input signal (e.g. a sensing event). Response time of a sensor becomes extremely important when detecting small objects moving at high speed. Narrow gaps between adjacent objects also must be considered when verifying that sensor response is fast enough for an application.

$$\text{Required Sensor Response Time} = \frac{\text{Apparent object (gap) size as it passes the sensor}}{\text{Velocity of the object as it passes the sensor}}$$



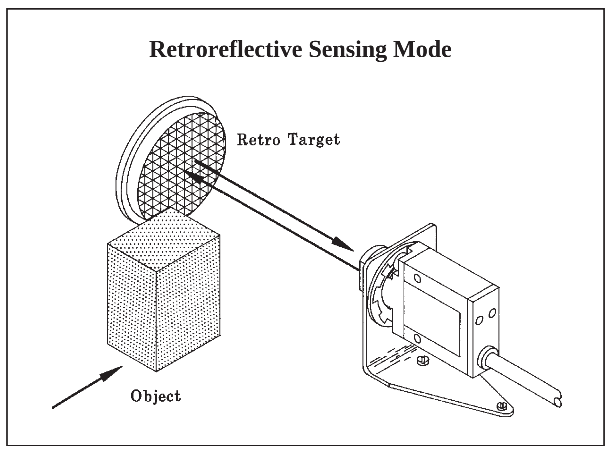
retriggerable (one shot)

One of two types of one-shot timing logic. The output pulse of a *retriggerable* one-shot is restarted with the reoccurrence of every input. The output will remain "on" as long as the time between consecutive inputs is shorter than the one-shot pulse time.

A *non-retriggerable* one-shot timer must complete its output pulse before it will recognize any new input signals. Sometimes they offer an advantage in indexing or registration control applications where multiple input signals are possible during the advance of the product.

retroreflective sensing mode

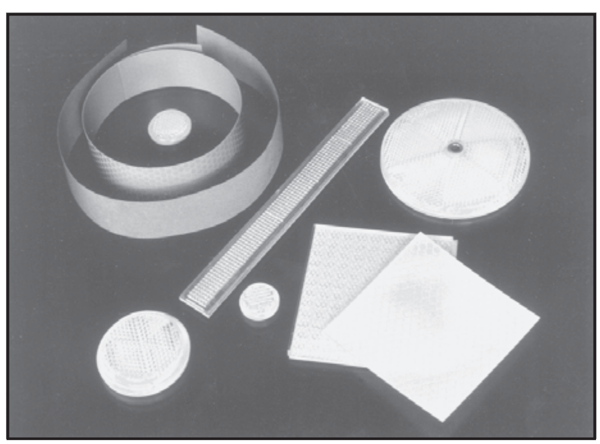
Also called the "reflex" mode, or simply the "retro" mode. A retroreflective photoelectric sensor contains both the emitter and receiver. A light beam is established between the sensor and a special retroreflective target. As in opposed sensing, an object is sensed when it interrupts this beam.



Retro is the most popular mode for conveyor applications where the objects are large (boxes, cartons, etc.), where the sensing environment is relatively clean, and where scanning ranges are typically a few feet. Retro is also used for code reading applications. Automatic storage and retrieval systems and automatic conveyor routing systems use retroreflective code plates to identify locations and/or products.

retroreflector

A reflector used in retroreflective sensing to return the emitted light directly back to the sensor. The most efficient type have corner-cube geometry (see **"corner-cube reflector"**). Reflective tapes use glass beads or smaller, less efficient corner-cubes. (Photo at right, below.)



reverse polarity protection

Refers to the design feature of Banner dc sensors which protects them from damage due to accidental reverse wiring to the power supply. Sensors without reverse polarity protection may be destroyed by accidental wrong-polarity connections.

ripple

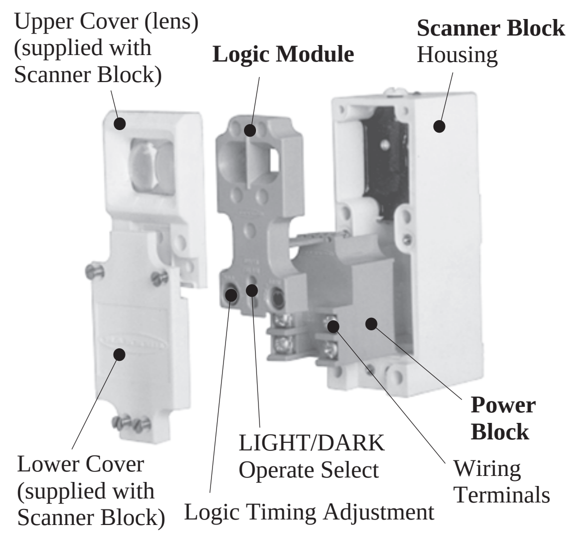
An ac voltage component on the output of a dc power supply. Usually expressed as a percentage of the supply voltage. Ripple may be suppressed ("smoothed") with capacitor filtering. Most dc-only devices require less than about 10% ripple for reliable operation.

saturation voltage

The voltage drop appearing across a switching transistor or SCR that is fully turned "on". See **"voltage drop"**.

scanner block
The modular component of Banner MULTI-BEAM sensors that contains the optoelements plus all of the emitter and/or receiver circuitry. The scanner block housing accommodates the other two modules: the power block and the logic module. The scanner block is supplied with a lensed upper cover and a lower cover that provides access to the wiring chamber. (Photo at right.)

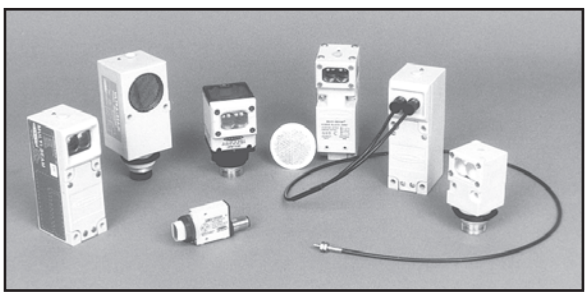
Exploded view, MULTI-BEAM Sensor



sensor head (sensor block)
The modular component of Banner OMNI-BEAM and MAXI-BEAM sensors that contains the optoelements, emitter and/or receiver circuitry, and lenses. The sensor head attaches to the power block with four bolts, and interconnects to the rest of the sensor circuitry with a wireless connector. In MAXI-BEAMs, the scanner head is rotatable around the vertical center axis in four 90° increments. See MAXI-BEAM exploded view, below right.

SCR (silicon controlled rectifier)
Also known as a "reverse blocking triode thyristor". A semiconductor device used as the output relay in many ac sensors and modules. It normally acts as an open circuit, but switches rapidly to a conducting state when an appropriate gate signal is applied.

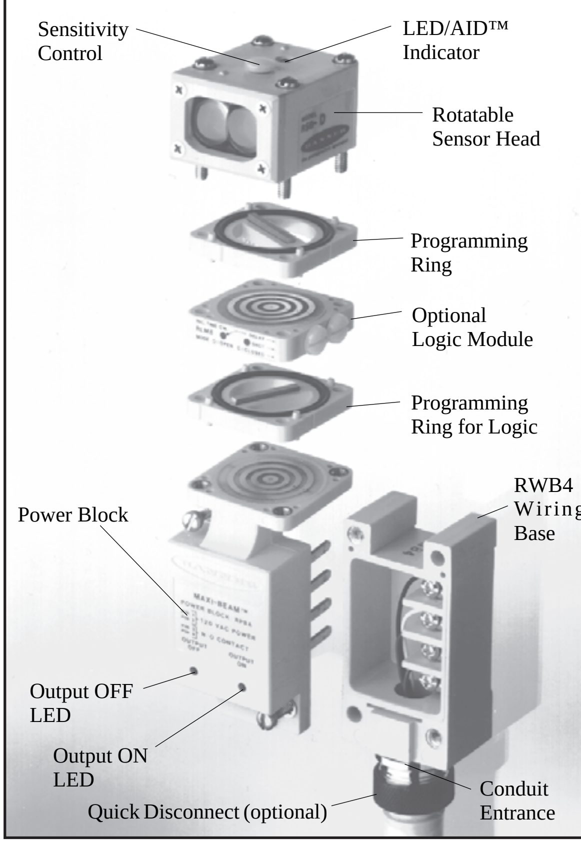
self-contained sensor
A sensor that contains the sensing element, amplifier, power supply, and output switch in a single package. Examples include Banner MULTI-BEAM, MAXI-BEAM, OMNI-BEAM, VALU-BEAM, MINI-BEAM, ECONO-BEAM, and ULTRA-BEAM sensor families. (See photo, below.)



sensitivity adjustment
An adjustment made to a sensor's amplifier that determines the sensor's ability to discriminate between different levels of received sensing energy (e.g. between two light levels reaching a photoelectric receiver). The adjustment control is usually a potentiometer located either on the sensor (if self-contained) or on a remote amplifier. Sometimes called the "gain adjustment".

sensing end
Term used to describe the end of any fiber optic cable at which sensing takes place (i.e. the end at which objects to be sensed are located). Sensing ends are manufactured in many mounting styles, and the sensing ends of glass fiber optic assemblies may be shaped to match the profile of the object to be sensed. See **"bifurcated fiber"** or **"individual fiber"**.

EXPLODED VIEW (MAXI-BEAM SENSOR)



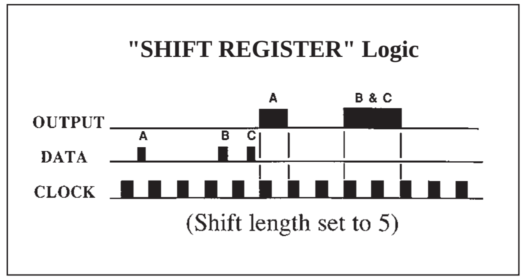
sensing window
Glass fiber optics: the size and shape of the fiber optic bundle as it is terminated on the sensing end. Sensing windows may be round, rectangular or other shapes. A single bundle of glass fiber optics may terminate in several sensing windows.

(continued on next page)

Analog sensing: the range of distance over which the sensor will recognize an object and produce an output. The near and far limits of the sensing window are set by the null and span controls, respectively. Sensing within a window is also called "ranging".

series operation
Refers to the interconnection of two or more output devices (e.g. several sensor outputs) in series to a single load. See **"AND logic"**.

shift register
A logic scheme that indexes ("clocks") data along a specified route (through "registers") and outputs that data at a programmed point. Shift registers are used as logic in sensing systems to coordinate the inspection of a product at one location and to allow the resultant action (if any) to take place at a location downstream in the process. The clock signal is usually generated by a second input that is tied to the mechanical movement of the transport mechanism (e.g. a signal generated by a cam or a sprocket on a conveyor drive, index wheel, etc.).



short circuit protection
The ability of a solid-state output device or circuit to endure operation in a shorted condition indefinitely or for a defined period of time with no damage.

showering arc (test)
NEMA test standard ICS 1-109. A severe test for the immunity of an electronic circuit (e.g. a self- contained sensor) to EMI. Consists of a calibrated arc drawn across a pair of open contacts. The test stand has a 100 foot multi-conductor cable that has two of its wires connected to the arcing contacts. The power and/or output circuits of the device under test are connected to other wires within the same 100 foot cable to simulate the noise coupling that occurs within wireways of machine systems.

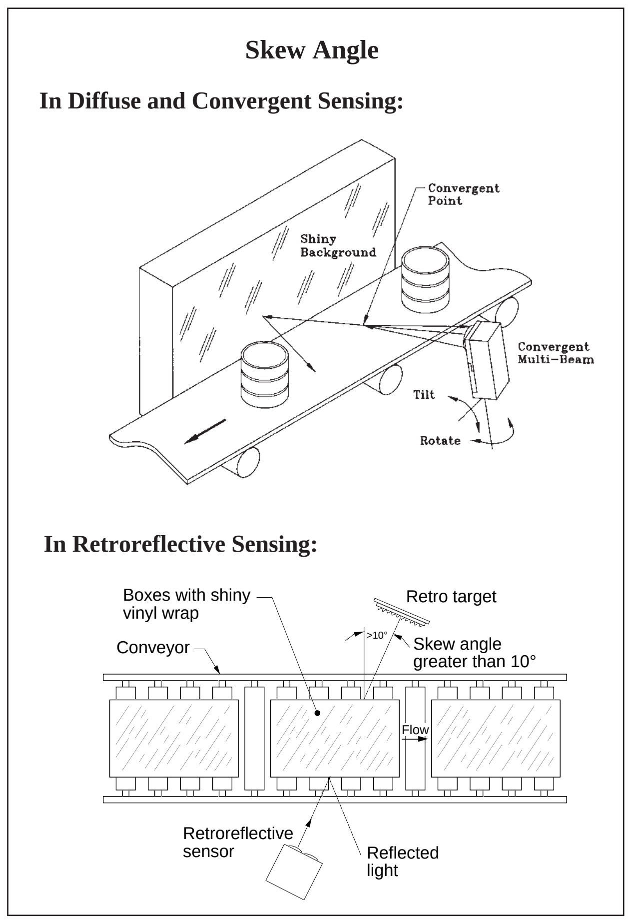
single-shot (see **"one-shot"**)

sinking output (see "**current sinking output"**)

SJT (cable)
UL designation for heavy-duty portable power cord with oil-resistant thermoplastic jacket. Conductors are stranded with individual color-coded rubber insulation. SJT cable is rated for 300 volts, 60 to 105°C. Banner model MBCC-312, MBCC-412, and MBCC-512 are examples of SJT-type cable.

skew angle
An alignment technique used in diffuse, retroreflective and convergent mode sensing to increase the optical contrast ratio. In diffuse and convergent sensing, it is done to reduce *background* reflections. The sensor is angled so that its beam strikes the background at an angle *other* than 90 degrees (i.e. straight on).

In retroreflective sensing, skewing the sensor is done to reduce the amount of light reflected directly back from the *object* that is supposed to break the beam established between the sensor and its retro target.



SMD (surface mount device)
Surface mount devices are flat, rectangular, leadless discrete electronic components that are much smaller than equivalent components with lead wires. Their small size significantly reduces the overall size of circuitry and electronic assemblies. Their leadless design and consistent geometry allows robotic placement of the components onto a PC board. They attach to one side of pre-solder masked PC boards by heating the entire board assembly and reflowing the solder. Most state-of-the-art sensors make use of SMD technology.

snubber
A series combination of a resistor and a capacitor (R-C network) used to limit the maximum rate of rise of a voltage. Snubbers are connected across the contacts of electromechanical relays that switch a large resistive load or any inductive load, to suppress contact

arcing. Snubbers are used across solid-state relay contacts to help prevent false turn-on of the switch by voltage transients. Also called a "snubber network".

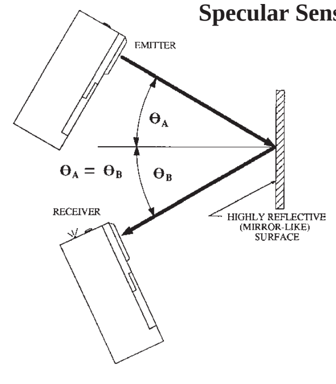
solid-state relay (see **"relay"**)

sourcing output (see **"current sourcing output"**)

span
This term is used in analog sensing and control to describe the maximum voltage (or current) in an analog output range. Analog sensors have an adjustment for setting the span value.

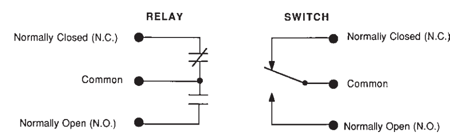
specular sensing mode (specular reflection)
A photoelectric sensing mode where an emitter and a receiver are mounted at equal and opposite angles from the perpendicular to a highly reflective (mirror-like) surface. The distance from the shiny surface to the sensors must remain constant. The specular sensing mode is useful in some applications where it is necessary to differentiate between a shiny and a dull surface. It is particularly useful for detecting the presence of materials which do not offer enough height differential from their background to be recognized by a convergent mode sensor. A common example is sensing cloth (diffuse) on a steel sewing machine table (shiny).

Specular Sensing Mode



SPDT
Abbreviation for "Single Pole Double Throw". Refers to a switch or an electromechanical relay having one set of form 1C contacts. One contact is open when the other is closed (complementary switching).

SPDT



SPST
Abbreviation for "Single Pole Single Throw". Refers to a switch or a relay contact (electromechanical or solid-state) with a single contact that is either normally open or normally closed.

threshold (of a photoelectric amplifier)
The value of voltage in a dc-coupled photoelectric amplifier that causes the output of the sensor or sensing system to change state. This voltage level is directly related to the amount of light that is incident on the photoelectric receiver. The threshold is the value of received signal representing an excess gain of **1x**. The sensitivity control (where one is available) adjusts the threshold voltage level.

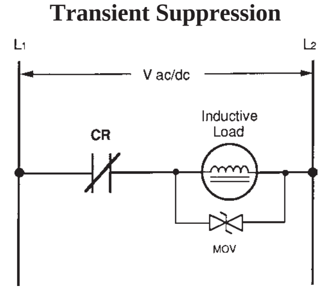
through-beam sensing mode (see **"opposed sensing mode"**)

tracer beam
A visible red beam available with many Banner modulated infrared emitters, used as an alignment aid. The tracer beam is inactive, in that it does not supply any of the sensing energy. The sensing energy is supplied by an invisible infrared beam.

The tracer beam is used during alignment to mechanically align the emitter to the receiver. A retroreflective target is temporarily attached to the lens of the receiver, and the tracer beam is sighted on the target from behind the emitter. The retro target is then removed and fine alignment is made using the AID signal strength indicator. The tracer beam is also used as a "power-on" indicator for the emitter. Tracer beams are a feature of MAXI-BEAM and VALU-BEAM infrared emitters.

transducer
A device that converts energy of one form into another form. The sensing element of a non-contact presence sensor that converts a change in incident sensing energy (e.g. light, sound, etc.) into a proportional electrical quantity such as voltage or current.

Transient Suppression



For best results, install transient suppressors directly across offending loads.

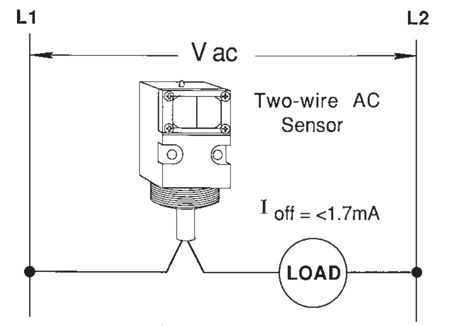
transient
A very short duration pulse of voltage (or current) that is many times larger in magnitude than the supply voltage. Transients are usually caused by the operation of a heavy resistive load or of any size inductive load like motors, contactors, and solenoids.

Voltage transients can cause false actuation of fast electronic circuits such as solid-state counters, one-shot timers, and latching outputs. The problems resulting from transients are dealt with by careful shielding and grounding of remote sensor lead wires, by physical separation of signal wires from power wires in wireways, and by installing transient suppressors directly across offending loads.

translucent

Term used to describe materials that have the property of reflecting a part and transmitting a part of incident radiation.

2-wire Sensor



2-wire sensor

A sensor designed to wire in series with its load, exactly like a limit switch. A 2-wire sensor remains powered when the load is "off" by a residual "leakage current" that flows through the load.

UL Listed:

UL Recognized:

UL

A third-party organization which tests a manufacturer's products for compliance with appropriate Standards, electrical and/or safety codes. Compliance is indicated by their listing mark on the product. See logos at right.

ultrasonic

Sound energy at frequencies just above the range of human hearing, above about 20 kHz. The use of ultrasound is of advantage in many sensing applications because of its ability to detect objects without regard to their reflectivity or translucency to light. Banner ULTRA-BEAM sensors are ultrasonic sensors.

upper cover

The removable component of a photoelectric sensor that includes the lensing. Upper covers are replaceable and, in some cases, are interchangeable for changes of sensing mode and/or sensing range.

UV (ultraviolet)

Invisible short wavelength light energy that lies immediately beyond the violet end of the color spectrum between approximately 100 and 380 nm. Some materials "fluoresce" and produce light of visible wavelengths when excited by UV energy. This re-radiation of visible light can be detected by a "UV sensor". See **"LED"**.

VALOX®

A family of thermoplastic polyester materials manufactured by General Electric Company. Noted for its toughness, mechanical stability, and excellent insulating properties. Used for the housing material of many Banner products, including MULTI-BEAM, MAXI-BEAM, VALU-BEAM, MINI-BEAM, ULTRA-BEAM, and MICRO-AMP.

voltage

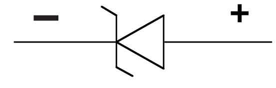
The term used most often in place of "electromotive force", "potential", "potential difference", or "voltage drop" to designate the electric pressure that exists between two points and is capable of producing a flow of current when a closed circuit is connected between the two points.

voltage drop

The voltage that occurs across a solid-state device when its output is driving a load, or the voltage that exists across each element of a series circuit. The magnitude of the voltage drop is dependent upon the circuit demand of the load. Also referred to as "saturation voltage".

window (see "sensing window")

Zener Diode (symbol)



zener diode

A PN junction diode used as a voltage regulator because of its uniform breakdown characteristic when reverse biased. See the electronic symbol at the right.

Section F
Data Reference Material

TABLE 1. Units for Photoelectric Specifications

UNIT	SYMBOL	PHYSICAL QUANTITY
ac volts	V ac	electrical potential -- alternating current
ampere	A	electrical current
dc volts	V dc	electrical potential -- direct current
degrees Celsius	°C	temperature (see Table 9)
degrees Fahrenheit	°F	temperature (see Table 9)
Hertz	Hz	frequency
lumen•	lm	light energy
lux	lx	illumination (lm/m^2)
meter	m	length
microamp	µA	electrical current (10^{-6} A)
microsecond	µs	time (10^{-6} s)
milliamp	mA	electrical current (10^{-3} A)
millimeter	mm	length (10^{-3} m)
millisecond	ms	time (10^{-3} s)
nanometer	nm	length (light wavelength)
ohm	Ω	electrical resistance
second	s	time
volt	V	electrical potential
volt-amp	VA	power
watt	W	power

*1 lumen = 0.001496 watt of monochromatic light at a wavelength of 546nm.

TABLE 2. Unit Prefixes

DECIMAL EQUIVALENT	PREFIX	SYMBOL	EXPONENTIAL EXPRESSION
1 000 000 000 000	tera	T	10^{12}
1 000 000 000	giga	G	10^{9}
1 000 000	mega	M	10^{6}
1 000	kilo	k	10^{3}
100	hecto	h	10^{2}
10	deka	da	10
0.1	deci	d	10^{-1}
0.01	centi	c	10^{-2}
0.001	milli	m	10^{-3}
0.000 001	micro	µ	10^{-6}
0.000 000 001	nano	n	10^{-9}
0.000 000 000 001	pico	p	10^{-12}

TABLE 3. English-Metric Conversion

Inch Fraction	Inch Decimal	Millimeter	Inch Fraction	Inch Decimal	Millimeter	Inch Fraction	Inch Decimal	Millimeter
---	.0039	0,1	9/32	.2812	7,144	21/32	.6562	16,669
---	.0079	0,2	19/64	.2969	7,541	---	.6693	17
---	.0118	0,3	5/16	.3125	7,938	43/64	.6719	17,066
1/64	.0156	0,397	---	.3150	8	11/16	.6875	17,462
---	.0157	0,4	21/64	.3281	8,334	45/64	.7031	17,859
---	.0197	0,5	11/32	.3438	8,731	---	.7087	18
---	.0236	0,6	---	.3543	9	23/32	.7188	18,256
---	.0276	0,7	23/64	.3594	9,128	47/64	.7344	18,653
1/32	.0312	0,794	3/8	.375	9,525	---	.7480	19
---	.0315	0,8	25/64	.3906	9,922	3/4	.750	19,050
---	.0354	0,9	---	.3937	10	49/64	.7656	19,447
---	.0394	1	13/32	.4062	10,319	25/32	.7812	19,844
3/64	.0469	1,191	27/64	.4219	10,716	---	.7874	20
1/16	.0625	1,588	---	.4331	11	51/64	.7969	20,241
5/64	.0781	1,984	7/16	.4375	11,112	13/16	.8125	20,638
---	.0787	2	29/64	.4531	11,509	---	.8268	21
3/32	.0938	2,381	15/32	.4688	11,906	53/64	.8281	21,034
7/64	.1094	2,778	---	.4724	12	27/32	.8438	21,431
---	.1181	3	31/64	.4844	12,303	55/64	.8594	21,828
1/8	.125	3,175	1/2	.500	12,700	---	.8661	22
9/64	.1406	3,572	---	.5118	13	7/8	.875	22,225
5/32	.1562	3,969	33/64	.5156	13,097	57/64	.8906	22,622
---	.1575	4	17/32	.5312	13,494	---	.9055	23
11/64	.1719	4,366	35/64	.5469	13,891	29/32	.9062	23,019
3/16	.1875	4,762	---	.5512	14	59/64	.9219	23,416
---	.1968	5	9/16	.5625	14,288	15/16	.9375	23,812
13/64	.2031	5,159	37/64	.5781	14,684	---	.9449	24
7/32	.2188	5,556	---	.5905	15	61/64	.9531	24,209
15/64	.2344	5,953	19/32	.5938	15,081	31/32	.9688	24,606
---	.2362	6	39/64	.6094	15,478	---	.9842	25
1/4	.250	6,350	5/8	.625	15,875	63/64	.9844	25,003
17/64	.2656	6,747	---	.6299	16	1"	1.000	25,400
---	.2756	7	41/64	.6406	16,272	---	---	---

To convert millimeters to inches, multiply by 0.0394. To convert inches to millimeters, multiply by 25.4

TABLE 4. Drill Sizes for Sensor Mounting Hardware

Thread Size	Tap Drill	Clearance Drill
#2-56	#50 (0.0700")	#42 (0.0935")
#4-40	#43 (0.0890")	#31 (0.1200")
#6-32	#36 (0.1065")	#25 (0.1495")
#6-40	#33 (0.1130")	#25 (0.1495")
#8-32	#29 (0.1360")	#16 (0.1770")
#10-24	#25 (0.1495")	#7 (0.2010")
#10-32	#21 (0.1590")	#7 (0.2010")
1/4"-20	#7 (0.2010")	#H (0.2660")
5/16"-24	#I (0.2720")	#Q (0.3320")
3/8"-32	11/32 (0.3438")	25/64" (0.3906")
7/16"-20	25/64" (0.3906")	15/32" (0.4687")
1/2"-14 NPSM	23/32" (0.7188")	55/64" (0.8594")
1/2"-32	15/32" (0.4688")	17/32"(0.5312")

Thread Size	Tap Drill	Clearance Drill
M2,5 x 0,45	2,05mm (0.0807") or #46 (0.0810")	2,9mm (0.1142") or #32 (0.1160")
M3 x 0,5	2,50mm (0.0984") or #39 (0.0995")	3,4mm (0.1339") or #29 (0.1360")
M4 x 0,7	3,30mm (0.1299") or #29 (0.1360")	4,5mm (0.1772") #15 (0.1800")
M6 x 0,75	5,00mm (0.1969") or #8 (0.1990")	6,6mm (0.2598") or #G (0.2610")
M18 x 1	15,5mm (0.6102") or 39/64" (0.6094")	20,0mm (0.7874") or 51/64" (0.7969")
M30 x 1,5	26,5mm (1.0433") or 1-3/64" (1.0469")	33,0mm (1.2992") or 1-5/16" (1.3125")

TABLE 5. Velocity Conversion

1		2		3		4	
feet/minute	**meters/ minute**	**inches/ minute**	**millimeters/ minute**	**inches/second**	**millimeters/ second**	**seconds/inch**	**seconds/ millimeter**
.5	,152	6	152,4	.10	2,540	10.0	.394
1	,305	12	304,8	.20	5,080	5.0	.197
2	,610	24	609,6	.40	10,16	2.50	.098
3	,914	36	914,4	.60	15,24	1.67	.0656
4	1,22	48	1219,2	.80	20,32	1.25	.0492
5	1,52	60	1524,0	1.0	25,40	1.00	.0394
6	1,83	72	1828,8	1.2	30,48	.833	.0328
7	2,13	84	2133,6	1.4	35,56	.714	.0281
8	2,44	96	2438,4	1.6	40,64	.625	.0246
9	2,74	108	2743,2	1.8	45,72	.555	.0219
10	3,05	120	3048,0	2.0	50,8	.500	.0197
11	3,35	132	3352,8	2.2	55,88	.455	.0179
12	3,66	144	3657,6	2.4	60,96	.417	.0164
13	3,96	156	3962,4	2.6	66,04	.385	.0151
14	4,27	168	4267,2	2.8	71,12	.357	.0141
15	4,57	180	4572,0	3.0	76,20	.333	.0131
16	4,88	192	4876,8	3.2	81,28	.313	.0123
17	5,18	204	5181,6	3.4	86,36	.294	.0116
18	5,49	216	5486,4	3.6	91,44	.278	.0109
19	5,79	228	5791,2	3.8	96,52	.263	.0104
20	6,10	240	6096,0	4.0	101,6	.250	.00984
21	6,40	252	6400,8	4.2	106,7	.238	.00937
22	6,71	264	6705,6	4.4	111,8	.227	.00895
23	7,01	276	7010,4	4.6	116,8	.217	.00856
24	7,31	288	7315,2	4.8	121,9	.208	.00820
25	7,62	300	7620,0	5.0	127,0	.200	.00787
30	9,14	360	9144,0	6.0	152,4	.167	.00656
40	12,19	480	12192	8.0	203,2	.125	.00492
50	15,24	600	15240	10	254,0	.100	.00394
60	18,29	720	18288	12	304,8	.083	.00328
70	21,34	840	21336	14	355,6	.071	.00281
80	24,38	960	24384	16	406,4	.063	.00246
90	27,43	1080	27432	18	457,2	.056	.00219
100	30,48	1200	30480	20	508,0	.050	.00197
125	38,10	1500	38100	25	635,0	.040	.00157
150	45,72	1800	45720	30	762,0	.033	.00131
175	53,34	2100	53340	35	889,0	.029	.00112
200	60,96	2400	60960	40	1016	.025	.00098
225	68,58	2700	68580	45	1143	.022	.00087
250	76,20	3000	76200	50	1270	.020	.00079
275	83,82	3300	83820	55	1397	.018	.00072
300	91,44	3600	91440	60	1524	.016	.00066
325	99,06	3900	99060	65	1651	.015	.00061
350	106,7	4200	106680	70	1778	.014	.00056
375	114,3	4500	114300	75	1905	.013	.00052
400	121,9	4800	121920	80	2032	.012	.00049
450	137,2	5400	137160	90	2286	.011	.00044
500	152,4	6000	152400	100	2540	.010	.00039
600	182,9	7200	182880	120	3048	.0083	.00033
700	213,4	8400	213360	140	3556	.0071	.00028
800	243,8	9600	243840	160	4064	.0063	.00025
900	274,3	10800	274320	180	4572	.0055	.00022
1000	304,8	12000	304800	200	5080	.0050	.000197
1250	381,0	15000	381000	250	6350	.0040	.000157
1665	507,5	19980	507492	333	8458	.0030	.000118
2500	762,0	30000	762000	500	12700	.0020	.000079
5000	1524	60000	1524000	1000	25400	.0010	.000039

TABLE 6. Velocity Conversion Factors

From: \ To:	miles/ hour	feet/ minute	inches/ minute	meters/ minute	centimeters/ minute	feet/ second	inches/ second	meters/ second	millimeters/ second
1 mile/ hour	1.0	88	1056	26.822	2682.24	1.4667	17.60	0.4470	447.0
1 foot/ minute	1.1364×10^{-2}	1.0	12.0	0.3048	30.48	1.6667×10^{-2}	20.000	5.08×10^{-3}	5.08
1 inch/ minute	9.470×10^{-4}	8.333×10^{-2}	1.0	2.540×10^{-2}	2.54	1.3888×10^{-3}	1.6666×10^{-2}	4.23×10^{-4}	0.0423
1 meter/ minute	3.7282×10^{-2}	3.281	39.372	1.0	100.0	5.468×10^{-2}	0.6562	1.667×10^{-2}	16.667
1 centi- meter/ minute	3.2782×10^{-4}	3.281×10^{-2}	0.3937	0.01	1.0	5.468×10^{-4}	6.5616×10^{-3}	1.667×10^{-4}	0.1667
1 foot/ second	0.6818	60	720	18.29	1829	1.0	12	0.3048	304.8
1 inch/ second	5.6818×10^{-2}	5	60	1.524	152.4	8.333×10^{-2}	1.0	2.540×10^{-2}	25.40
1 meter/ second	2.2369	196.85	2362.2	60.0	6000.0	3.281	39.372	1.0	1000
1 milli- meter/ second	2.2369×10^{-3}	0.1969	2.3622	6.0×10^{-2}	6.000	3.281×10^{-3}	3.937×10^{-2}	1×10^{-3}	1.0

TABLE 7. Length Conversion Factors

From: \ To:	Ang- stroms Å	milli- meters	centi- meters	inches	feet	yards	meters	kilo- meters	miles (imperial)
1 Angstrom (Å)	1.0	1.0×10^{-7}	1.0×10^{-8}	3.937×10^{-9}	3.2808×10^{-10}	1.0936×10^{-10}	1.0×10^{-10}	1.0×10^{-13}	6.2137×10^{-14}
1 millimeter (mm)	1.0×10^{7}	1.0	0.1	0.0394	3.2808×10^{-3}	1.0936×10^{-3}	1.0×10^{-3}	1.0×10^{-6}	6.2137×10^{-7}
1 centimeter (cm)	1.0×10^{8}	10.0	1.0	0.3937	0.0328	0.0109	0.01	1.0×10^{-5}	6.2137×10^{-6}
1 inch (in)	2.54×10^{8}	25.4	2.54	1.0	0.0833	0.0278	0.0254	2.54×10^{-5}	1.5783×10^{-5}
1 foot (ft)	3.048×10^{9}	304.8	30.48	12.0	1.0	0.3333	0.3048	3.048×10^{-4}	1.8939×10^{-4}
1 yard (yd)	9.144×10^{9}	914.4	91.44	36.0	3.0	1.0	0.9144	9.144×10^{-4}	5.6818×10^{-4}
1 meter (m)	1.0×10^{10}	1.0×10^{3}	100.0	39.3701	3.2808	1.0936	1.0	1.0×10^{-3}	6.2137×10^{-4}
1 kilometer (km)	1.0×10^{13}	1.0×10^{6}	1.0×10^{5}	3.937×10^{4}	3.2808×10^{3}	1.0936×10^{3}	1.0×10^{3}	1.0	0.6214
1 mile (imperial)	1.6093×10^{13}	1.6093×10^{6}	1.6093×10^{5}	6.336×10^{4}	5.280×10^{3}	1.760×10^{3}	1.6093×10^{3}	1.6093	1.0

TABLE 8. Temperature Conversion: °C ⟷ °F

CELSIUS°	FAHRENHEIT°	CELSIUS°	FAHRENHEIT°	CELSIUS°	FAHRENHEIT°
-62	-80	0.0	32	22.2	72
-57	-70	0.6	33	22.8	73
-51	-60	1.1	34	23.3	74
-46	-50	1.7	35	23.9	75
-40	-40	2.2	36	24.4	76
-34	-30	2.8	37	25.0	77
-29	-20	3.3	38	25.6	78
-23	-10	3.9	39	26.1	79
-17.8	0	4.4	40	26.7	80
-17.2	1	5.0	41	27.2	81
-16.7	2	5.6	42	27.8	82
-16.1	3	6.1	43	28.3	83
-15.6	4	6.7	44	28.9	84
-15.0	5	7.2	45	29.4	85
-14.4	6	7.8	46	30.0	86
-13.9	7	8.3	47	30.6	87
-13.3	8	8.9	48	31.1	88
-12.8	9	9.4	49	31.7	89
-12.2	10	10.0	50	32.2	90
-11.7	11	10.6	51	32.8	91
-11.1	12	11.1	52	33.3	92
-10.6	13	11.7	53	33.9	93
-10.0	14	12.2	54	34.4	94
-9.4	15	12.8	55	35.0	95
-8.9	16	13.3	56	35.6	96
-8.3	17	13.9	57	36.1	97
-7.8	18	14.4	58	36.7	98
-7.2	19	15.0	59	37.2	99
-6.7	20	15.6	60	37.8	100
-6.1	21	16.1	61	43	110
-5.6	22	16.7	62	49	120
-5.0	23	17.2	63	54	130
-4.4	24	17.8	64	60	140
-3.9	25	18.3	65	66	150
-3.3	26	18.9	66	71	160
-2.8	27	19.4	67	77	170
-2.2	28	20.0	68	82	180
-1.7	29	20.6	69	88	190
-1.1	30	21.1	70	93	200
-0.6	31	21.7	71	100	212

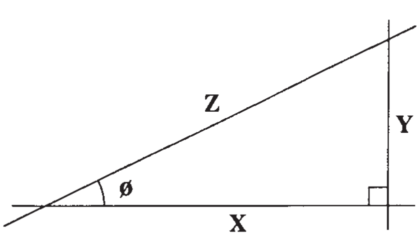
NOTE: For temperatures not given in the table, use the conversion information at the right.

Temperature Scale	Water Boiling Point	Water Freezing Point	To Convert Scales:
°F (Fahrenheit)	212°F	32°F	°C = (°F-32) x 5/9
°C (Celsius or Centigrade)	100°C	0°C	°F = (°C x 9/5) + 32

TABLE 9. Trigonometric Functions and Formulas

Degrees	sin	cos	tan	cot	sec	csc	
0	0.0000	1.0000	0.0000	-----	1.0000	-----	90
1	.0174	.9998	.0175	57.290	1.0002	57.299	89
2	.0349	.9994	.0349	28.636	1.0006	28.654	88
3	.0523	.9986	.0524	19.081	1.0014	19.107	87
4	.0698	.9976	.0699	14.301	1.0024	14.336	86
5	.0872	.9962	.0875	11.430	1.0038	11.474	85
6	.1045	.9945	.1051	9.5144	1.0055	9.5668	84
7	.1219	.9925	.1228	8.1443	1.0075	8.2055	83
8	.1392	.9903	.1405	7.1154	1.0098	7.1853	82
9	.1564	.9877	.1584	6.3138	1.0125	6.3924	81
10	.1736	.9848	.1763	5.6713	1.0154	5.7588	80
11	.1908	.9816	.1944	5.1446	1.0187	5.2408	79
12	.2079	.9781	.2126	4.7046	1.0223	4.8097	78
13	.2250	.9744	.2309	4.3315	1.0263	4.4454	77
14	.2419	.9703	.2493	4.0108	1.0306	4.1336	76
15	.2588	.9659	.2679	3.7320	1.0353	3.8637	75
16	.2756	.9613	.2867	3.4874	1.0403	3.6280	74
17	.2924	.9563	.3057	3.2708	1.0457	3.4203	73
18	.3090	.9511	.3249	3.0777	1.0515	3.2361	72
19	.3256	.9455	.3443	2.9042	1.0576	3.0715	71
20	.3420	.9397	.3640	2.7475	1.0642	2.9238	70
21	.3584	.9336	.3839	2.6051	1.0711	2.7904	69
22	.3746	.9272	.4040	2.4751	1.0785	2.6695	68
23	.3907	.9205	.4245	2.3558	1.0864	2.5593	67
24	.4067	.9135	.4452	2.2460	1.0946	2.4586	66
25	.4226	.9063	.4663	2.1445	1.1034	2.3662	65
26	.4384	.8988	.4877	2.0503	1.1126	2.2812	64
27	.4540	.8910	.5095	1.9626	1.1223	2.2027	63
28	.4695	.8829	.5317	1.8807	1.1326	2.1300	62
29	.4848	.8746	.5543	1.8040	1.1434	2.0627	61
30	.5000	.8660	.5774	1.7320	1.1547	2.0000	60
31	.5150	.8572	.6009	1.6643	1.1666	1.9416	59
32	.5299	.8580	.6249	1.6003	1.1792	1.8871	58
33	.5446	.8387	.6494	1.5399	1.1924	1.8361	57
34	.5592	.8290	.6745	1.4826	1.2062	1.7883	56
35	.5736	.8192	.7002	1.4281	1.2208	1.7434	55
36	.5878	.8090	.7265	1.3764	1.2361	1.7013	54
37	.6018	.7986	.7536	1.3270	1.2521	1.6616	53
38	.6157	.7880	.7813	1.2799	1.2690	1.6243	52
39	.6293	.7771	.8098	1.2349	1.2868	1.5890	51
40	.6428	.7660	.8391	1.1918	1.3054	1.5557	50
41	.6561	.7547	.8693	1.1504	1.3250	1.5242	49
42	.6691	.7431	.9004	1.1106	1.3456	1.4945	48
43	.6820	.7314	.9325	1.0724	1.3673	1.4663	47
44	.6947	.7193	.9567	1.0355	1.3902	1.4396	46
45	.7071	.7071	1.0000	1.0000	1.4142	1.4142	45
	cos	sin	cot	tan	csc	sec	Degrees

Trigonometric Formulas for Distance or Angle Calculation



Relationships:

sin Ø = Y/Z
cos Ø = X/Z
tan Ø = Y/X
csc Ø = Z/Y = 1/sin Ø
sec Ø = Z/X = 1/cos Ø
cot Ø = X/Y = 1/tan Ø

Given Ø and X: Y = X tan Ø Z = X sec Ø
Given Ø and Y: X = Y cot Ø Z = Y csc Ø

Given Ø and Z: X = Z cos Ø Y = Z sin Ø
Given X and Y: $Z = \sqrt{X^2 + Y^2}$ Ø = arctan (Y/X)

Basic Electrical Formulas

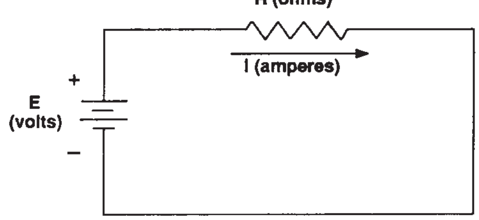
Ohm's Law describes the relationship between voltage, resistance, and current in electrical circuits. As stated by Ohm's Law, the current in the figure below is directly proportional to the applied voltage and inversely proportional to the resistance of the circuit. This relationship, in the form of an equation, is written as follows:

$$I = \frac{E}{R}$$

where **I** is the current (in amperes), **E** is the electromotive force (in volts), and **R** is the resistance (in ohms). It follows that:

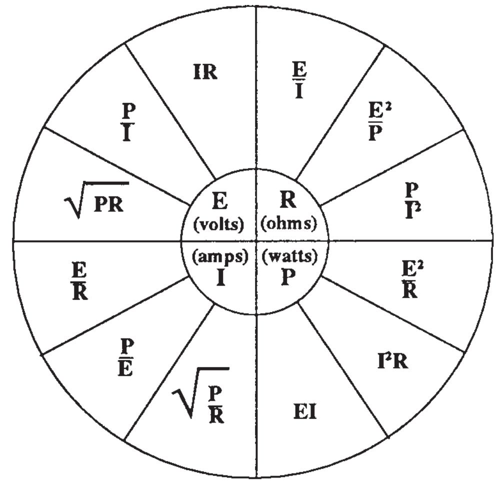
$$E = I \times R \qquad \text{and} \qquad R = \frac{E}{I}$$

Ohm's Law Circuit:



As an example, if R=100 ohms and E=10 volts, then the current in the circuit is equal to:

$$I = \frac{10}{100} \quad \text{or 1/10 amp, or 100 milliamps.}$$



Electrical power may also be quantified in terms of a simple equation. Power is the rate of doing work, and is measured in units called *watts*. Watts are equal to *voltage x current. DC power equations* relate power (in watts), current (in amperes), and resistance (in ohms), as follows:

$$P = E \times I \qquad P = \frac{E^2}{R} \qquad P = I^2 \times R$$

As an example, if R=1000 ohms and E = 10 volts, the power used in the circuit is:

$$P = \frac{E^2}{R} = \frac{100}{1000} = 1/10 \text{ watt} = 100 \text{ milliwatts}$$

TABLE 10. Resistor Color Codes

Color	Digit	Multiplier	Tolerance
black	0	1	±1%
brown	1	10	±2%
red	2	100	±3%
orange	3	1000	±4%
yellow	4	10000	
green	5	100000	
blue	6	1000000	
violet	7	10000000	
gray	8	100000000	
white	9		
gold		0.1	±5%
silver		0.01	±10%
no color			±20%

The colored bands on the bodies of resistors denote their *value* (in ohms), and their *tolerance* (in ±%). With the resistor positioned as shown below, the first two color bands are digits, the next is the multiplier, and the next (if present) is the tolerance.

As an example, a resistor color-coded YELLOW-VIOLET-BROWN-GOLD would be 47 x 10, ±5% tolerance or: 470 ohms (±5% tolerance).

Precision resistors usually have their values stamped on the resistor body. Some film-type resistors may have three significant figures and, therefore, use five color bands (including *3* digit bands and 1 multiplier band).

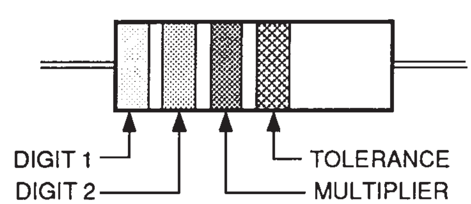


TABLE 11. COPPER WIRE INFORMATION

AWG	Solid Wire Diameter American Wire or Brown and Sharpe Gage		Approximate Stranded Wire Diameter[1]		Approximate Resistance per 100 feet (30 meters)[2]
	inches	millimeters	inches	millimeters	ohms
0000	.4601	11,687	.522	13,26	.0050
000	.4097	10,406	.464	11,79	.0060
00	.3648	9,266	.414	10,52	.0080
0	.3249	8,252	.368	9,35	.010
1	.2893	7,348	.328	8,33	.012
2	.2576	6,543	.292	7,42	.016
3	.2294	5,827			.020
4	.2043	5,189	.232	5,89	.025
5	.1819	4,620			.030
6	.1620	4,115	.184	4,67	.040
7	.1443	3,665			.050
8	.1285	3,264	.147	3,73	.060
9	.1144	2,906			.080
10	.1019	2,588	.116	2,95	.10
11	.0907	2,304			.13
12	.0808	2,052	.095	2,41	.16
13	.0720	1,829			.20
14	.0641	1,628	.073	1,85	.25
15	.0571	1,450			.32
16	.0508	1,290	.059	1,50	.40
17	.0453	1,151			.50
18	.0403	1,024	.048	1,22	.64
19	.0359	0,912			.80
20	.0320	0,813	.036	0,91	1.0
21	.0285	0,724			1.3
22	.0253	0,643	.030	0,76	1.6
23	.0226	0,574			2.0
24	.0201	0,511	.024	0,61	2.6
25	.0179	0,455			3.2
26	.0159	0,404	.020	0,51	4.1
27	.0142	0,361	.018	0,46	5.2
28	.0126	0,320	.015	0,38	6.5
29	.0113	0,287			8.2
30	.0100	0,254	.012	0,30	10
31	.00892	0,227			13
32	.00795	0,202	.008	0,20	16
33	.00708	0,180			20
34	.00630	0,160	.007	0,18	26
35	.00561	0,142			33
36	.00500	0,127	.006	0,15	42
37	.00445	0,113			52
38	.00396	0,101			66
39	.00353	0,090			83
40	.00314	0,080			105
41	.00280	0,071			130
42	.00249	0,063			170
43	.00222	0,056			210
44	.00198	0,050			270
45	.00176	0,045			330
46	.00157	0,040			420

NOTE 1: Exact diameter is dependent upon the wire gage used for the strands.
Diameter listed represents the most common wire type for each AWG.

NOTE 2: Resistance values assume the resisitivity of solid copper wire.
Stranding and/or copper alloy increase the resistance values.

TABLE 12. Hazardous Location Classifications per National Electrical Code (NEC) Article 500

CLASS	DIVISION	GROUP
CLASS I Locations in which flammable gases or vapors are (or may be) present in the air in quantities great enough to produce explosive or ignitable mixtures.	**DIVISION 1:** Locations in which hazardous concentrations of flammable gases or vapors exist continuously, intermittently, or periodically under normal conditions. -or- Locations in which hazardous concentrations of flammable gases or vapors may exist frequently because of repair or maintenance operations or because of leakage. -or- Locations in which breakdown or faulty operation of equipment or processes might release hazardous concentrations of flammable gases or vapors. **DIVISION 2:** Locations in which volatile flammable liquids or flammable gases are handled, processed, or used, but are normally kept in closed containers and can only escape due to accidental rupture. -or- Locations in which hazardous concentrations of gases or vapors are normally prevented by mechanical ventilation and might become hazardous due to failure of the ventilating equipment. -or- Locations that are adjacent to Class I, Division 1 locations.	**GROUP A:** Atmospheres containing acetylene **GROUP B:** Atmospheres containing: acrolein (inhibited) butadiene ethylene oxide hydrogen manufactured gases containing more than 30% hydrogen by volume propylene oxide **GROUP C:** Atmospheres containing: allyl alcohol carbon monoxide cyclopropane diethyl ether ethylene hydrogen sulfide methyl ether n-propyl ether or gas or vapors of equivalent hazard **GROUP D:** Atmospheres containing: acetone ammonia benzene butane butyl alcohol ethane ethyl alcohol gasoline heptanes hexanes methane (natural gas) methyl alcohol methyl ethyl ketone (MEK) naphtha octanes pentanes propane styrene toluene xylenes or gas or vapors of equivalent hazard
CLASS II Locations in which there are explosive mixtures of air and combustible dust.	**DIVISION 1:** Locations in which explosive or ignitible amounts of combustible dust is or may be in suspension in the air continuously, intermittently, or periodically under normal operating conditions. -or- Locations where mechanical failure or abnormal operation of machinery or equipment might cause explosive or ignitable mixtures to be produced. -or- Locations in which combustible electrically conductive dust is present. **DIVISION 2:** Locations where combustible dust deposits exist but are not likely to be thrown into suspension in the air, but where the dust deposits may be heavy enough to interfere with safe heat dissipation from electric equipment. -or- Locations where combustible dust deposits may be ignited by arcs, sparks, or burning material from electric equipment.	**GROUP E:** Atmospheres containing combustible: metal dusts regardless of resistivity -or- dusts of similarly hazardous characteristics having resistivity of less than 100,000 ohm-centimeter **GROUP F:** atmospheres containing combustible: carbon black, charcoal, or coke dusts which have more than 8% total volatile material -or- carbon black, charcoal, or coke dusts sensitized by other materials so that they present an explosion hazard, and having a resistivity greater than 100 ohm-centimeter but equal to or less than 100,000,000 ohm-centimeter **GROUP G:** Atmospheres containing dusts having resistivity of 100,000,000 ohm-centimeter or greater (nonconductive dusts)
CLASS III Locations in which there is the presence of easily-ignited fibers or flyings, but where the fibers or flyings are not likely to be in suspension in the air in quantities great enough to produce ignitable mixtures.	**DIVISION 1:** Locations in which easily ignitable fibers or materials producing flyings are handled, manufactured, or used. **DIVISION 2:** Locations in which easily ignitable fibers are stored or handled (except in a manufacturing process).	(NOT GROUPED) Manufacturers include: textile mills, clothing plants, fiber processing plants Easily ignitable fibers include: cotton, rayon, sisal, hemp, jute

TABLE 13: Enclosure Standards for Nonhazardous Locations

Enclosure Standards for Nonhazardous Locations
Provides protection against:

STANDARD NEMA (IEC)*	Intended Use	Accidental bodily contact	Falling dirt	Dust, lint, fibers (non-volatile)	Windblown dust	Falling liquid, light splash	Hosedown & heavy splash	Rain, snow, & sleet	Ice buildup	Oil or coolant seepage	Oil or coolant spray & splash	Occasional submersion	Prolonged submersion	Corrosive agents
NEMA 1 (IP10)	Indoor	Yes	Yes	...	...	...	...	...	...	...	...	...	...	...
NEMA 2 (IP11)	Indoor	Yes	Yes	...	...	Yes	...	...	...	...	...	...	...	...
NEMA 3 (IP54)	Outdoor	Yes	Yes	Yes	Yes	Yes	...	Yes	...	...	...	...	...	...
NEMA 3S (IP54)	Outdoor	Yes	Yes	Yes	Yes	Yes	...	Yes	Yes	...	...	...	...	...
NEMA 4 (IP56)	Indoor or Outdoor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	...	...	...	...	...	...
NEMA 4X (IP56)	Indoor or Outdoor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	...	...	...	...	...	Yes
NEMA 6 (IP67)	Indoor or Outdoor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	...	...	...	Yes	...	...
NEMA 6P (IP67)	Indoor or Outdoor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	...	...	...	Yes	Yes	Yes
NEMA 12 (IP52)	Indoor	Yes	Yes	Yes	...	Yes	...	...	...	Yes	...	...	...	...
NEMA 13 (IP54)	Indoor	Yes	Yes	Yes	...	Yes	...	...	...	Yes	Yes	...	...	...

*The IEC equivalents listed in this column are approximate: NEMA types *meet or exceed* the test requirements for the associated IEC classifications.

TABLE 14: NEMA Ratings of Banner Sensors

Banner Sensor Family	NEMA Ratings									
	1	2	3	3S	4	4X	6	6P	12	13
OMNI-BEAM™ (Standard, E Series, Analog, Sonic, PHOTOBUS)	X	X	X	X	X	...	...	...	X	X
MULTI-BEAM®	X	X	X	X	...	...	...	...	X	X
MAXI-BEAM®	X	X	X	X	X	...	...	...	X	X
VALU-BEAM® MINI-BEAM®	X	X	X	X	X	X	...	...	X	X
ECONO-BEAM™	X	X	X	...	X	...	...	...	X	X
QØ8 & C3Ø Series	X	X	X	...	X	...	X	...	X	X
SM512 Series	X	X	X	X	X	X	...	...	X	X
Q19 Series	X	X	X	X	X	X	X	...	X	X
SM30, Q85, & S18 Series	X	X	X	X	X	X	X	X	X	X
BEAM-ARRAY™	X	X	X	X	X	...	...	...	X	X
OPTO-TOUCH™	X	X	X	...	X	X	...	...	X	X
SP12 Series	X	X	X	X	X	X	X	X	X	X

TABLE 15. Relative Chemical Resistance of Sensor Housing Materials and Lenses

HOUSING MATERIAL	WHERE USED	RESISTANCE TO: Industrial Solvents	Dilute Acids	Concentrated Acids	Dilute Caustic Alkalis	Concentrated Caustic Alkalis	10% Sodium Hydroxide in Steam	Sunlight and Weathering
VALOX® Polyester	MULTI-BEAM, MAXI-BEAM, OMNI-BEAM[1], VALU-BEAM, MINI-BEAM; S18, SP12, C30 & SM30 Series; ULTRA-BEAM, OPTO-TOUCH, MICRO-AMP, SP100 Series, SP320D, LR/PT300	**FAIR** Attacked by: acetone, MEK, and methylene chloride	**EXCELLENT**	**GOOD**	**POOR**	**POOR**	**POOR**	**GOOD**
Lexan® Polycarbonate	ECONO-BEAM[2] C3Ø Series	**POOR** Attacked by: acetone, MEK, and methylene chloride	**GOOD**	**FAIR**	**POOR**	**POOR**	**POOR**	**GOOD**
NORYL® Polyphenylene oxide (PPO)	MAXI-AMP	**FAIR** Attacked by: chlorinated hydrocarbons[3]	**GOOD**	**FAIR**	**EXCELLENT**	**GOOD**	**GOOD**	**EXCELLENT**
Delrin® Acetal	LR/PT200, 250, L4, L16, L16F AP400 apertures	**GOOD**	**FAIR**	**POOR**	**FAIR**	**POOR**	**FAIR**	**GOOD**
Epoxy-coated zinc-aluminum alloy	SM512 Series, THIN-PAK	**GOOD**	**GOOD**	**FAIR**	**GOOD**	**FAIR**	**FAIR**	**EXCELLENT**
Anodized aluminum	LR/PT400, LP400WB, LP510CV,SP300 Series, SP1000V, L9, L16AL, BEAM-ARRAY	**EXCELLENT**	**FAIR**	**POOR**	**GOOD**	**FAIR**	**FAIR**	**GOOD**
Stainless steel	SP12 & SM30 Series; SM512 series cover plate; Glass fiberoptics with "S" in model number suffix Special sensors[4]	**EXCELLENT**	**FAIR**	**POOR**	**EXCELLENT**	**GOOD**	**GOOD**	**GOOD**
PVC (Polyvinyl-chloride)	Glass fiberoptics with "P" in model number suffix	**FAIR** Attacked by: acetone, MEK, and methylene chloride	**GOOD**	**FAIR**	**EXCELLENT**	**EXCELLENT**	**EXCELLENT**	**GOOD**
Polyethylene	Jacket for all plastic fiberoptics	**FAIR** Attacked by: chlorinated hydrocarbons[3]	**EXCELLENT**	**EXCELLENT**	**GOOD**	**GOOD**	**GOOD**	**POOR**
Cycolac® ABS	Q19 and Q85 Series	**POOR** Attacked by: acetone, MEK, esters, ketones, & some chlorinated hydrocarbons	**GOOD**	**POOR**	**GOOD**	**GOOD**	**GOOD**	**FAIR**

LENS MATERIAL	WHERE USED	Industrial Solvents	Dilute Acids	Concentrated Acids	Dilute Caustic Alkalis	Concentrated Caustic Alkalis	10% Sodium Hydroxide in Steam	Sunlight and Weathering
Glass[5]	All remote sensors except LP400WB, SP12s, and specials; ECONO-BEAMs except SE612CV and LV; SM512 Series; OMNI-BEAM, MULTI-BEAM SBC Series; all thread-on lens assys. (e.g.- L9, L16, etc); Glass fiberoptics	**EXCELLENT**	**GOOD**	**FAIR**	**EXCELLENT**	**GOOD**	**GOOD**	**EXCELLENT**
Acrylic[6]	OMNI-BEAM, MULTI-BEAM (except SBCs); MAXI-BEAM; VALU-BEAM; MINI-BEAM; ECONO-BEAM 612CV/LV, SM30s, BEAM-ARRAY	**POOR**	**FAIR**	**POOR**	**GOOD**	**FAIR**	**FAIR**	**GOOD**
Polysulfone	OPTO-TOUCH, Opposed THIN-PAK	**FAIR** Attacked by: chlorinated hydrocarbons[3]	**FAIR**	**POOR**	**FAIR**	**POOR**	**POOR**	**POOR**
Lexan® Polycarbonate	S18 Series C30 Series	**POOR** (see **Lexan®**, above)	**GOOD**	**FAIR**	**POOR**	**POOR**	**POOR**	**GOOD**

KEY TO PERFORMANCE

Rating	Percent retention of strength	Degree of attack
Excellent	85 to 100%	Slight (or no) attack
Good	75 to 84%	Moderate attack
Fair	50 to 74%	Noticeable swelling, softening, etching, or corrosion
Poor	<50%	Severe degradation

NOTES:

NOTE 1: The control access cover of the OMNI-BEAM is Lexan® polycarbonate.
NOTE 2: ECONO-BEAM models SE612CV, F, FP, and LV have VALOX® housings.
NOTE 3: Chlorinated hydrocarbons include Freon, methylene chloride, trichlorethane, and trichloroethylene.
NOTE 4: Specials include LR/PT400SS and L16FSS.
NOTE 5: Plastic lens covers are available for some sensors to meet FDA requirements.
NOTE 6: Glass covers are available for some sensors to protect the acrylic lens.

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Delrin® is a registered trademark of Dupont Co.

Section E: Troubleshooting

By recognizing just a few different symptoms of sensing problem behavior, the task of troubleshooting the majority of photoelectric (or ultrasonic) sensing system problems becomes easy. Only three tools are needed for most troubleshooting procedures (Figure E.1):

1) VOM (volt-ohm milliameter or "multimeter"). The choice between a digital- or analog-meter VOM is a matter of personal preference. The use of an analog meter may be beneficial in some situations, such as set-up and/or troubleshooting of sensors with analog outputs. This is because a digital VOM requires a second or two to update its readout each time the measurement changes.

2) The Banner BEAM-TRACKER™ is very useful for photoelectric sensor alignment and for a quick check of emitter and/or receiver function. The BEAM-TRACKER has a receiver with wide-band frequency response, which allows it to track-down most strong sources of radio frequency interference (RFI) plus the rf component of EMI "noise".

3) Self-contained sensors and component amplifiers have small potentiometers for sensitivity and timing adjustments. Most adjustments use rugged (yet small) 15-turn, clutched potentiometers with slotted brass elements. A small flat-blade screwdriver is needed for adjustments. The Banner screwdriver is sized to work for all adjustments. (Contact your Banner field sales engineer to obtain Banner screwdrivers.)

In addition to these troubleshooting tools, an oscilloscope is useful (and sometimes required) for diagnosing timing-related problems, such as sensor and/or load response time shortcomings, where the relationship between sensing events and resultant load switching typically involves timing in the millisecond or the microsecond range.

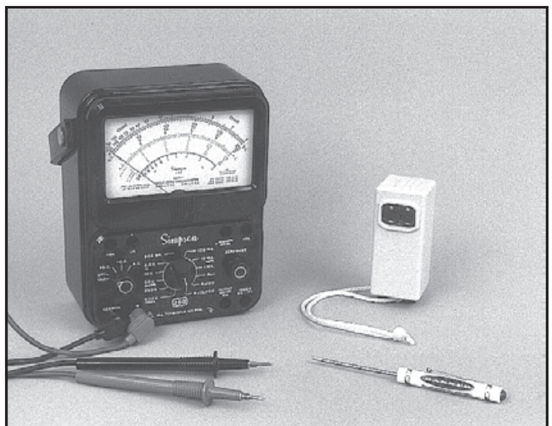


Figure E.1. Sensor troubleshooting requires only a few simple tools.

How to Spot Problem Symptoms:
Most problem symptoms are described by observing the relationship between a sensing event and the resultant sensor output. The sensor's *alignment indicator* is used to observe the sensor's response to a sensing event (Figure E.2, page E-6). The load status is observed (directly) to determine the action of the sensor's output.

Some sensors and component amplifiers also include an indicator for output status, which is useful for supplying an additional clue in any problem analysis (Figure E.3, page E-6). Sensors with output status indicators include: OMNI-BEAMs, MAXI-BEAMs, Q85s, and MAXI-AMP component amplifiers.

Many photoelectric sensors include a signal strength measurement indication. Signal strength measurement is very useful when analyzing problems that relate to marginal alignment or sensing contrast (light vs. dark). OMNI-BEAM photoelectric sensors (excluding E Series) have a ten-element LED signal strength meter (see the discussions on "Excess Gain" and "Contrast" in Section A). OMNI-BEAM sensors also output an alarm signal when sensing conditions become marginal.

Many other sensors have Banner's "Alignment Indicating Device" (AID™) feature. The AID feature is a patented design that superimposes a low-frequency pulse rate on the alignment indicator LED. As alignment is improved, the pulse rate increases, indicating increased excess gain. The sensor is adjusted so that the indicator LED is "off" in the dark condition and is flashing at the fastest possible rate in the light condition. The AID feature also signals when maintenance is needed. Whenever the pulse rate is slow, the sensor's lenses should be cleaned and the alignment checked.

(text continued on page E-6)

Table E-1. Indicator Systems used for Sensor Alignment and Troubleshooting

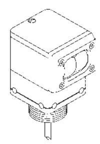
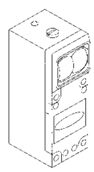
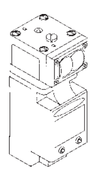
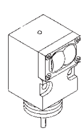
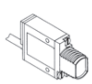
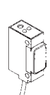
Product Family	Models	Alignment Indicator	AID™ System	Separate Output Indicator	Notes:
OMNI-BEAM™ 	OSB Series	Labled "SENSE": lights when light is sensed (in light operate); or when dark is sensed (in dark operate)	No	Yes	Also has 10-element signal strength indicator; alarm output for marginal sensing conditions
	OSE Series		No	Yes	Output indicator labled "LOAD"
	Sonic OMNI-BEAM	Labled "TARGET PRESENT"; lights when object is sensed	No	Yes	Status of output indicator is ignored when using analog power block
	Analog OMNI-BEAM	Moving-dot output array indicates signal strength	No	Yes	Moving-dot output indicator; 0-10V dc output (direct or inverse)
MULTI-BEAM® 	SB and 2SB Series	Lights when light is sensed	Yes	No	Models SBAR1, SBAR1GH, & SBAR1GHF do not have AID system
	3GA Series edgeguide system	Lights when light is sensed	No	No	
	LS10 Series light curtain	Goes "off" when all beams are aligned (and unblocked)	No	No	
MAXI-BEAM® 	All	Lights when light is sensed	Yes	Yes	Dual output status LEDs in power block, labled "OUTPUT ON" and "OUTPUT OFF"
VALU-BEAM® 	SM912 & SMI Series	Lights when light is sensed	Yes	No	
	915 Series, 990 Series	Lights when light is sensed	No	No	
	SM2A912 Series (2-wire ac)	Lights when light is sensed (light operate); or when dark is sensed (dark operate)	No	No	Alignment indicator doubles as output indicator (comes "on" when output is energized)
MINI-BEAM® 	SM312 Series (dc models)	Lights when light is sensed	Yes	No	
	SM2A312 Series (2-wire ac models)	Lights when light is sensed (light operate); or when dark is sensed (dark operate)	No	No	Alignment indicator doubles as output indicator (comes "on" when output is energized)
ECONO-BEAM™ 	All	Lights when light is sensed	No	No	
QØ8 Series 	All	Lights when light is sensed (light operate); or when dark is sensed (dark operate)	No	No	Alignment indicator doubles as output indicator (comes "on" when output is energized)
Q19 Series 	All	Lights when light is sensed	No	No	LED flashes to indicate marginal excess gain condition (less than 1.5x)

Table E-1. Indicator Systems used for Sensor Alignment and Troubleshooting (continued)

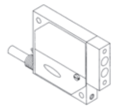
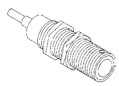
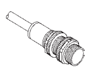
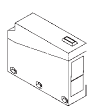
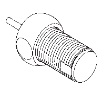
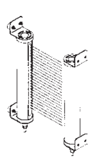
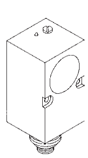
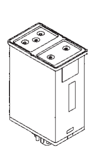
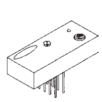
Product Family	Models	Alignment Indicator	AID™ System	Separate Output Indicator	Notes:
SM512 Series 	All	Lights when light is sensed	No	No	
SM30 Series 	SM30 Series (dc models)	Lights when light is sensed	No	No	
	SM2A30 Series (2-wire ac models)	Lights when light is sensed (light operate); or when dark is sensed (dark operate)	No	No	Alignment indicator doubles as output indicator (comes "on" when output is energized)
S18 Series 	AC models	Lights when light is sensed	No	No	LED flashes to indicate marginal excess gain condition (less than 1.5x)
	DC models				
Q85 Series 	All	Lights when light is sensed	Yes	Yes	
C3Ø Series 	All	Lights when light is sensed (light operate); or when dark is sensed (dark operate)	No	No	
BEAM-ARRAY™ 	All	Lights when all beams are established (unblocked)	No	No	
ULTRA-BEAM™ 	923 Series (analog models)	Lights when power is applied	No	No	Alignment indicator pulses at a rate proportional to the level of the analog output; output indicator is labled "LOAD OUT".
	925 Series (relay output)	Lights when object is sensed	No	No	
MAXI-AMP™ 	CM Series, CR Series	Labled "SIGNAL IN"; lights when light is sensed	Yes	Yes	
MICRO-AMP® 	MA3 and MA3-4	Labled "SIGNAL IN"; lights when light is sensed	Yes	No	

Table E-2: Troubleshooting - Self-contained Sensors and Component Systems

Symptom	Probable Cause	Analysis & Correction
Alignment indicator never comes "on", and output never switches the load. (See Note 1, next page) * applies to dc sensors and component amplifiers with solid-state output switch and short-circuit protection.	1. Sensitivity control is set too low	23
	2. Sensor lenses are obscured or broken	15, 16, 26
	3. Loose power supply connection	2
	4. Wrong sensor supply voltage or faulty power supply	1, 9
	5. Component systems:	
	a. shorted emitter or receiver cable	2
	b. failure of amplifier	11
	c. failed emitter or receiver	12
	6. Overloaded output - short circuit protection is activated*	7
	7. Failure of self-contained sensor (or of one or more modules of a modular self-contained sensor)	5a, 11
	8. Receiver saturation from intense ambient light	25
	9. OPPOSED mode: emitter and receiver are misaligned	28, 29a
	10. RETRO mode: a. retro target outside sensor's field of view	28, 29b
	b. retro target is obscured or broken	17
	11. PROXIMITY modes: object to be sensed is outside the sensor's field of view	28, 29c
	12. FIBER OPTIC modes: broken fibers	18
Alignment indicator never comes "on", but output does switch load correctly.	1. Broken alignment indicator LED (sensor will continue to otherwise function normally)	14
Alignment indicator is always "on", and output never switches load (See Note 1, next page) * applies to dc sensors and component amplifiers with solid-state output switch and short-circuit protection.	1. Crosstalk from adjacent sensors	24
	2. Receiver saturation from constant EMI or RFI source	4, 27
	3. Failure of sensor (or of component amplifier module)	11
	4. Overloaded output - short circuit protection is activated*	7
	5. Wrong sensor supply voltage or faulty power supply	1, 9
	6. Component systems: false response of component amplifier to electrical crosstalk (i.e.- cross coupling of emitter signal to receiver along remote sensor lead wires)	10
	7. OPPOSED mode: a. sensing energy is penetrating material ("burn-through")	22, 23, 29a
	b. object is transparent and beam is never broken	22, 29a
	8. RETROREFLECTIVE mode: a. shiny object is reflecting light (beam is never broken)	22, 23, 29b
	b. object is transparent and beam is never broken	22, 23, 29b
	9. PROXIMITY modes: a. background object is returning emitted light signal	22, 23, 29c
	b. optical crosstalk from broken lens (high power models)	16
	c. optical crosstalk from moisture on lens (high power models)	26
	10. FIBER OPTIC modes: a. broken fibers in bifurcated glass fiber optic assembly	18

Table E-2: Troubleshooting - Self-contained Sensors and Component Systems (continued)

Symptom	Probable Cause	Analysis & Correction
Alignment indicator and/or output operate erratically: one may or may not follow the action of the other.	1. DC sensors: faulty power supply	9
	2. Optical crosstalk from adjacent sensors	24
	3. False return of emitted signals	29a, 29b, 29c
	4. False response to intermittent EMI or RFI	3, 4, 27
	5. Component systems: false response of component amplifier to electrical crosstalk (i.e.- cross coupling of emitter signal to receiver along remote sensor lead wires)	10
Alignment indicator follows the sensing action normally, but output is energized all of the time.	1. Sensors or component amplifiers with solid-state output relay:	
	a. output of sensor or amplifier has failed (shorted)	5a, 11
	b. leakage current of solid-state output device too high	6
	c. saturation voltage of solid-state output device too high	8
	2. Sensors or component amplifiers with electromechanical output relay: output relay has failed	13
Alignment indicator follows the sensing action normally, but output either: 1) *never* energizes load, or 2) only *sometimes* energizes load	1. Failure of sensor or component amplifier module	5a, 5b, 11
	2. Loose wiring connection	2
	3. Response time of sensor or component amplifier module too slow	19
	4. Response time of load too slow	19
	5. Mistimed sensor interrogation	20, 21
Sensor or amplifier sensitivity cannot be set to sense the difference between LIGHT and DARK conditions. Sensitivity seems to be either too high or too low.	1. Sensing contrast is too low	22, 29a, 29b, 29c
	2. False response of component amplifier module to electrical crosstalk between remote emitter and receiver cables	10
	3. Power supply voltage is too low	1, 9
Sensing system works only when the sensor or the amplifier is set at very high sensitivity	1. Marginal alignment	29a, 29b, 29c
	2. Marginal application	28

Note 1: Status of the alignment indicator is reversed for the following models:

LS10R
Standard sensor models with model suffix "NC"
OMNI-BEAM sensors programmed for DARK operate
VALU-BEAM SM2A912 Series sensors programmed for DARK operate
MINI-BEAM SM2A312 Series sensors programmed for DARK operate
QØ8 Series DARK operate models
SM2A30 Series DARK operate models
C3Ø Series DARK operate models

(continued from page E-1)

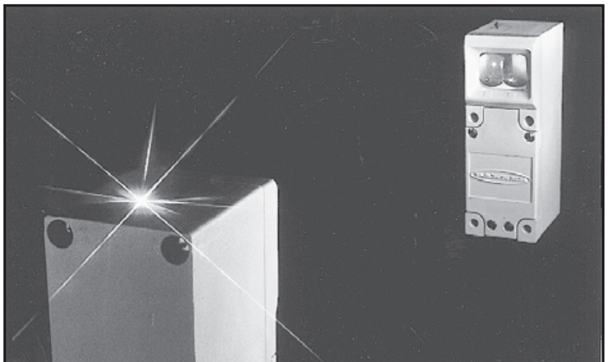


Figure E.2. A sensor's alignment indicator provides an important clue for solving sensing problems.

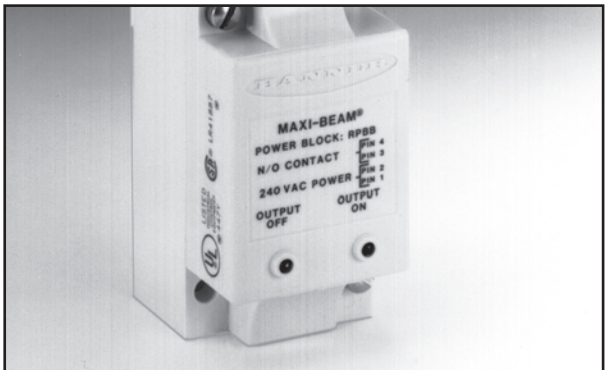


Figure E.3. In addition to an alignment indicator, some sensors and component amplifiers have indicators for output status.

The AID feature is found on most sensors within the following product families: MULTI-BEAM, MAXI-BEAM, plus MAXI-AMP and MICRO-AMP component amplifiers. The AID feature is also offered on Q85 Series sensors, dc 912 Series VALU-BEAM (including intrinsically-safe models), and dc MINI-BEAM sensors. Table E-1 on pages E-2 and E-3 lists the type of indicator system used for each product family.

Tackling the Problem

This troubleshooting section explains, in general terms, the most common causes of sensing problems, and discusses how to identify and deal with them. These causes include:

a.) **Wiring and/or interface problems**, including straightforward causes like wrong connections and intermittent connections, plus more subtle problems, such as the incompatibility of a load with a particular sensor output.

b.) **Sensing component failures** including infant mortality and failures due to environmental factors.

c.) **Timing problems** such as sensor and/or load response time shortcomings or mis-timed sensor interrogations.

d.) **Marginal sensing conditions** such as low sensing contrast or sensor misalignment.

Table E-2 (pages E-4 and E-5) lists problem symptoms in the first column. The "Probable Cause" column may be used to help narrow the reasons for the particular sensing problem. For each probable cause, a reference number is indicated which leads to a more detailed explanation of the problem and a discussion of possible corrective measures.

Troubleshooting References:

Analysis and Corrections

The troubleshooting reference information given below is keyed to the reference numbers given in the *Analysis & Correction* column of the *Troubleshooting Table* (Table E-2, pages E-4 and E-5).

A. Wiring and Interface Problems

1. Supply Voltage

A check of the supply voltage to the sensor (or component amplifier) is a good first step in any problem analysis. The wrong sensor supply voltage can result in several problem symptoms ranging from an apparent decrease in switching hysteresis to catastrophic failure of the sensor and/or the load. The operating range of input voltage for the sensing device in use is found on the label of the device, in the data sheet packed with the device, in the Banner product catalog, or in Tables B-15 through B-18 or the reference hookup drawings in this handbook.

AC Supplies: Most ac voltage level problems result from localized line or isolation transformer failure. The voltage in the circuit will typically drop; often to one-half of the proper supply voltage level. 2-wire ac sensors are most likely to not function at all on low voltage. This condition is not damaging. However, low voltage applied to 4-wire ac sensors and component amplifiers (those with transformer inputs) is likely to cause the sensor's output to oscillate. This condition may simply cause the load to "chatter". However, if the voltage level to the load is also too low, the load may draw excessive current that can damage the load and/or the sensor's output device (see #5a, "Failed Output").

When the supply voltage to an ac sensor or component amplifier module is too high, there will usually be no apparent operational symptom until one or more sensor components fail. However, before and after a catastrophic failure occurs, the sensor (or component amplifier) may feel very warm or even hot to the touch. If the load shares the sensor's supply voltage, it too may exhibit unusual behavior before the sensor fails. This failure mode also occurs with high voltage applied to a dc sensor.

DC Supplies: Most dc power supply problems result from the dc supply failing to deliver enough current for the total sensing system or enough pure dc (i.e. - the ac component or "ripple" is too high). See #9, "Faulty DC Power Sources", for more information.

Low voltage to a dc sensing device is likely to result in an apparent loss of switching hysteresis. This would be apparent in low contrast applications when it suddenly becomes difficult or impossible to find a stable setting for the sensitivity (also see #22, "Low Sensing Contrast").

2. Bad Connections

When erratic behavior or intermittent failures cannot be identified as being optical or electrical in nature, it is always possible that there is an intermittent connection somewhere in the sensing system. A thorough inspection of the wiring will sometimes identify the fault. Use a VOM set to a low resistance scale (or a continuity tester) to check the continuity of all point-to-point wiring. The most common problems occur in connectors, relay sockets, or where the insulation of a wire extends under a connector screw terminal. In areas of high vibration or in highly corrosive environments, all connector pins of plug-in modules should be inspected for signs of wear or corrosion (oxidation).

In remote (component) sensor systems, *shorted* sensor wiring may cause problems. Shorted emitter or receiver wiring causes the system to act as if the receiver is always "seeing dark": the amplifier's alignment indicator LED never comes on, and the output never changes state.

3. Improper Grounds

Occasionally, a sensor will operate correctly until it is bolted to a machine frame. It will then behave erratically, either giving random false "light" outputs or locking on in the "light" state. This is an indication that the machine is not properly grounded, and that the point on the machine where the sensor is mounted is at a different potential than the earth ground to which the sensor power supply is connected. In these cases, the best solution is to run a #16 ga. wire (minimum size) from this point on the machine directly to the earth ground location. The worst offender is often a motor, in which current is leaking from the armature to the motor frame and then to the entire machine. This can be corrected by running a ground wire directly from the motor frame to a good earth ground.

The ground wire of metal-cased dc sensors, including the shield wire of remote sensors in metal housings, will connect the machine frame to the common of the sensor's dc power supply, when the sensor is mounted directly to the machine frame. In severe cases, where the voltage on the machine frame is greater than a few volts, the dc power supply may perform erratically or even suffer damage. The sensing devices may also be damaged if the level of ac voltage on the machine frame is high enough. It is normally easy to measure these faulty "ground loops" by connecting an ac voltmeter between earth ground and various points on the machine. Any potential greater than a few volts indicates a ground loop, and should be corrected.

4. Voltage Surges, Spikes, and DV/dt

Inductive loads such as relays, solenoids, and motors can sometimes affect the performance of photoelectric sensors and component amplifiers. When a solenoid is energized, for example, an electromagnetic field expands around the solenoid coil. When the solenoid is de-energized the field collapses, creating a large voltage surge (transient) which attempts to maintain current flow in the circuit. This transient (also called an "inductive kick" or "spike") is both an instantaneous noise source and a potential source of damage to instruments (including amplifiers and sensors) that are connected to the same electrical circuit.

If of sufficient amplitude, such electrical noise can cause "false triggering" of the load. False triggering may often be prevented by adjustment of the sensor or amplifier's SENSITIVITY control, which influences the system's response to noise as well as to the received light signal. If this setting is reduced to just above the point where the system operates reliably, interfering signals can sometimes be made to fall so far below the amplifier threshold that they are no longer able to operate the output and are no longer a problem.

"DV/dt" is an electronic term that describes the rate at which a voltage transient ("spike") rises and falls. It is normally expressed in "volts per microsecond", and is of some concern when using sensors having thyristors (SCRs). This is because if a transient rises at a rate in excess of the rating of the thyristor, the thyristor will be turned on for 1/2 cycle of the sine wave. A single "transient turn-on event" will not normally damage a thyristor, but if it happens continually it can lead to failure. Most thyristor (ac sensor output) circuits have a great deal of protection against DV/dt, including capacitive snubber circuits and clamping suppressors.

If an ac sensor output presents this "one-cycle" behavior, it is an indication that some other load is generating high-level transients. The best solution is to identify the offending load and suppress it with a clamping device and/or a snubber (see Figue C.7). It is less effective to place the suppressor across the sensor output, since all Banner ac solid-state outputs include built-in suppression networks; but if the offending load cannot be identified, this latter approach may help.

The contacts of electromechanical relays do not have built-in suppression networks. When sensors or component amplifiers with electromechanical relay outputs are used to switch inductive loads or large resistive loads, some form of arc suppression device must be added to the switching circuit. For information on arc suppression techniques, see Section C, "Interfacing".

5. Sensors and Component Amplifiers with Outputs that Switch AC: Shorted Load and Overload

a) Failed Output

Output transistors and thyristors (SCRs) nearly always fail due to excessive heat inside the device, caused by excess current flow. The most common cause of excess current is a short circuit of the load, where the current is limited only by the resistance (impedance) of the power source. This type of damage is most likely to occur in ac circuits, where the external power source may be capable of delivering tens or hundreds of amperes of current.

In such situations, damage occurs within just a few milliseconds. Even a single strand (of a stranded wire) that momentarily brushes against another terminal, resulting in a short circuit of the load, can destroy the output switching semiconductor. Pinched wires inside a conduit are another potential source of short circuits. Certain loads such as motors and solenoids can sometimes cause short circuits if a loose or bare wire inside the load touches the metal frame of the load. This situation can be particularly difficult to identify in motors, where a wire on the armature may brush against the motor frame only when the armature is rotating at high speed, and the short is not detectable when the armature is at rest.

It is also possible for an output semiconductor to fail due to an overload condition in which excess current flows for some period of time. AC loads are most troublesome because of the high inrush currents that occur while the inductance of the load is building up. An ac load may be rated at an acceptable current level, including the inrush current, but may still cause failures if it is being recycled rapidly. This is because the average current, including the inrush, is in excess of the output rating. If high cycle rates are anticipated, it is best to assume that the inrush current must be within the continuous current rating of the output.

Output semiconductors can fail either in the shorted or the open condition, but are most likely to fail shorted. It is frequently possible to identify a shorted output by measuring the resistance across the output using a VOM set to a low resistance scale (Rx1 or Rx100). This measurement must be done with the power off and the load disconnected. Any reading of less than about 10,000 ohms indicates a shorted output. Measurements should be taken in both polarities, and if either shows a low resistance the output is probably blown.

Identification of an open output is usually not possible in the field, but can be determined by the factory.

In Banner modular sensors (OMNI-BEAM, MULTI-BEAM, and MAXI-BEAM), sensor block, power block, and logic modules may be separately replaced. The Banner model LMT plug-in test module allows in-the-field identification of damaged MULTI-BEAM sensor head, power block, and logic modules. In troubleshooting situations where the output never switches but the alignment indicator LED does follow the sensing action, the fault is most likely with the power block module. In these situations, if a logic module is in use, check to ensure that a programmed logic delay is not causing the sensor to just appear to be inoperative.

If the alignment LED is always on or always off, and the sensor's output never switches, the fault may be with either the sensor block or the power block (or logic module, if used). If the output switch of the sensing device is an electromechanical relay contact, that contact is likely to survive the high current surge caused by a shorted load if the ac circuit is protected by a fuse or a circuit breaker. However, some amount of contact damage can be expected with each incident, leading to eventual contact failure.

b) Half-wave ac Output

In rare cases, it is possible for a thyristor (SCR) to fail in a mode where it is shorted or open to one half-cycle of the ac sine wave, but not to the alternate half-cycle. When this occurs, the equivalent of a dc voltage is applied to the load. With highly inductive loads, this can cause further damage, including overheating of the load. A VOM connected across the load will read some intermediate voltage (either ac or dc), e.g. 60 volts for a 120 volt load. This may occur in either the energized or de-energized state. If such a situation is encountered, remove the sensor immediately to prevent damage to the load.

This problem can occur in ac sensors with thyristor (SCR) outputs, MAXI-AMP modules with solid-state outputs, and in component systems using a BTR-1A as the interface device.

6. Leakage Current (See Table C-4)

The lower the off-state leakage current specification for a sensor or component amplifier, the lower the potential for interfacing problems. The off-state leakage current is significant only for 2-wire ac sensors. The 1.7 milliamp leakage of 2-wire ac sensors can be too high for some solid-state input circuits, like those of some PLCs (programmable logic controllers). This is especially true when several 2-wire ac sensors are wired in parallel to a common input (leakage current is additive). Excessive leakage current is evident by the PLC input locking "on" (i.e. once energized, the input will not switch "off" until power is removed).

The effect of leakage current can be measured with a VOM (on an ac range) connected between the PLC input and PLC common (neutral), with the sensor powered and in its "off" state. If the measured voltage is greater than the PLC manufacturer's specification for the "highest input voltage that will not energize the input", an artificial load resistor must be installed across the PLC input (in parallel with the 2-wire sensor). A resistor value of 5KΩ (at 5 watts or larger) is usually sufficient. Leakage current is rarely a problem when interfacing to an electromechanical (inductive) load.

7. Sensors and Component Amplifiers with Solid-state Outputs that Switch DC: Short Circuit and Overload Protection Circuitry

Many self-contained dc sensors and component amplifiers have short-circuit protected outputs that disable the output transistor in the event of a short or an overload (see Table C-3). When these sensors are used to run incandescent light bulbs, there is an inrush current to the cold filament of at least 10 times the steady-state current. This inrush can trigger the short-circuit protection, which turns off the output transistor. When the output automatically tries to energize again (a few milliseconds later) the inrush again turns it off. This causes the output to appear not to energize.

This same phenomenon occurs when there is a capacitor placed directly across the load. The inrush current (to charge the capacitor) triggers the short protection, and if the capacitor discharges at all during the time that the output is waiting to try to energize again, the process recurs.

Both problems can usually be solved by installing a resistor in series with the output. This reduces the current that can be delivered to the load, but is usually acceptable. Typical resistor values range from 10 to 100 ohms. Banner's applications department can recommend a value if the load is defined.

8. Sensors and Component Amplifiers with Solid-state Outputs that Switch DC: Saturation Voltage (See Tables C-3 and C-5)

The lower the output saturation voltage specification for a sensor or component amplifier, the lower the potential for interfacing problems. In some cases, especially with dc self-contained sensors, the output saturation voltage in the energized state may be as high as 1 to 2 volts. This is acceptable for most loads, but may not be low enough to energize TTL level inputs or the base-emitter junction of an NPN transistor. Saturation voltage is easily determined by measuring the energized voltage at the output with respect to the negative of the supply (dc common): if it is higher than the known threshold voltage of the load, contact the factory for information about possible modifications to either the sensor or the external circuit.

9. Faulty DC Power Sources

There are three common problems of power supplies that can cause erratic operation of their associated sensors and/or component amplifiers.

The power supply may not be capable of supplying the current required at the voltage required. This situation may easily be evaluated in the passive state by measuring the voltage across the power supply output with all loads energized to verify that it (the voltage) is within the required limits of the sensor (or component amplifier in remote systems) in use. However, be aware that in some cases certain loads that operate for only a very short "one-shot" time can pull the supply voltage down so quickly that the pulldown will not register on a voltmeter. If in doubt, either use an oscilloscope to monitor the voltage or disconnect the load(s) in question to determine whether the "unloaded" sensor then operates properly.

The power supply in use may not adequately filter the dc voltage after it has been rectified. Most dc sensors require less than 10% maximum ripple. This problem seldom occurs with regulated power supplies, but is frequent when a user has created his own power supply using a transformer and bridge rectifier but has not included adequate filtering. If it is not known whether or not filtering is adequate, it can do no harm to install 500 or more microfarads across the power source (use an electrolytic capacitor and observe proper polarity).

Use of a dropping resistor may render existing power supply filtering ineffective. Sometimes a user will attempt to reduce the level of a supply voltage (for example, from 24V dc to 15V dc) by using a dropping resistor in series with a sensor. Filtering is no longer effective, and the resultant voltage depends upon the current draw of the sensor, which can vary from one unit to another. In rare cases this approach can be effective, but first consult Banner's applications department.

A "switching-type" dc power supply may cause interference. Photoelectric sensors that are powered by a switching dc power supply may exhibit a "lock-on" condition of their amplifier and output, due to high-frequency interference that is generated by the supply itself. The frequency of the interfering signal is affected by how heavily the supply is loaded. If the frequency of the supply coincides with the frequency of the sensor's tuned amplifier, the sensor will behave as if it is receiving a light signal.

This problem occurs most often when using photoelectric opposed mode emitters and receivers (with the exception of the SM30 Series). This is because opposed mode receivers are electrically separate from their emitters, which requires that the bandwidth of the receiver circuit be relatively large. Although the small size of a switching-type dc power supply is an attractive convenience, they are never recommended for powering sensing systems.

A dc power supply may fail. There are several dc power supply failure modes, usually caused by overloading of the supply. Failure symptoms include: low voltage output, high voltage output, and loss of rectification (i.e. high ac voltage component).

Low voltage to a dc sensing device is likely to result in an apparent loss of switching hysteresis. This would be apparent in low contrast applications when it suddenly becomes difficult or impossible to find a stable setting for the sensitivity.

When the supply voltage to a dc sensor or component amplifier is too high, there will usually be no apparent operational symptom until one or more sensor components fail. However, before and after a catastrophic failure occurs, the sensor (or component amplifier) may feel very warm or even hot to the touch. If the load shares the sensor's supply voltage, it too may exhibit unusual behavior before the sensor fails.

Reverse polarity protection. Many dc sensing devices are equipped with circuitry that causes the device to shut down if it is connected backwards to the dc supply.

10. Remote Sensors and Component Amplifiers: Component Amplifier Response to Electrical Crosstalk

A photoelectric component amplifier may "lock on" or behave erratically due to "electrical crosstalk" between the remote emitter and receiver leads. To check for electrical crosstalk, block the opposed mode receiver with an opaque object, or make sure that the proximity or retroreflective sensor is not seeing any reflecting objects (including background). If the amplifier still locks "on", crosstalk is present between the emitter and receiver leads.

When electrical crosstalk occurs, it is usually at high amplifier sensitivity settings in remote sensor systems where there is insufficient separation or shielding between emitter and receiver wiring. The wires act like radio antennas, with signals from the emitter wiring being radiated to the receiver wiring, even though the wires may not be touching. The longer the leads, the more chance there is that electrical crosstalk will occur. The following precautions should be observed:

1) The shield (drain) wire of each shielded cable must be securely connected to the designated terminal at the *amplifier end only.*
2) When splicing, never combine emitter and receiver wires in one common cable (even if that cable is shielded).
3) Avoid running remote sensor cable in lengths in excess of the maximum length specified for the amplifier in use.
4) Avoid running remote sensor cables in wireways with power- carrying conductors.
5) Avoid running remote sensor cables through areas of extreme electrical interference (e.g. areas of inductive or arc welding, etc.).

These same precautions will reduce the sensing system's susceptibility to EMI and RFI (see troubleshooting references # 27 and #4) . Note that a constant EMI or RFI source can mimic the effects of electrical crosstalk.

Electrical crosstalk can reduce the apparent contrast in a sensing application when it is sufficiently strong to lock the amplifier "on" in what would otherwise be the "off" state. In applications having adequate optical contrast, this situation is evidenced by an inability to find a sensitivity setting that enables the amplifier to both switch on and switch off when it should.

If lock-on does not occur when the receiver is blocked with an opaque object but does occur during operation, then the emitter is "burning through" the object (opposed mode, see troubleshooting references #22 and 29a), or is reflecting off a background object (proximity and retroreflective modes; see references # 22, #29b, and #29c).

B: Sensing Component Failures

11. Infant Mortality

In a statistically small percentage of cases, a component will fail in a circuit for no other reason than "infant mortality". This is most likely to occur in the first few weeks of operation, but is not limited to that time. When no other explanation seems plausible, the defective sensor should be returned to the factory for a failure analysis.

Most component failures are catastrophic, and easily discovered. It is possible, however, for a component to fail intermittently. In these cases, it is very important to describe the sensor's behavior to the factory so that the device can be thermally cycled in an attempt to recreate the fault. It is possible for the emitter LED to fail in a self-contained sensor, but such a failure is neither more nor less likely than is the failure of any other electronic component. LED failure is not normally a user-caused failure, but rather is due to "infant mortality" of the LED itself.

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12. Failed *Remote* Emitter or Receiver

Remote emitters and receivers may fail due to "infant mortality" (troubleshooting reference #11) or improper hookup (follow hookup instructions closely). Remote emitters are the most prone to be damaged by improper hookup. The most common damaging mistake involves connection of the negative (green) wire to dc common instead of to the negative of the LED oscillator circuit.

Remote emitters and receivers may be checked as follows:

1) An undamaged emitter LED will show high resistance when measured in one direction (polarity) using a VOM, and lower resistance in the opposite direction (polarity). A shorted LED shows little or no resistance in both directions. A "blown" (open) LED shows infinite resistance in both polarities. Set the VOM to a low resistance (Rx1, Rx10, or Rx100) scale when measuring. Disconnect the emitter from all external circuitry before measuring its resistance.

2) Receiver phototransistors (and amplifier semiconductors) can also fail either "open" or "shorted". They are most likely to fail shorted. It is possible to identify a shorted phototransistor by measuring its resistance with a VOM set to a low resistance scale. Measure resistance in both directions (polarities), with the receiver disconnected from all external circuitry. A reading of less than 10,000 ohms in either direction indicates a shorted output.

A shorted output semiconductor can usually be identified in the same way. Identification of an "open" output, however, is usually not possible in the field, but can be done at the factory.

If both the emitter and receiver of a remote sensing system check out "okay" and the system still does not operate, the problem is in the amplifier or in the interconnecting wiring between the sensors and the amplifier or between the amplifier and its load.

13. Failed Electromechanical Output Relay

Electromechanical relays have a finite service life (see Table C-2). This is one of several important considerations when specifying a sensor or component amplifier with an electromechanical output relay (see Table C-1).

An electromechanical relay may fail in either an open or a closed mode. In an open mode, a normally open contact never conducts. This is often caused by an "open" relay coil, and is sometimes caused by a broken contact or a jammed armature.

In a closed failure mode, a normally open contact remains permanently conducting. This may be caused by contacts "welding" themselves together when switching too much power, and is sometimes caused by a jammed armature.

If the load being switched by an electromechanical relay contact only energizes sometimes, the problem may be "burnt" contacts. Overload of the relay contacts, and/or arcing between them, can cause carbon deposits and pitting on the contact surfaces. This can result in intermittent load switching. Any inductive load or large resistive load requires some means of arc suppression. For information on arc suppression techniques, see Section C, "Interfacing" .

If electromechanical relay contacts are used to switch logic-level signals, it is important to check the relay's specification for minimum voltage and current. Many relays are not designed to reliably conduct low current levels (see Table C-2).

14. Broken Alignment LED

It is possible for the alignment indicator LED to fail without affecting the operation of the amplifier output. It is usually not necessary to replace the amplifier or sensor unless the indicator is required for the application.

15. Lens Corrosion

Some Banner sensors (including most Banner remote sensors) use a hermetically sealed glass lens for both the emitter and receiver (see page B-76). Upon close inspection, a metal flange may be seen around the perimeter of the lens. This flange forms the seal, and in some cases is electrically conductive. If the sensor is used in an environment where there is a great deal of moisture containing free ions (such as salt water) the metal can corrode due to electrolysis. In extreme cases, the corrosion can obscure the lens, and even destroy it. If this situation becomes apparent, an accessory lens cover should be used.

16. Discolored or Cracked Lenses

The acrylic lens used on some sensors (see table B-14) has a lower melting point than the case, and is therefore the first indicator of excessive temperatures. If there is a discoloration or warping of the lens, the sensor should be removed immediately from the application, since the temperature is far in excess of the operating temperature of the electronics. In these cases, fiber optics are the only alternative.

Some solvents attack acrylic lenses. For example, isopropyl alcohol, when it contacts an acrylic lens, will release stresses that quickly result in hundreds of micro-cracks. See Table 15 in the Data Reference section for more information.

17. Retro Target Obscured or Broken

If a retroreflective target is obsured or broken, it cannot efficiently return light to a retroreflective mode sensor. A broken target should be replaced. A retro target should be kept clean for best results. Use only mild detergents to clean a retro target. Avoid solutions containing alcohol for cleaning retro targets that have acrylic lenses. Also, the scan path to a target should be free of objects that might partially block or reflect the beam.

18. Broken Fiber optics

Occasionally a bifurcated glass fiber will cause a sensor to "lock on" at very high sensitivity settings, especially when used on the more powerful sensors. This is an indication that some of the individual fibers in the combined bundle are broken. Light is being "piped" down the bundle, where it leaks out of the broken fibers and is reflected off the other end of the breaks and back to the receiver. The only solution to this problem is to reduce the sensitivity to the point where this reflected light no longer actuates the receiver. In applications where this phenomenon becomes troublesome, it is best to replace the bifurcated fiber with two individual fibers mounted parallel to each other and looking in the same direction. Broken fibers will then have no effect, except to reduce the signal by the percentage of fibers that are broken (this is seldom more than a few percent).

The most common cause of glass fiber optic breakage is continued flexing of the fiber bundle. While glass fiber optics can withstand very high levels of shock and vibration, the individual strands cannot withstand continual rubbing against one another. A few hundred cycles of significant flexing may cause breakage of some strands, and the bundle will begin to deteriorate until it no longer has enough light transmission for the application.

It is possible to "see" the broken strands by holding one end of the fiber bundle (either individual or bifurcated) up to a bright light while examining the opposite end with a magnifying glass. Broken fibers will appear as dark spots scattered among the otherwise bright fiber strands at the end of the bundle. It is not unusual for about 10 percent of the strands to be broken. If more are broken, it is a warning of potential sensor failure.

This problem of broken glass fiber strands can be avoided by using plastic fiberoptic assemblies in applications where environmental conditions allow. They withstand flexing much better, and coiled models are available for use on reciprocating mechanisms.

C. Sensing Timing Problems

19. Response Time

The response time of most Banner sensors and component amplifiers is independent of signal strength, and is within the specification shown for the device. If an application works at slow speeds but not at high speeds, it is probably due to the signal becoming faster than the response time. The problem could be with either the light signal or the dark signal. The specification applies to both, independently. If it is not possible to use a faster sensor, it may help to identify whether it is the "light" signal or the "dark" signal that is too "fast". It may then be possible to redirect or shape the effective beam so that it is broken (or established) for a longer time.

Also, if load response is too slow, the sensing event (and the signal to the load from the sensor) may "come and go" before the load can respond. It may be necessary to use "one-shot" logic to artificially lengthen the signal to the load, thereby giving it adequate time to respond.

20. Interrogation Timing

In many inspection schemes, the logic is "interrogated" (or "gated") momentarily to allow the inspection sensor to "look" at the product only at the proper time. If ONE-SHOT or DELAY logic is used, logic timing settings may be critical, and will have to be readjusted for various product speeds. It is always best to design interrogation systems so that the interrogate "window" is a function of the mechanical references in the process rather than of time (see Section D, "Sensing Logic").

21. Behavior on Power-up

Most sensors have a 0.1 to 0.3 second delay upon power-up that prevents the possiblity of a false output during the time that the supply voltage is rising to its final value. For example, without the power-up delay period, a sensor in the dark operate mode with OFF delay timing logic might "think" that it was in the dark state just prior to application of power. As a result, the OFF delay timer might falsely hold the output energized for one time period.

A power-up delay usually precludes the possibility of interrogating a sensor by powering it only during the interrogation window. Sensors requiring that their output be gated should be powered continually. Gating should be accomplished by combining the sensor's output with the gate signal, using a logic module (dc sensors) or series hookup (4-wire ac sensors and sensors with electromechanical output relays).

D. Marginal Sensing Conditions

22. Low Sensing Contrast

One of the most common causes of intermittent sensor operation is a lack of contrast between the "light" and "dark" conditions. Lack of contrast is usually manifested by a situation where the sensor or amplifier "hangs up", in either the light or dark condition, or (in counting applications) where counts are missed or excessive. These things happen when the SENSITIVITY is set up just on the verge of operation. When the sensing event occurs, the sensor sees the change, but cannot overcome the hysteresis of the operating point. The best solution is to reconfigure the sensing setup (sensor position, background type and location, sensing angle, etc.) or to choose a different sensing mode that can provide more contrast. (See discussion of contrast in Section A, "Sensing Theory".)

In retroreflective sensing mode applications, low sensing contrast results from the following causes:

1) Excess gain is too low (sensor hangs-up in the "dark" state). Low excess gain is often a result of the retro target size being too small to return enough incident light to the retro sensor. Also, the reflecting efficiency of retro materials varies. Retro materials in the Banner product catalog are assigned a reflectivity factor to indicate their relative efficiency. Low excess gain also results from objects (like guide rails, supports, etc.) located in the sensing path that partially block the effective beam.

2) Contrast is too low when not enough light is blocked as the item to be sensed passes through the beam (sensor hangs-up in the "light" state). This results when:

a) an object is smaller than the effective beam (Fig. A.24),

b) the material to be sensed is too transparent to reliably break the retro beam,

c) an object with a shiny surface (when viewed straight-on) returns as much or more light to the sensor as does the retro-reflective target. The best approach to solving this "proxing" problem depends on the particular situation. For more information, see #29b, "Retroreflective Alignment".

In proximity mode applications, low contrast is most often caused by a reflection from some background or foreground object, other than the one to be detected. Sensing angle, background reflectivity and/or color, and background distance should be adjusted to provide maximum sensing contrast.

Some control over the effects of background reflections may be gained with the use of convergent beam sensors. Fixed-field mode photoelectric and proximity mode ultrasonic sensors offer excellent rejection of background reflections, where they can be applied.

In opposed mode applications, as in "retro", the problem is usually either low excess gain or an attempt to sense an object that is not sufficiently opaque to the sensing beam. Also, in opposed sensing, the effective beam of the sensor pair may be too large to sense the object. In these cases, light "leaks" around the object, activating the receiver even when the object is in "sensing position" (see figure A.20).

For more information on maximizing contrast in each sensing mode, see troubleshooting reference #29.

23. Sensitivity Control Improperly Set

Most photoelectric self-contained sensors and all component amplifiers have sensitivity (GAIN) adjustment controls. Sensitivity controls allow electrical attenuation of the excess gain in sensing situations where enough light signal is returned to the sensor in the dark conditon to satisfy the amplifier. Excess gain may be reduced in those sensors with no sensitivity adjustment (or in any sensor) by intentional misalignment or (in the opposed mode) by the addition of apertures.

The sensitivity should always be increased to the highest point that still allows the sensor to reliably switch in the dark conditon. If the sensitivity is set too low, the sensor’s output might never change state because the light condition might never be recognized. Conversely, if the sensitivity is set too high, the sensor’s output might never change state because the sensor (or component amplifier) might never recognize the "dark" condition.

If the sensitivity is difficult to set (i.e. it is either too high or too low), the cause may be one or more of the following:

1) the sensing contrast is too low (see #22, above);

2) the sensor supply voltage is out of range (see #1, above);

3) the sensor or component amplifier is responding to optical "crosstalk" (see #24, below);

4) the sensor or component amplifier is responding to external "noise" (see # 4, above and #27, below);

5) the component amplifier is responding to "cable crosstalk" between its remote emitter and receiver (see #10, above);

6) the receiver is "saturated" by intense ambient light (see #25, below).

24. Optical (or Acoustical) Crosstalk

OPTICAL CROSSTALK

It is always possible for modulated LED photoelectric controls to interact in an undesirable way, even when the emitter and receiver circuits are synchronized (phase locked). The most common crosstalk problem, however, occurs with opposed (beam-breaking) self-contained emitters and receivers, since they are seldom synchronized. This means that any emitter of a particular model type will energize any receiver of a compatible model type (see Figure A.38).

In addition, an opposed mode receiver may be affected by a nearby retroreflective or proximity mode sensor if the light from that sensor is not prevented from reaching the self-contained receiver. Except in the case of Banner SM30 Series emitter/receiver pairs (which offer a choice of two modulation frequencies), it is not normally practical to operate receivers at different frequencies as is possible with radio transmissions.

When the emitter and receiver circuitry are housed in a single package, as in self-contained retroreflective, proximity, and most fiberoptic sensors, the emitter and receiver are generally synchronized. This means that the receiver is "gated" to look for a signal only during the time that the emitter is actually sending a signal. This tends to statistically reduce the possibility that sensors will interact, but it is still possible that occasionally the frequencies of two sensors will drift in and out of synchronization. In this event, if the optical fields of view of two sensors overlap, a false or missed actuation could occur.

The probability that synchronized sensors might interact is greater at very high excess gain levels, because at high excess gains the received signal tends to become a much longer-duration pulse, and thus has a greater likelihood of being present during the "gate window". Fast-response sensors have a much greater possibility of interacting than do slower-response sensors because the duty cycle of the emitted pulses is much greater. For minimum probability of crosstalk, use sensors with a slow (e.g. 10 millisecond) response time, and adjust sensor sensitivity for the minimum practical excess gain.

The possibility of optical crosstalk in arrays of multiple self-contained sensors can be eliminated by the use of *multiplexing*. Multiplexing is a scheme in which each receiver in a multiple-sensor array is, in turn, allowed to look for a signal from its corresponding emitter only while that emitter is operating. For such applications, investigate the Banner model MP8 multiplexer module. Other Banner products (MULTI-BEAM light screens and BEAM-ARRAY System light curtains) use multiple multiplexed emitters in one emitter housing along with multiple multiplexed receivers in a single receiver housing.

Another type of optical crosstalk may be caused in *high-power* proximity or retroreflective sensors by a broken or cracked lens or by moisture on one or both sides of the lens. The sensor sees its own light reflected back from the lens and "locks on" in the "light" state.

ACOUSTICAL CROSSTALK

Acoustical crosstalk in ultrasonic sensors is analogous to optical crosstalk in photoelectric sensors. The symptoms of the problem are the same. The usual solution to acoustical crosstalk (in situations where interfering sensors cannot be reoriented to positions that do not interfere) is the use of baffles. The baffle is placed between the sensor being interfered with and the interfering sound signal. When placing baffles, make sure that they are out of sensing range so that they do not themselves become the cause of unwanted reflections. The best baffles are made of sound *absorbing* material such as polyfoam. Sound reflecting materials also work, but more care must be taken in their placement.

25. Ambient Light Saturation

Most modulated LED sensors are assumed to be completely immune to ambient light. This is true in the sense that it is very unlikely that ambient light will ever cause the sensor to erroneously sense a "light" condition. There is for each model, however, a level of light that will cause the sensor to become "blind" to any signal (much the same as human vision). At these extreme light levels, the sensor will appear to see a continuous "dark" signal. This most commonly occurs when the sensor is outdoors, and is looking within a few angular degrees of the sun. The only solution is to shield the lens, as much as possible, from direct sunlight.

Whenever possible, angle the sensor (receiver of an opposed pair) just a few degrees downward (toward the ground) to the eliminate the possibility of it "seeing" any direct sunlight.

26. Moisture on the Lens

Moisture (and frost or ice) on the lens of a photoelectric sensor can severely scatter and block the incoming and/or outgoing beam to the point where the sensor will seem to always "see" the dark condition. Moisture on the lens of a high-powered diffuse, divergent, convergent, or retroreflective sensor will sometimes provide a return path for the emitted light, causing the sensor to lock-on in the light condition.

If the application involves wide temperature swings that will cause moisture to condense on sensing equipment, use a sensor with a hermetically sealed lens whenever possible. Otherwise, use sensors with very high excess gain, such as SM30 Series opposed mode sensors. Keeping the surrounding air in motion can help prevent condensation.

27. Radio Frequency Interference (RFI)

RFI (Radio Frequency Interference) can energize modulated LED sensors if the intensity of the interference is high enough. The frequencies are normally so high that they render the synchronizing circuits useless. RFI is most troublesome when it is generated by walkie-talkies, high-current welders, or RF welding equipment. RFI can also be caused by some computer peripherals, such as terminals, but this problem is becoming less severe due to FCC suppression requirements.

If the source of the interference is not apparent, it may be located by using a BEAM-TRACKER in the receive mode. The indicator LED on the BEAM-TRACKER flashes at a rate that is proportional to RFI strength. The best cure for RFI is to treat its source by connecting a good earth ground (water pipe ground) to its shielding or metal housing (if either exist). When this is not possible, the sensors should be shielded from the RFI.

For self-contained sensors, the best protection against RFI is to insulate the sensor from the environment by essentially "wrapping" it in a conductor. Copper is best, but aluminum or steel is usually sufficient. Wrap the entire sensor, leaving an opening just large enough for the sensing beam to exit and enter. This wrap must then be connected to a good earth ground.

In remote (component) systems, emitter and receiver wiring must also be shielded. Emitter and receiver wiring should be run in separate shielded cables. In severe cases, it might also help to run shielded wire to the load, and from the sensing system's power supply. All shields (drains) should be connected to ground only at the amplifier end of the cabling.

Long response time sensors generally are less susceptible to RFI than are the faster units. Also, the lower the sensitivity (gain) control setting, the greater the immunity.

28. Unit-to-unit Variations, Marginal Sensor Performance, Marginal Applications

Banner's published sensor range specifications are conservative. The range and performance specifications for all Banner devices are *minimums*. Due to manufacturing tolerances, the *actual* performance of a quantity of units follows a standard distribution curve: most units will outperform the minimum specifications by a substantial amount. Sensors on the "powerful" end of the distribution curve will work well considerably beyond their published maximum range, but should not be used routinely in this manner. The best procedure is to contact the field sales engineer if an application seems to require that the sensitivity be set higher than about 75% of maximum and a large quantity of sensors is pending. This will prevent the possibility of problems resulting from decisions based only on the performance of one or two sensors that may have come from the extremely "powerful" end of the distribution curve.

Typically, when sensors and component amplifiers are used beyond their upper limits of specified performance, they will operate only with the sensitivity set at or near maximum, and will operate inconsistently or erratically. Even small accumulations of dirt on the sensor lens or airborne contamination (dust, haze, fog, etc.) can cause such sensing applications to fail. Such a situation indicates that the *sensing application itself is marginal.* Switch to a more powerful sensor or reconfigure the application to physically move the sensor well within its range.

In opposed fiberoptic mode applications, addition of lenses to unlensed fibers may help to increase sensing power. In the retroreflective mode, it often helps to increase the size of the retro target. In the proximity sensing modes, it is often of benefit to change the sensing angle to take better advantage of the object's reflective surfaces.

Marginal operation may simply indicate a basic alignment problem: see sections #29a, 29b, and 29c. See also references #26, 15, and 16.

29. Sensor Alignment

Troubleshooting reference #29 refers to sensor alignment procedures, which begin on the next page.

Alignment procedures are given for three photoelectric sensing modes:

Opposed: pages E-18 and E-19
Retroreflective: pages E-19 and E-20
Proximity (including Diffuse, Convergent, and Divergent): page E-21

Before beginning an alignment procedure, read the information in the box (below) to familiarize yourself with the alignment indicator system in the sensor you are working with.

Also, Section A of this manual (Sensing Theory) presents valuable background information, much of which relates directly to sensor alignment. We recommend that you read Section A before beginning an alignment procedure.

Notes about the Alignment Indicator *(refer to Table E-1)*

A. Some self-contained sensors have alignment indicators that follow the output status. They come "on" whenever the output is energized.

These sensors include:

OMNI-BEAM sensors	VALU-BEAM 2-wire ac sensors	QØ8 Series
MINI-BEAM 2-wire ac sensors	SM30 Series 2-wire ac sensors	

When these sensors are being aligned in the dark operate mode, the alignment indicator will go "off" when the receiver is detecting its modulated light. Consequently, references in the following alignment procedures to the alignment indicator coming "on" should instead read "off" (and vice-versa) for these sensors under dark operate conditions.

B. Most self-contained sensors and component amplifiers include a signal strength measurement system.

Signal strength measurement is very useful during the alignment process. The following alignment procedures include steps for the use of a signal strength measurement system (when available).

OMNI-BEAM photoelectric sensors (except the E Series) have a 10-element LED signal strength meter (see Section A and the note below). Many other sensors have the "Alignment Indicating Device" (AID™) feature (see page E-1). The following sensors have the AID system:

MULTI-BEAM sensors (except 3GA edgeguide system and LS10 series light curtains)
MAXI-BEAM sensors
VALU-BEAM SM912 Series (dc models) and SMI912 Series (intrinsically-safe models)
MINI-BEAM SM312 Series (dc models)
MAXI-AMP component amplifier modules
MICRO-AMP component amplifier modules
Q85 Series Sensors

Notes about the alignment of standard OMNI-BEAM Sensors featuring the D.A.T.A.™ signal strength indicator system

Standard OMNI-BEAM sensors (OSB Series) have both an output status indicator and Banner's exclusive **D.A.T.A.™** signal strength indicator system.

These sensors may be easily aligned by using only the output status indicator in the manner described in the alignment procedures on the following pages.

However, standard OMNI-BEAM sensors may be aligned more precisely using the D.A.T.A. LED signal strength indicator system. The D.A.T.A. system is a 10-element LED array: the stronger the received modulated light signal, the more LEDs in the array will be lit. In the following alignment procedures, the position of the OMNI-BEAM sensor should be adjusted to light the maximum possible number of LEDs in the D.A.T.A. array. Note: During alignment, reduce or increase sensitivity, as may be required, to bring the array indication into a "comfortable" working range.

Another use for the D.A.T.A. indicator system is in the measurement of excess gain and contrast in specific sensing applications. See pages A-17 through A-21 of this manual for more information.

29a. Opposed Mode Sensor Alignment *(See also pages A-6 and A-7)*

Opposed mode sensor pairs are used at sensing ranges of from only inches (or less) up to 300 feet or more. At ranges inside a few feet, the enormous power of opposed mode modulated LED sensors makes alignment simple. However, even at short range, it may be important to optimize alignment, especially if high excess gain is needed to "burn" through dirt, dust, steam, etc. As these sensors are used at ranges approaching their specified far range limits, excess gain is much decreased, and the need for accurate alignment becomes highly important.

Short range alignment procedure:

The best way to accurately align a receiver to its emitter at short range is to drastically reduce the strength of the light signal. This is easily accomplished by placing a diffuser, such as a sheet of paper or light-colored masking tape, in front of the emitter and/or receiver lens. The signal may be be reduced in smaller increments by adjusting the sensitivity (GAIN) control downward (counter-clockwise adjustment). A Banner screwdriver is sized to fit all sensitivity adjustments. Note, however, that some self-contained sensors *do not have a sensitivity adjustment*, including ECONO-BEAM and SM30, C30, S18, and Q08 Series sensors.

For short-range alignment of opposed sensors:

1) Begin with the emitter mounted securely in place. At ranges up to a few feet, the receiver may simply be mounted using line-of-sight alignment. At distances beyond a few feet, locate and loosely mount the receiver opposite the emitter, leaving a means for movement. Banner offers a variety of 2- and 3-axis adjustment mounting brackets for use with opposed sensors. See the Banner product catalog for bracket information.

2) If sensing is to occur at an exact location, tie or tape a string to the emitter at the center of its lens and extend it to the center of the receiver lens to make certain that the center of the beam intersects the sensing point.

Before going further, check the "Notes" in the box on page E-17.

3) Refer to the hookup information for the sensors in use to double-check the hookup, and apply power to the emitter and the receiver (or component amplifier). The alignment indicator should be "on".

4) Place a diffusing material (paper, tape, etc.) in front of the lens of the emitter and/or receiver and/or decrease the sensitivity (GAIN) adjustment (counterclockwise rotation). Reduce the signal enough to cause the alignment indicator LED to *just* go "off". Now move the receiver up-down-right-left (including angular rotation) to find the center of the area where the indicator comes back "on" (Figure E.3). This locates the center of the beam, where the excess gain is the highest. Secure the receiver in this position.

For sensors (or component amplifiers) with a signal strength indicator system:

Attenuate the signal by using a diffusing material and/or by reducing the receiver's sensitivity so that the indicator displays a low signal level (e.g. a slow pulse rate on the AID indicator, or 1 to 4 LEDs lit in the OMNI-BEAM D.A.T.A. system array). Move the receiver up-down-left-right (include angular rotation) to try to increase the signal strength. Reduce sensitivity again, if necessary, to bring the signal indication back into a comfortable working range. Secure the receiver in the position where the signal is the strongest.

5) Remove any diffusing material and increase the sensitivity to maximum (clockwise adjustment).

6) Place the object to be detected at the sensing position. If the receiver alignment LED goes "off", alignment is complete.

NOTE: If the receiver alignment LED does not go "off" when the object is in place at the sensing position, the reason may be one or both of the following:

Flooding: A portion of the effective beam may be passing around one or both sides of the object to be sensed. Check the profile that the object presents to the beam and compare it against the size of the effective beam (Figure A.20). Install apertures, if needed. Also, move the object back and forth to locate the center of the beam, and re-position the sensors if necessary.

"Burn-through": If the object to be sensed is non-metallic and is thin, there may be too much light energy for the object to completely block. With the object in place in the sensing position, decrease the sensitivity adjustment (CCW rotation) until the alignment indicator LED goes "off". Remove the object, and verify that the indicator LED comes "on" solidly. If this fails, consider an alternate sensing scheme that will offer greater sensing contrast (e.g. the ultrasonic proximity mode).

Long range alignment procedure:

When long scanning distances are needed, the requirement for accurate alignment becomes much more important. It is very difficult to align opposed sensors at a separation of fifty feet or more after they have been permanently mounted. It is easier to mount the emitter and install a long extension cord on the receiver. With the receiver pointed at the emitter, slowly walk back to the receiver mounting location, while moving the receiver up-down-left-right (including angular rotation) to track the center of the emitted beam. At long scanning distances, accurate *angular* sensor alignment is even more important than vertical or horizontal placement.

Alternately, the receiver mounting point may be determined by walking backward from the emitter with the Banner BEAM-TRACKER™, model BT-1 (see page E-1). The BEAM-TRACKER is a battery operated handheld device which will sense the beam of any modulated emitter with approximately the same sensitivity as the equivalent receiver. The BEAM-TRACKER includes Banner's Alignment Indicating Device (AID) circuitry. Once the best receiver position has been determined, the receiver may be permanently mounted, and fine adjustment may be made using the receiver's own alignment indicator.

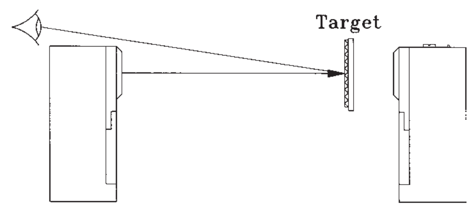
Aligning a visible emitter:
MAXI-BEAM, VALU-BEAM, MULTI-BEAM (model SBEV), Q85, and Q19 emitters use a visible red light that can simplify alignment to the receiver. If a retroreflective target is temporarily placed directly in front of the receiver lens, the emitter can be aligned by sighting the visible image on the target. Sight toward the receiver from behind the emitter, looking past the top of the emitter (Figure E.4). Move the emitter up-down-left-right (include angular rotation) until the visible red image (returned by the retroreflective target) is seen. Remove the retroreflective target and adjust the receiver's position for optimum alignment, using the alignment indicator.

Final Adjustments and Checkout:

Secure all mounting hardware. Complete the wiring by connecting the load to the output circuit of the receiver. Refer to the hookup information for the receiver in use (see the data sheet packed with the receiver, or the Hookup Reference information in Section C of this manual).

Check the operation of the load by alternately placing an object at the sensing position and then removing it. The load and the receiver alignment indicator LED should "follow" the action. Adjust timing logic (if any) as required.

Figure E.4. Use of a retroreflective target to align an opposed mode sensor pair.



29b. Retroreflective Mode Sensor Alignment ***(See also pages A-8 and A-9)***

Retroreflective mode photoelectric sensing is ideal for many applications for which opposed mode sensing would be the first choice, but where sensing is possible from only *one side* of the process.

Retroreflective sensors work with special target materials that reflect the emitted light beam back to the sensor. The efficiency of these targets (and therefore the sensing range) depends upon the *size* and *reflectivity* of the target. Size is important because, at ranges beyond a few feet, the retro target may not intercept the complete beam. At extended ranges, a 3" diameter target will intercept nine times as much light as will a 1" diameter target (the area ratio is the square of the diameter ratio). The 1" target will, therefore, require nine times the excess gain required for the 3" target. At close range, however, both targets may work equally well. Recommended reflectors available from Banner are listed in the box below.

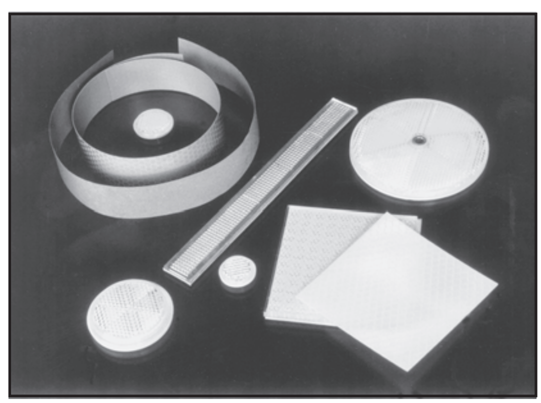
Reflectivity is a function of target construction. Most plastic targets are made up of small, highly efficient *corner-cube* reflectors. Most reflective tape, on the other hand, uses glass beads or smaller, less reflective corner cubes. The listing of retroreflective materials given below is in order of reflectivity, with model BRT-3 being the best. See the Banner product catalog for additional information.

Successful retoreflective sensing depends upon adequate optical contrast between the dark (beam broken) state and the light (beam unbroken) state. Retroreflective sensing, therefore, works best with objects of *low* reflectivity. Highly reflective materials such as polished metal, mirrors, etc., may be difficult to sense because they can reflect as much or nearly as much light back to the sensor as does the retroreflective target. This effect, known as "proxing", can sometimes be overcome by sensing at a "skew angle" to the object's reflective surface (see drawing, next page). Use of a polarizing filter and corner-cube reflector may also help minimize proxing. At the other extreme, *transparent* objects are difficult to sense retroreflectively because they may not sufficiently interrupt the sensor's light beam.

Retroreflective Target Materials

Retroreflective sensors require special retroreflective targets for proper operation. The reflector models listed below are recommended. For information on the complete line of Banner retroreflective materials, see the Banner product catalog.

BRT-3	3" dia. round corner-cube reflector with central mounting hole
BRT-1.5	1.5" dia. round corner-cube reflector with mounting flange
BRT-1	1" dia. round corner-cube reflector with mounting flange
BRT-L	Linear target, 0.75"H x 6.5"W, with adhesive backing
BRT-THG	High-grade micro corner-cube tape, squares and sheets, various widths and lengths, adhesive backing
BRT-T	Reflective tape, 1" wide, various lengths, adhesive backing
BRT-THT	High-temperature reflective tape, 1" wide, various lengths, adhesive backing



Alignment procedure:

1) Begin with the retroreflective sensor at the desired distance from the retroreflective target and at the approximate position at which it will be mounted. Banner offers a variety of 2- and 3-axis mounting brackets for use with many of its retroreflective mode sensors. Refer to the Banner product catalog for bracket information. Direct the sensor at the target. Retroreflective targets are forgiving of beam angle in that they do not begin to lose effectiveness until they are more than 15 degrees off of perpendicular to the beam axis. An object placed at the "sensing position" should pass through the "core" of the sensor's light beam. Remove the object from the sensing position before continuing.

Before going further, check the "Notes" in the box on page E-17.

2) Refer to the hookup information for the sensor in use to double-check the hookup, and apply power to the sensor (or component amplifier). The alignment indicator LED should now be "on".

3) If the *target* position is fixed, move the sensor up-down-left-right to locate the boundaries of the "movement zone" within which the alignment indicator remains lit. If the *sensor* position is fixed, move the target up-down-left-right to define the zone. If necessary (and where possible), reduce the sensing system sensitivity to "narrow" the zone and repeat the sensor (or target) movement to locate the center. Secure the sensor and/or target at the center of the alignment indicator "on" zone.

For sensors (or component amplifiers) with a signal strength indicator system:
Reduce the sensitivity control to yield a "countable" pulse rate of the AID system LED indicator, or 1-4 LEDs lit in the OMNI-BEAM D.A.T.A. system array. Move the sensor up-down-left-right to try to increase the signal strength. Reduce sensitivity again, if necessary, to bring the signal indication back into a comfortable working range. Secure the sensor in the position where the signal is the strongest.

4) Increase the sensor's sensitivity to maximum by rotating the control to its clockwise end of rotation.

Final Adjustments and Checkout:

Secure all mounting hardware. Complete the wiring by connecting the load to the output circuit of the sensor. Refer to the hookup information for the sensor in use (see the data sheet packed with the sensor, or the Hookup Reference information in Section C of this manual).

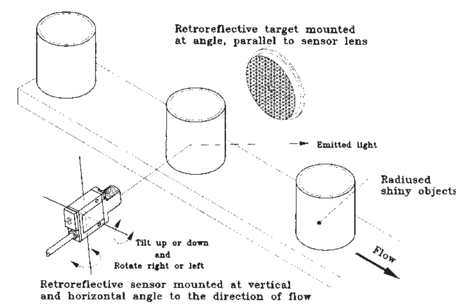
Check the operation of the load by alternately placing an object in the sensing position and then removing it. The load and the alignment indicator LED should "follow" the action. Adjust timing logic (if any) as required.

If the sensor alignment LED does not go "off" when the object is placed in the sensing position, see "Alignment tips: retroreflective proxing" (above, right).

Alignment tips: retroreflective "proxing"

If the sensor cannot be adjusted so that the alignment indicator LED goes from "on" to "off" when the object is placed in sensing position, "proxing" may be occurring. The optical contrast of the sensing application is reduced because the sensor is reacting to light reflected off the object's reflecting surfaces.

If the object has *flat* sides, mount the sensor and the retro target so that the light beam encounters the object's reflecting surface at an angle (see drawing below). The angle may be vertical or horizontal or both (incorporating both angles may be necessary when attempting to sense shiny *radiused* objects; see below). Skew angles of 10 to 15 degrees are usually sufficient to eliminate unwanted reflections.



If the distance to the retro target is more than a few feet, try using a larger target (or a cluster of several targets) to reflect more light back to the sensor. If possible, substitute a more efficient retroreflective material (i.e. a plastic corner-cube reflector in place of reflective tape, etc.).

If the application allows use of a visible light sensor, try a *polarized* model (model number suffix "LVAG"). These sensors block the light reflected from a shiny object by means of a specially-oriented polarizing filter in front of the sensor's optoelement. The light from corner-cube reflectors is allowed through. (Note: You *must* use a corner-cube reflector with this type of sensor.)

Alignment tips: visible light alignment, long-distance alignment

With visible light retroreflective sensors, it should be possible to visually "sight" the red sensing beam on the retro target and then make final sensor and/or target position adjustments using the LED indicator. Dimming the room lights will make the task easier.

At long sensing distances (over 15 feet), "finding" the target with the sensor beam may be difficult. Take a second target and walk backwards away from the sensor, always keeping the target aligned to the beam (up-down-right-left target movement; monitor the LED indicator). When you reach the target's mounting surface, the correct target position or sensor orientation changes will be obvious.

29c. Proximity Mode Sensor Alignment *(See also pages A-9 through A-11)*

"Proximity mode" is a general term which includes the diffuse, convergent, divergent (wide angle diffuse), and fixed-field sensing modes. These modes are very useful for sensing any reflective object or material.

Range and performance of proximity mode sensors are always specified using a white test card. Objects with less reflectivity produce shorter sensing ranges or less excess gain at a given range. More reflective objects yield longer ranges and more excess gain. Size may also be important: given two objects of the same reflectivity, the large object may return more light to the sensor than the smaller object.

Successful proximity mode sensing depends upon adequate optical contrast between the object being sensed and the background. This means that the greater the difference between light reflected from the object and light reflected from the background, the more reliable proximity mode sensing will be. Note: Nearby reflective background objects are less significant in divergent diffuse sensing because the energy of these sensors falls off rapidly with distance, and in convergent sensing because the emitter and receiver are focused at a specific distance. Also, most background objects may be totally ignored by using the fixed-field sensing mode.

Most problems in proximity mode sensing arise because of backgrounds that return as much, or nearly as much, light to the sensor as does the object to be sensed. In general, this problem is solved by using as dark a background as possible and by placing that background as far behind the object as possible. There is a general rule for proximity mode sensing which states that the object-to-background distance should be at least three times the sensor-to-object distance. This rule assumes that the background is no more reflective than the object: see *Application Cautions - diffuse mode* (page B-10).

Shiny materials usually require close control of the scanning angle to maximize the amount of light actually returned to the sensor. The sensor should be mounted so that the sensing beam is exactly perpendicular to the surface of any shiny object (Figure A.31).

Alignment procedure:

1) Begin with the sensor at the desired distance from the object and at the approximate position at which it will be mounted. Banner offers a variety of 2- and 3-axis mounting brackets for use with many of its sensors. Refer to the Banner product catalog for bracket information. Direct the sensor at the target object. An object placed at the "sensing position" should pass through the "core" of the sensor's light beam in the diffuse, divergent, and fixed-field modes. Convergent mode sensing requires the object to pass through the focus point of the sensor.

Before going further, check the "Notes" in the box on page E-17.

2) Refer to the hookup information for the sensor in use to double-check the hookup, and apply power to the sensor (or component amplifier). The alignment indicator LED should now be "on".

3) Move the sensor up-down-left-right (include rotation) to locate the center of the zone within which the LED remains "on". With convergent sensors, include movement toward and away from the object. If necessary (and where possible), reduce the sensitivity to "narrow" the zone, and repeat the sensor movement to locate the center. When the center has been found, secure the sensor in position.

For sensors (or component amplifiers) with a signal strength indicator system:
Reduce the sensitivity control to yield a "countable" pulse rate of the AID system LED indicator, or 1-4 LEDs lit in the OMNI-BEAM D.A.T.A. system array). Adjust the sensor up-down-right-left (with rotation) and (for convergent sensors) toward and away from the object to try to increase the signal strength. Secure the sensor in the position where the signal is the strongest. Reduce sensitivity again, if necessary, to bring the signal indication back into a comfortable working range.

4) Increase the sensor's sensitivity to maximum by rotating the control to its clockwise end of rotation.

Final Adjustments and Checkout:

Secure all mounting hardware. Complete the wiring by connecting the load to the output circuit of the sensor. Refer to the hookup information for the sensor in use (see the data sheet packed with the receiver, or the Hookup Reference information in Section C of this manual).

Check the operation of the load by alternately placing an object in front of the lens and then removing it. The load and the alignment indicator LED should "follow" the action. Adjust timing logic (if any) as required.

If the sensor alignment LED does not go "off" when the object is removed from the sensing position, see "Alignment tips: proximity mode sensors" (below).

Alignment tips: proximity mode sensors

If, after following the alignment procedure, the sensor's alignment LED does not go "off" when the object is removed from the sensing position, consider one or more of the following alternatives:

1) Move the sensor closer to the object (except in convergent mode) and reduce the sensitivity setting.

2) Reduce background reflectivity by painting the background with a flat black paint, cutting a hole through it, scuffing its surface, etc.

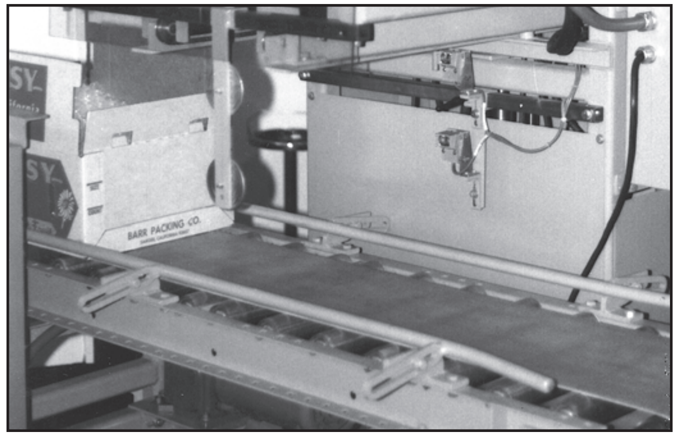
3) If the background surface is shiny, **tilt the sensor (or the background surface)** in any direction so that the sensing beam is not perpendicular to the background surface.

Section D: Sensing Logic

Sensing logic involves one or both of the following situations:

Multiple sensor hookup involves a simple interconnection of two or more sensors to common load. The sensors are wired together so that the load will energize *only* when a defined combination of simultaneous sensing conditions occurs.

Control logic is used to condition a sensor output signal by way of timing or counting, or to coordinate control of a process by comparing multiple sensor outputs. *Control logic* is offered in the form of add-on "logic modules" to which sensors are wired as inputs. *Timing control* may actually be an integral part of some sensors, including OMNI-BEAM, MULTI-BEAM, MAXI-BEAM, and Q85 Series self-contained sensors, plus MAXI-AMP CD, CM and CR Series component amplifiers.



Multiple Sensor Hookup

The outputs of multiple sensors are often configured so that they will operate a common load only when a defined combination of sensing events occurs. The most commonly used combinations of sensor outputs are defined by the logic terms **AND** and **OR**. The **AND** configuration refers to the situation where the load is energized only when the outputs of *all* sensors in the group are energized at the same time. **OR** logic means that the load will be energized whenever the output of *any* of the sensors in the group is energized.

As an example, consider an array of multiple opposed mode sensors used to detect web flaws and faults such as holes, rips, runout, or end-of-roll (Figure D.1). If light is detected at one or more of the five receivers, the motor that feeds the web is shut down.

Figure D.1. Multiple opposed mode sensors are wired together to detect web flaws.

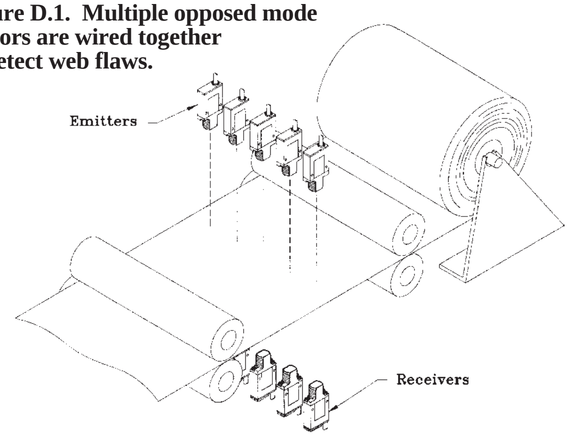
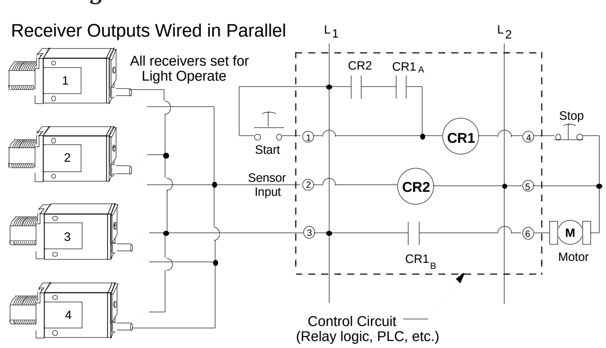


Figure D.2 shows a multiple sensor hookup scheme where all four receivers are connected in *parallel* to a common load. The load is control relay "CR2". The receivers are all programmed for *light operate*. CR2 energizes to stop the motor if *one or more* of the receivers "sees" light. This illustrates how **OR** logic is created by simply combining the output of all of the sensors in parallel to a common load.

Figure D.2. Sensors are wired in parallel for OR logic. If any receiver "sees" the modulated light from the emitter, CR2 energizes to shut off the motor.



A more common approach to this type of web control uses **AND** logic. In Figure D.3, the outputs of all four sensors are "chained" together in a series connection. Also, all four receivers are programmed for *dark operate*. The motor will run as long as all four receivers (#1 *and* #2 *and* #3 *and* #4) "see" dark simultaneously. If one or more of the receivers detects light (indicating a problem) the motor will stop and stay "off" until it is manually restarted after the problem is corrected.

AND logic suggests a series hookup and **OR** logic suggests a parallel hookup of sensor outputs. However, when dealing with sensors with solid-state outputs, series connection of outputs is not always possible. Following is a review of the possibilities for interconnection of multiple sensors and of the switching logic that results from each possible wiring scheme.

a) Sensors with Electromechanical Output Relay

With the exception of the application warnings listed in Table C-1, the most straightforward sensor interconnection schemes use the contacts of electromechanical relays. Contacts are simply wired in series for **AND** logic or in parallel for **OR** logic. Table B-20 lists those sensors and component amplifiers that offer an electromechanical output relay and Table C-2 lists relay contact specifications.

b) Sensors with Solid-state Output Relay

4-wire ac Sensors

4-wire ac sensors isolate the switching contact from the sensor power circuit. As a result of this design, the solid-state output contacts of 4-wire ac sensors may be wired in series for **AND** logic or in parallel for **OR** logic, exactly like electromechanical "hard" contacts.

When wiring 4-wire ac sensor solid-state output contacts in series (see Figure C.26), there will be a voltage drop of about 3V ac across each sensor output contact. The total voltage drop across the series will be the sum of the individual voltage drops across the sensor outputs (i.e. 3V ac times the number of sensors in series). With most loads, 10 or more sensors may be wired together in series before the voltage at the load becomes too low.

When wiring 4-wire ac sensor solid-state output contacts together in parallel to a common load for **OR** logic, the total off-state leakage current through the load is the sum of the leakage currents of the individual sensor output circuits. However, the leakage current for the output circuit of a 4-wire ac sensor is always less than 0.1 milliamp. As a result, many 4-wire ac sensors may be wired in parallel without need for an artificial load resistor.

Sensor families that offer 4-wire ac sensors include: OMNI-BEAM, MULTI-BEAM, and MAXI-BEAM. MAXI-AMP modules with the solid-state output option also offer an isolated ac relay for 4-wire hookup (see Table C.4).

2-wire ac Sensors

2-wire ac sensors present some wiring challenges. The following rules govern the interconnection of multiple 2-wire ac sensors:

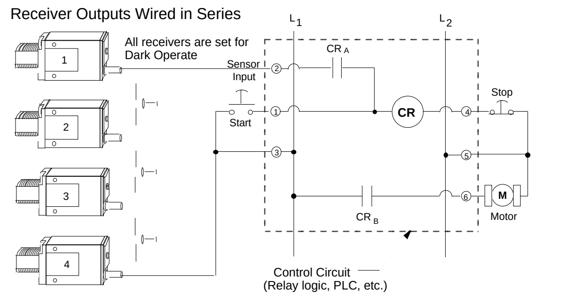
1) Multiple 2-wire ac MULTI-BEAM or MAXI-BEAM sensors *cannot* be wired together in series.

2) Multiple 2-wire ac VALU-BEAM, MINI-BEAM, or SM30 Series sensors *can* be wired together in series. However, there is a significant voltage drop (up to 10V ac) across each sensor that is additive for the series combination. See the reference hookup drawings in Section C for more information.

3) Multiple 2-wire ac sensors (all families) can be wired together in parallel. However, the leakage current for the parallel combination of sensors is the sum of the leakage currents of the individual sensors. This total leakage may become high enough to prevent a load from de-energizing. See the reference hookup drawings in Section C for specific information.

4) There are several application warnings for wiring of 2-wire ac sensors in series and/or parallel with "hard" contacts of switches, contactors, or electromechanical relays. These precautions vary between sensor families. See the hookup reference drawings in Section C for specific information.

Figure D.3. These sensors are wired in series. If any receiver "sees" the modulated light from the emitter, CR drops out to shut off the motor.



Aside from the exceptions and precautions noted above, multiple 2-wire ac sensors may be wired together in series for **AND** logic or in parallel for **OR** logic. Figures D.2 and D.3 are examples of how these wiring combinations might appear if 2-wire MINI-BEAM sensors are used.

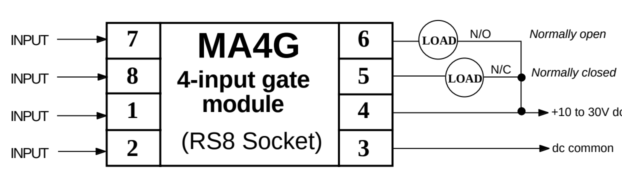
3-wire dc Sensors

All self-contained dc sensors with a solid-state output use a 3-wire configuration. These dc sensors often have a fourth wire, but this fourth wire has a separate function such as a second separate output. This means that outputs are *not* isolated from the input power. As a result, 3-wire dc sensors cannot be wired in series. However, parallel connection of multiple 3-wire dc sensors for **OR** logic is straightforward.

AND logic is possible when using 3-wire dc sensors by connecting a MICRO-AMP model MA4G logic module between the sensors and the load. The current sinking (NPN) outputs of two, three, or four sensors are connected to the individual inputs of the MA4G **AND** gate (Figure D.4). The normally open output of the MA4G will energize its load only when all of the sensor inputs are energized (i.e. "low"), simultaneously. Unused inputs are simply connected directly to dc common.

When there is a requirement to **AND** the outputs of more than four 3-wire dc sensors, more than one MA4G may be used. The

Figure D.4. Model MA4G combines the signals of up to four current sinking (NPN) 3-wire dc sensor outputs for AND logic.

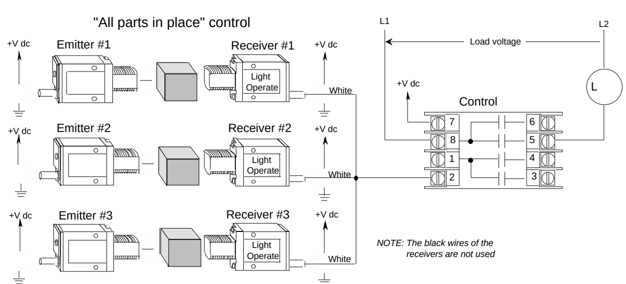


MA4Gs may be "cascaded" together to accomodate as many sensors as necessary. The discussion on "Control Logic" explains two additional multiple sensor logic functions that are possible by using the MA4G logic module (see page D-12).

Another way to connect multiple 3-wire dc sensors for **AND** logic is to connect them together in *parallel* to an inverting device. The inverter may be as simple as a relay with a normally closed contact. Figure D.5 illustrates an example where three sensors must simultaneously detect an object before the load is energized. Here, a DPDT relay with a dc coil is interposed between the sensors and the load. The sensors are programmed for the *opposite mode* (i.e. light operate versus dark operate) than would be used for **OR** logic. The relay de-energizes only when all of the sensors simultaneously detect an object. The normally closed contact of the relay is used to energize the load.

In this example, the relay could be replaced with a multi-channel inverter, like PLUG-LOGIC model BN2-2 (see page D-12). Alternately, any number of 3-wire dc current sinking (NPN) sensor outputs may be wired in parallel to the input of a logic control module (e.g. MAXI-AMP CL Series) that has been programmed for dark operate. In all of these approaches, the input of the interposing logic device responds to the *simultaneous absence* of all sensor inputs. This indicates that **NOR** logic is actually being used to simulate an **AND** condition.

Figure D.5. The load energizes only when all beams are simultaneously interrupted (NOR logic).



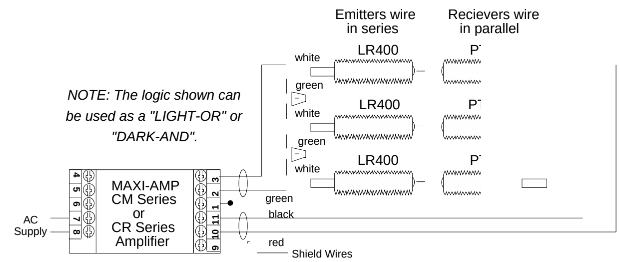
c) Remote Modulated Sensors

Up to 3 remote sensors may be wired together into a single MAXI-AMP modulated amplifier/logic module. The emitters wire together in series. The receivers can wire together only in parallel (Figure D.6). As a result, the input circuit of the amplifier will respond to modulated light that is detected by *any* of the receivers.

Consequently, multiple remote modulated sensors produce **OR** logic if the amplifier is programmed for light operate (i.e. if one or more remote receiver detects its modulated light, the amplifier output will energize). Conversely, this combination results in **AND** logic if the amplifier is programmed for dark operate (i.e. the amplifier output will energize only when the light is blocked to all receivers simultaneously).

A dark-operated **OR** and a light-operated **AND** are not possible with multiple remote modulated sensors. These logic modes require use of one modulated amplifier module per remote sensor, with the outputs of the amplifiers combined for the required logic.

Figure D.6. MAXI-AMP modulated amplifiers allow wiring of up to three receivers in parallel (emitters wire in series).



Multiple remote sensor logic is possible using either CM or CR Series MAXI-AMP amplifier modules, but multiple sensor connections are not possible to MICRO-AMP modulated amplifier modules MA3 or MA3-4 or CD Series MAXI-AMP modules.

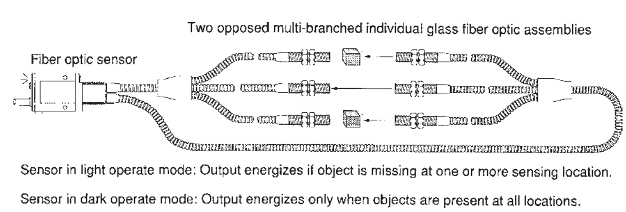
It is important to remember that wiring multiple remote sensors to a MAXI-AMP module decreases the available excess gain of each sensor. When two sensors are connected to one amplifier, the excess gain (as indicated on the excess gain curve for the sensor in use) is multiplied by a factor of 1/2. When three sensors are connected, the excess gain is multiplied by a factor of 1/3.

d) Glass Fiber Optic Assemblies- Individual Fiber Optic Assemblies

Individual glass fiber optic assemblies may be made with the bundle split into multiple branches for sensing at more than one location. Two identical assemblies are used in the opposed sensing mode. One assembly carries the emitted light to the sensing locations. The other assembly carries the detected light back to the receiver (Figure D.7).

The receiver is satisfied if it detects light from one or more of the sensing locations. So if the sensor is programmed for light operate, the logic is that of a light-operated **OR** (i.e. the sensor's output will energize if the object that blocks the beam is missing at one or more of the sensing locations). Conversely, if the sensor is programmed for dark operate, the output will not energize until all of the beams are blocked. This is dark-operated **AND** logic.

Figure D.7. Multi-branched individual fiber optics are used to sense "all parts in place".

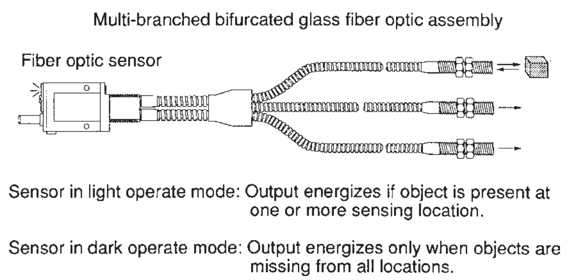


It is sometimes possible to distinguish between one and two unblocked beams when using a pair of two-channel individual opposed fibers. However, the sensing contrast in this situation is only 2-to-1 (at best). So, sensing variables must remain very stable in order for this type of application to be successful.

Bifurcated Fiber Optic Assemblies

Bifucated glass fiber optic assemblies may be made with the bundles that connect to the emitter and the receiver each split into several randomly mixed sensing bundles, each with an equal number of emitter and receiver fiber strands (Figure D.8).

Figure D.8. Multi-branched bifurcated fiber optics are used to sense part presence at any of several locations.



The sensing logic produced by a multi-branched bifurcated fiber optic assembly is the same as for a pair of multi-branched individual opposed fibers (see above). However, since sensing with a bifurcated assembly is accomplished in a reflective (proximity) mode (versus a beam-break mode), the conditions of object present or absent are reversed. If the sensor is programmed for light operate, the sensor's output will energize if an object is present at one or more of the sensing locations (light-operated **OR**). If the sensor is programmed for dark operate, the sensor's output will not energize until objects are missing at all sensing points, simultaneously (dark-operated **AND**).

When using a double-bifurcated (two-channel) fiber optic assembly, it is sometimes possible to adjust a sensor's gain to distinguish between one and two objects present. However, the sensing contrast in this situation is only 2-to-1 (at best). Sensing variables must remain very stable in order for this type of application to be reliable.

Applying multi-branched fiber optics often results in significant cost savings. The cost of one sensor per fiber optic sensing point is saved. Also saved are the costs of multiple sensor wiring and mounting. Furthermore, multi-branched fiber optic assemblies usually contribute greatly toward a clean and neat sensor installation.

Summary

Interconnection of multiple sensors or application of multi-branched fiber optics are often smart ways to save sensing system cost. It is important in the sensing system design stage to understand exactly what sensing logic can (and cannot) result from any particular sensor combination. Your Banner field sales engineer can assist you with the most cost-effective approach to your application requirements.

Control Logic

Today, sensors used in an automated process are most likely to supply information to a computer or programmable logic controller (PLC) rather than perform an actual control function. However, when inputs to a computer or PLC are unavailable, the addition of a simple control logic function at the sensing location can become an attractive (and often cost effective) alternative. Localized sensing control logic is also the smart approach in systems where there are not enough control functions to justify the expense of a PLC, or where localized control represents a significant savings in wiring.

There are three types of sensing control logic:

1) Timing control,
2) Counting control, and
3) Multiple input coordination control logic.

All three types of sensing control logic are available as add-on "logic modules" that wire between the sensor(s) and the load that is to be controlled. These add-on modules include MAXI-AMP, MICRO-AMP, and PLUG-LOGIC modules. Timing control functions are also available as options for some self-contained sensors, including OMNI-BEAM, MULTI-BEAM, MAXI-BEAM, and Q85 Series sensors.

On the following pages are descriptions of the most commonly used control logic functions. Each function description indicates which product families offer that logic function. For information on any specific logic module, refer to the Banner product catalog. (You may locate the description of any module by using the alphabetical product index at the back of the catalog.) If you do not find the logic function that is required for your application, please contact your Banner sales engineer.

About the following control logic descriptions...

TIMING DIAGRAMS: The term "input signal", as used in the following definitions, generally refers to a sensing event. The timing diagrams do not differentiate between "high" and "low" input signals. All inputs and outputs are indicated above a reference line to illustrate only their timing relationship.

TIMING RANGES: The time ranges in the following charts are for the standard (stocked) models listed. Other time ranges may be possible with modification by special order. Please contact your local Banner sales engineer or the applications group at the factory for information on a special timing range for your specific application.

ON Delay

The *ON delay* is a timing control function that requires a sensing event to last for at least the ON delay time period before the output will energize. The timing begins at the *leading edge* of an input signal, but the output is energized only after the preset ON delay time has elapsed. If the input signal is not present for the ON delay time period, no output occurs. If the input signal is removed momentarily and reestablished, the ON delay timing starts over again from the beginning.

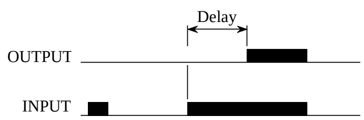
An ON delay is used to allow sensing controls to ignore short sensing events. For example, an ON delay may be used to ignore material falling past a fill-level sensor, or to ignore the *normal* flow of products past a sensor in conveyor flow control applications. *Note:* MAXI-AMP, MICRO-AMP, and OMNI-BEAM timing logic modules are *programmable* to allow selection of the timing *range* that offers the greatest accuracy and setability in any particular application. The product selection charts that follow indicate the timing ranges supplied in each module.

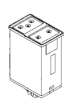
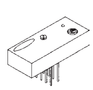
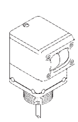
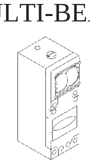
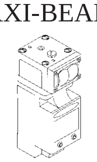
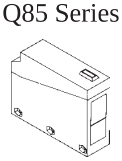
OFF Delay

The *OFF delay* timing control function "holds" the output for a preset time after the input signal is removed. The output is energized immediately when an input signal is received, and remains energized as long as the input signal is present. The OFF delay timing begins at the trailing edge of the input signal, keeping the output energized. If a new input signal is received during the OFF delay timing, the timer is reset, and the OFF delay period begins again at the trailing edge of the new input signal.

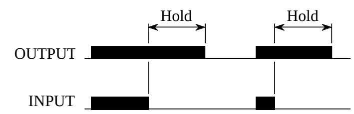
An OFF delay is used to allow sensing controls to ignore intermittent signal losses. For example, an OFF delay is used in edgeguiding applications to ignore quick, temporary movements of the material outside of the deadband. An OFF delay is also used in flow control applications to indicate a jam or empty reservoir upstream, when no products are detected for a predetermined length of time.

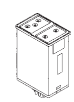
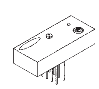
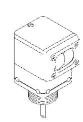
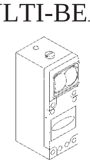
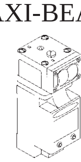
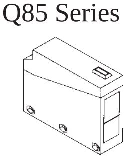
ON-DELAY

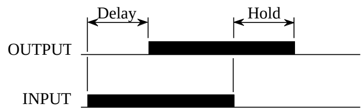
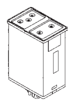
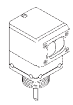
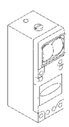
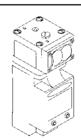
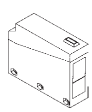


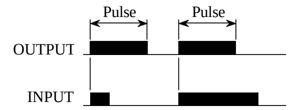
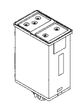
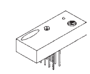
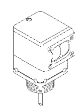
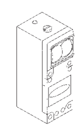
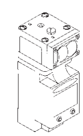
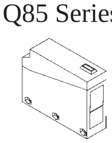
Product Family	Models	Delay Time
MAXI-AMP™ 	CD5, CL5, CM5, & CR5 Series	0.01 to 0.15 second or 0.1 to 1.5 seconds or 1 to 15 seconds
MICRO-AMP® 	MA5	0.01 to 1 second or 1 to 15 seconds
OMNI-BEAM™ 	OLM5	0.01 to 1 second or 0.15 to 15 seconds
MULTI-BEAM® 	LM5 or 2LM5	0.15 to 15 seconds
MAXI-BEAM® 	RLM5	0.5 to 15 seconds
Q85 Series 	Models with -T9 suffix	0.1 to 5 seconds

OFF-DELAY



Product Family	Models	Hold Time
MAXI-AMP™ 	CD5, CL5, CM5, & CR5 Series	0.01 to 0.15 second or 0.1 to 1.5 seconds or 1 to 15 seconds
MICRO-AMP® 	MA5	0.01 to 1 second or 1 to 15 seconds
OMNI-BEAM™ 	OLM5	0.01 to 1 second or 0.15 to 15 seconds
MULTI-BEAM® 	LM5 or 2LM5	0.15 to 15 seconds
MAXI-BEAM® 	RLM5	0.5 to 15 seconds
Q85 Series 	Models with -T9 suffix	0.1 to 5 seconds

ON and OFF DELAY 		
Product Family	Models	Delay & Hold Time
MAXI-AMP™ 	CD5, CL5, CM5, & CR5 Series	0.01 to 0.15 second or 0.1 to 1.5 seconds or 1 to 15 seconds
OMNI-BEAM™ 	OLM5	0.01 to 1 second or 0.15 to 15 seconds
MULTI-BEAM® 	LM5-14 or 2LM5-14	0.15 to 15 seconds
MAXI-BEAM® 	RLM5	0.1 to 1 second or 0.5 to 15 seconds
Q85 Series 	Models with -T9 suffix	0.1 to 5 seconds

ONE-SHOT 			
Product Family	**Models**	**Hold Time**	**Retrig-gerable**
MAXI-AMP™ 	CD5, CL5, CM5, & CR5 Series	0.01 to 0.15 second or 0.1 to 1.5 seconds or 1 to 15 seconds	Yes
MICRO-AMP® 	MA4-2	0.001 to 0.1 second or 0.01 to 1 second or 1 to 15 seconds	Yes *or* No
OMNI-BEAM™ 	OLM8	0.01 to 1 second or 0.15 to 15 seconds	Yes
	OLM8M1	0.001 to 0. 1 second or 0.15 to 15 seconds	Yes
MULTI-BEAM® 	LM4-2 or 2LM4-2	0.01 to 1 second	Yes
	LM4-2NR	0.01 to 1 second	No
MAXI-BEAM® 	RLM8	0.01 to 0.1 second or 0.1 to 1 second	Yes
Q85 Series 	Models with -T9 suffix	0.1 to 5 seconds	Yes

ON and OFF Delay

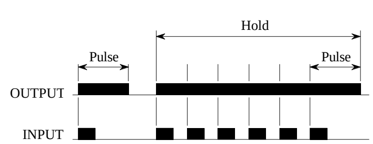
ON and OFF delay timing control logic combines ON delay and OFF delay into a single function. The ON delay and OFF delay ("hold") times are independently adjustable within the (same) time range selected or specified (except Q85 Series sensors). ON and OFF delay timing is often used in jam and void control, high/low level control, and edgeguiding applications.

One-shot

A *one-shot* is a timing control function in which a timed output pulse ("hold" time) begins at the leading edge of an input signal. The pulse is always of exactly the same duration, regardless of the length of the input signal. The output cannot reenergize until the input signal is removed and then reapplied.

A one-shot timer is useful for initiating a control function that is keyed to the passing of *either* the leading or the trailing edge of a product. In photoelectric sensing, the choice between leading or trailing edge is made by selecting between light and dark operate.

D.9 Retriggerable One-shot

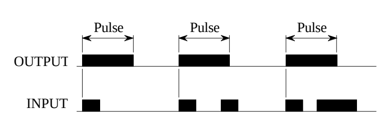


There are two types of one-shot timing control. The output of a *retriggerable* one-shot is restarted with each reoccurrence of an input. The output remains "on" as long as the time between consecutive inputs is shorter than the one-shot "hold" time.

A *non-retriggerable* one-shot timer must complete its output pulse before it will recognize any new input signals. This sometimes offers an advantage in indexing or registration control applications, where multiple input signals are possible during the advance of a product.

The output of any ac-coupled amplifier is a one-shot pulse. A one-shot timer is also called a "single-shot", a "pulse timer", or a "pulse stretcher".

D.10. Non-retriggerable One-shot



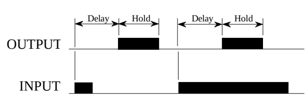
Delayed One-shot

A *delayed one-shot* is timing control logic in which an input signal initiates an adjustable delay period, at the end of which the output pulses for an adjustable pulse ("hold") time. The input may be either momentary or maintained. No further action occurs until the input signal is removed and then reapplied, at which time the sequence begins again. The delay and hold times are independently adjustable within the (same) time range selected or specified (except Q85 Series sensors).

A delayed one-shot is frequently used to sense a product and then act on that product a short time later, when it is clear of the sensing location. For example, a delayed one-shot may be used with a sensor that is inspecting for open flaps on cartons moving along on a conveyor. The output pulse of the delayed one-shot is used to divert cartons with open flaps after they have cleared the sensing location.

MAXI-AMP modules have a second "auxiliary" input that is particularly useful when delayed one-shot logic is used. In an inspection/rejection control scheme, the sensor(s) connected to the primary input is used as the product sensor (Figure D.11). The product sensor is also referred to as the "interrogate" or "gate" sensor. Its function is to begin the delay timer as soon as it detects a passing product.

DELAYED ONE-SHOT



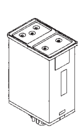
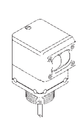
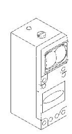
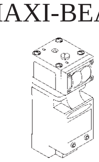
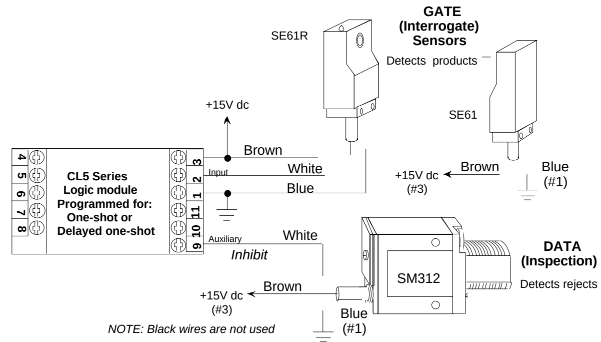
Product Family	Models	Delay & Hold Time
MAXI-AMP™ 	CD5, CL5, CM5, & CR5 Series	0.01 to 0.15 second or 0.1 to 1.5 seconds or 1 to 15 seconds
OMNI-BEAM™ 	OLM8	0.01 to 1 second or 0.15 to 15 seconds
	OLM8M1	0.001 to 0.1 second or 0.015 to 1.5 seconds
MULTI-BEAM® 	LM8-1	0.15 to 15 seconds
MAXI-BEAM® 	RLM8	0.1 to 1 second or 0.5 to 15 seconds

Figure D.11. Use of delayed one-shot timing logic for inspection/rejection control.



An "inspection" sensor is connected to the auxiliary input. If, before the end of the delay period, the inspection sensor verifies that the passing product is acceptable, it will output a signal to the auxilary input that will *cancel* the timing and the subsequent output pulse. If no signal is received at the auxiliary input before the end of the delay period, the module will output the one-shot pulse to reject the product (Figure D.12a).

If the MAXI-AMP is programmed for one-shot logic (with no delay time), this same inspection scheme may be used. However, the decision to accept or reject the product is made at the *exact instant* that the interrogate sensor detects the leading (or trailing) edge of the product. The signal from the inspection sensor must overlap the *transition* of the input signal at the leading (or trailing) edge of the passing product in order to prevent the one-shot output from occurring. If no inhibit signal is present at the moment the product's leading (or trailing) edge is detected, the module will output a one-shot pulse to reject the product (Figure D.12b).

The one-shot pulse may be used to directly control a reject mechanism. However, the one-shot pulse is more often used as a data signal for logic that will track the product for rejection or diverting, downstream (see Shift Register Logic, page D-10).

Figure D.12a. Delayed One-shot (with auxiliary data input)

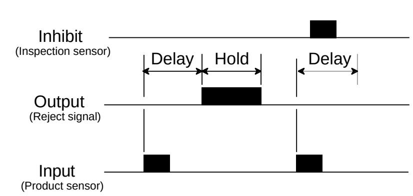
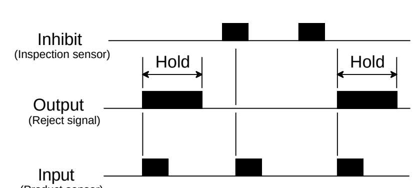


Figure D.12b. One-shot (with auxiliary data input)

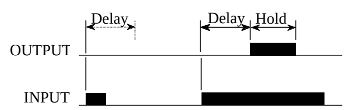


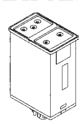
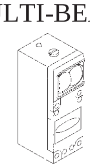
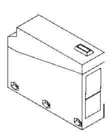
ON-delayed One-shot

An *ON-delayed one-shot* is timing logic that combines ON delay and one-shot timing into a single function. The input signal must be present for at least the time of the ON delay in order for a timed one-shot pulse to occur. (Contrast this to "delayed one-shot" timing logic, where a timed one-shot pulse occurs for any input signal, either momentary or maintained.)

Like any one-shot logic, no subsequent output can occur until the input is removed and then re-applied, at which time the delay period begins again. The delay and pulse ("hold") times are independently adjustable within the (same) time range selected or specified (except Q85 Series sensors). ON-delayed one-shot timing control logic is used in jam control applications for ejection of a part that remains at the sensor longer than the ON delay time.

ON-DELAYED ONE-SHOT



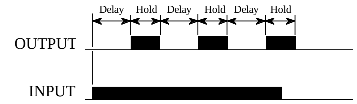
Product Family	Models	Delay & Hold Time
MAXI-AMP™ 	CD5, CL5, CM5, & CR5 Series	0.01 to 0.15 second or 0.1 to 1.5 seconds or 1 to 15 seconds
MULTI-BEAM® 	LM8A	0.15 to 15 seconds
Q85 Series 	Models with -T9 suffix	0.1 to 5 seconds

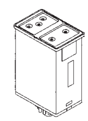
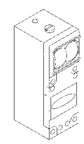
Repeat Cycle Timer

A *repeat cycle timer* or "repeat cycler" creates an oscillating output whenever an input is present. A delay period begins at the leading edge of the input, during which there is no output. If the input signal remains, the delay period is followed by a "hold" period, during which the output is energized. If the input signal remains after the first hold period, a new delay period is started, followed by the hold period, etc. This sequence continues indefinitely until the input signal is removed. Delay and hold times are independently adjustable within the (same) time range that is selected or specified (except Q85 Series sensors).

The repeat cycler is used in guidance control when it is desirable to pulse or "jog" the correction mechanism to avoid over-correction that might occur with a continuous output from, for example, an OFF delay timer. A repeat cycler is also used in carton sealing applications for application of glue in a "dot" or a "stripe" pattern.

REPEAT CYCLE TIMER



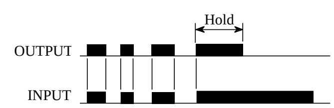
Product Family	Models	Delay & Hold Time
MAXI-AMP™ 	CD5, CL5, CM5, & CR5 Series	0.01 to 0.15 second or 0.1 to 1.5 seconds or 1 to 15 seconds
MULTI-BEAM® 	LM8	0.15 to 15 seconds

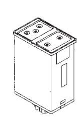
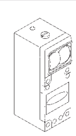
Limit Timer

A *limit timer* provides a means of automatic shutdown during periods of inactivity. During periods of normal activity, the output follows the input ("on-off" operation). However, an input signal that is present for longer than the adjustable "hold" time will cause the output of the limit timer to turn "off". The sustained input is generated by *either* part present *or* by part absent at the sensor by selection of *either* light or dark operate.

Limit timers are used to operate loads that must not run continuously for long periods of time, such as intermittent-duty solenoids or conveyor motors. For example, a limit timer is used to run a grocery checkout conveyor, always bringing items up to a sensor, which stops the motor. When the last item is removed, the motor times out and stops. A limit timer is also known as a "time-limited on/off" or an "interval timer".

LIMIT TIMER



Product Family	Models	Limit Time ("Hold" Time)
MAXI-AMP™ 	CD5, CL5, CM5, & CR5 Series	0.01 to 0.15 second or 0.1 to 1.5 seconds or 1 to 15 seconds
MULTI-BEAM® 	LM5T 2LM5T	0.15 to 15 seconds
Q85 Series 	Models with -T9 suffix	0.1 to 5 seconds

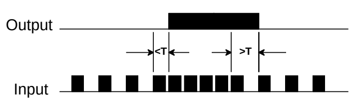
Rate Sensor

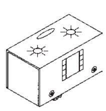
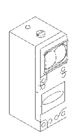
"True" *rate sensing* control logic detects overspeed or underspeed conditions with a timing circuit that continuously calculates the time between adjacent input signals, and compares that "period" with a preset reference. The light and dark operate programs of a rate sensor module are re-defined as "underspeed" and "overspeed". Underspeed detection results in the output of the module *de-energizing* when the sensed rate drops below the preset rate. Similarly, overspeed detection results in the output of the module de-energizing when the sensed rate exceeds the preset rate.

The time adjustment is used to set the period of the preset rate (period = 1/rate). Standard time ranges are listed, but both types of modules are routinely modified for faster or slower rate ranges. A MULTI-BEAM sensor, using a model LM6-1 logic module, represents the most economical rate sensing package available anywhere. The LM6-1 also includes a separate power-up inhibit timer that overrides the circuit and energizes the output for an adjustable time at startup.

A true rate sensor does not output nuisance pulses at low speeds, which is symptomatic of retriggerable one shots. Rate sensing logic is used for monitoring gear rotation, product flow, or any other periodic event.

RATE SENSOR
(underspeed shown)



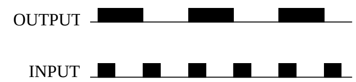
Product Family	Models	Period "T"	Rate
PLUG LOGIC 	B6-1	0.05 to 1 second	60 to 1,200 pulses/min.
MULTI-BEAM® 	LM6-1	0.05 to 1 second	60 to 1,200 pulses/min.

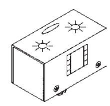
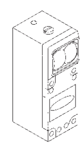
Flip-flop

Flip-flop control logic has several other names, including: "divisor logic", "alternate-action logic", "ratchet logic", and "toggling logic". A flip-flop control consists of a counter circuit that energizes the output after a preset (or fixed) number of sensing events, and de-energizes the output after an equal number of subsequent sensing events. The output switches "on" and "off" indefinitely, in this manner, as long as the logic module continues to receive inputs. No timing function is involved.

Flip-flop logic is used for grouping items into batches, or for splitting items into two lines in conveyor flow control. Flip-flop logic is also used to ease response time requirements of computers or programmable controllers when multiple count inputs occur at a rate that might be too high for the scan time of an input to "catch".

FLIP-FLOP



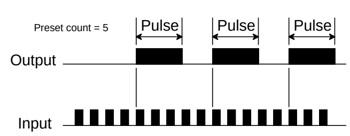
Product Family	Models	Divide by:
PLUG LOGIC 	BIC-99T	Programmable: 2 to 99
MULTI-BEAM® 	LM2	2
	LM10	10

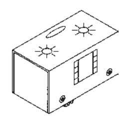
Preset Counter

The *preset counter* is a popular PLUG LOGIC module. This module counts sensing events and energizes its output when the preset count is reached. The preset count is programmed with thumbwheel switches. After the module accepts the programmed number of counts, it immediately resets itself to accept the next batch of counts. The output of the preset counter is an adjustable one-shot pulse. Counts that are input during the output pulse are accepted for the next total.

Model BIC-99 is programmable from 2 to 99 counts. Model BIC10K is programmable up to 9,999 counts. Preset counters are used for many applications that can be controlled by a count input, including: filling, stacking, positioning, and cut-to-length control.

PRESET COUNTER



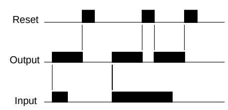
Product Family	Models	Preset Count
PLUG LOGIC 	BIC-99	Programmable: 2 to 99
	BIC-10K	Programmable: 2 to 9,999

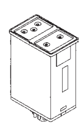
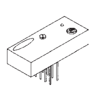
Latch

A *latching* logic control module accepts two inputs. One input latches the output "on". The output remains latched until the second "reset" input drops it out. Latching logic is useful in repetitive operations to provide mechanical control of the process, without the influence of a timing adjustment. Mechanical control is dependent upon the placement of the sensor(s).

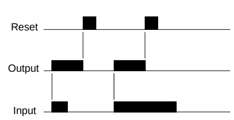
There are two types of latching logic. A **dc latch** will immediately latch "on" again if an input is present when the reset signal is removed. An **ac latch** is also called a "non-repeat latch". The output of an ac latch will not re-energize if an input is present when the reset signal is removed. Following a reset, the output will re-latch at the leading edge of the next input. An ac latch is useful for clutch/brake operation, like in cut-to-length or labeling applications.

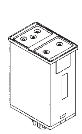
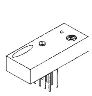
DC LATCH



Product Family	Models	Reset
MAXI-AMP™ 	CD5, CL5, CM5, & CR5 Series	Ground pin #9
MICRO-AMP® 	MA4L	Ground pin #1

AC LATCH



Product Family	Models	Reset
MAXI-AMP™ 	CD5, CL5, CM5, & CR5 Series	Ground pin #9
MICRO-AMP® 	MA4L	Ground pin #1

Shift Register

Shift registers are used primarily with conveyor and indexing tables to permit the inspection of an item at one location and to allow the resultant action (if any) to take place at a location downstream in the process. Unlike the delayed one-shot inspection scheme (see Figure D.11), the shift register tracks an item from the inspection point to the diverting or rejection point using a mechanical "clocked" reference, rather than a timed delay. This makes control by a shift register independent of the speed of production flow.

The logic of a shift register is like an electronic "bucket brigade". Information input to the shift register by an inspection sensor(s) is called "data". Inspection data is placed into the shift register's memory, and it is "clocked" along for the programmed number of "shift bits", at which point the shift register's output is energized.

As an example, Figure D.13 illustrates a system for sensing and rejecting cans with high or crooked caps. The opposed beam of the inspection sensors is interupted only by high or crooked caps of passing cans. This inspection information is entered as data to a model LSR-64 shift register (Figure D.14). Clock pulses are generated by a second pair of opposed sensors that sense the teeth of a timing sprocket that is attached to a drive shaft of the conveyor. Each clock pulse represents an equal increment of movement of the can on the conveyor between the inspection point and the rejection point (assuming there is no slippage of the can as it moves along on the conveyor).

The clock input is typically derived from a sprocket or gear that is coupled to a rotating member of a conveyor drive, or from a cam or contact closure in indexing (intermittent motion) applications. Clock sensors may be photoelectric or inductive (metal) proximity. Mechanical limit switches may also be used, because the LSR-64 module is programmable for slow input response which permits it to ignore contact "bounce". The LSR-64 also has an internal adjustable time-based oscillator that may be selected to supply the clocking signal.

Figure D.13.
Cans with crooked or high caps are sensed by the inspection sensor. Bad cans are rejected downstream by a shift register module.

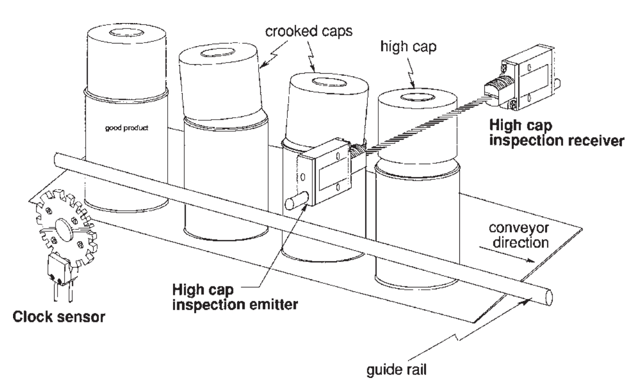


Figure D.14. The shift register module tracks each bad can from the inspection to the rejection point. A "clock" sensor supplies information on product movement.

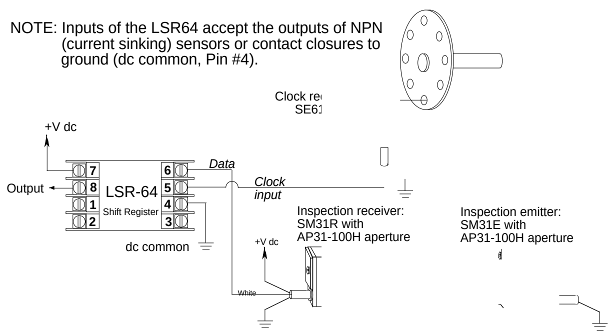
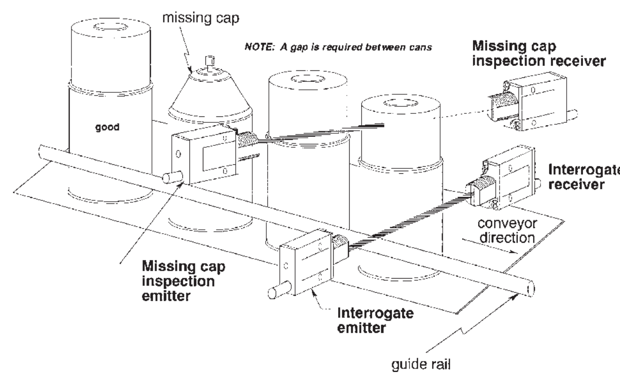


Figure D.16. An "interrogate" sensor must be added for *missing* cap detection.



The LSR-64 is programmable for either of two output modes. It may be programmed for an adjustable one-shot output pulse, corresponding to each data entry. This mode is useful for solenoid-type or air-blast ejection mechanisms. The other output mode is a "latch". The output latches "on" whenever data has been shifted the preset number of bits. The output unlatches at the leading edge of the next clock pulse for which there was no data entry. The latching output mode is used for diverting strings or "trains" of successive items for which data is entered. Figure D.15 illustrates both output modes.

D.15. Shift Register

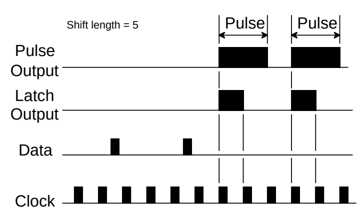
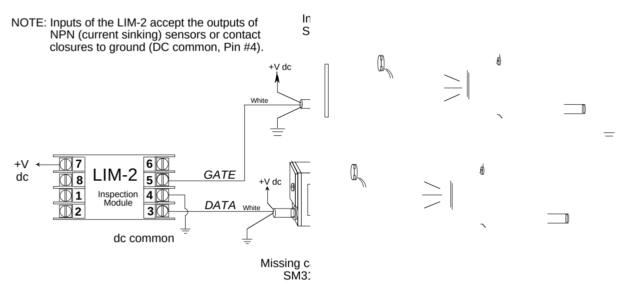


Figure D.17. The LIM-2 module coordinates interrogation and inspection inputs for many types of control applications.



Inspection Logic

In Figure D.13 (page D-10), the inspection for a high or crooked cap is straightforward: any time that the inspection beam is interrupted, a defective product is present. If this inspection application instead calls for detection of a *missing* cap (Figure D.16), then a second piece of information is needed. This is because a missing cap appears exactly the same to the inspection sensor as the *absence of a can.*

In this example, a second "product sensor" is used to "interrogate" the inspection sensor. To interrogate or "gate" a sensor means to ask it to report what it senses, so that a decision can be made to either accept or reject the item that is being examined. *Logic Inspection Module* model LIM-2 offers a means of coordinating the inspection information with an interrogate signal (Figure D.17).

The gate input to the LIM-2 may be generated by a product sensor, as in this example, or it might be generated by a cam or a control relay contact, once per cycle (or index) of a machine.

The LIM-2 module is programmable in several ways to control product: rejection, routing, or assembly; or to inhibit a machine function resulting from a defective, missing, or jammed part.

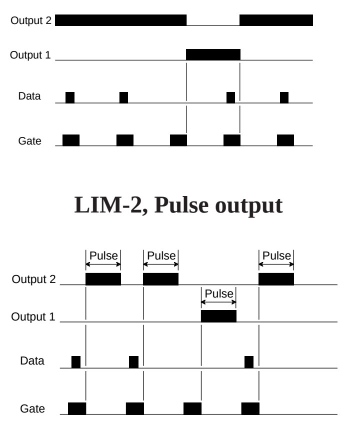
The gate signal establishes a "window" during which the LIM-2 looks for presence or absensce of "data" from the inspection sensor(s). There is a choice of two windowing modes. One mode accepts data at any time during the gate window. In the other mode, the interrogation of the data input occcurs only at the leading edge of the gate window. This leading-edge interrogation can substitute for the one shot inspection logic scheme, discussed above.

The LIM-2 has two outputs. One output energizes at the end of a gate window during which there was data present. The second output energizes at the end of a gate window during which *no* data was present (see Figure D.18). Either output may be used alone, or both may be used simultaneously.

The outputs may be programmed either as a one-shot or as a latch. The one-shot output is an adjustable pulse that occurs at the end of the gate window. The one-shot pulse may be used to directly control a reject mechanism, or to supply data to additional logic such as a shift register or a PLC. The latching output energizes (or de-energizes) at the end of the gate window, and remains in that state until the end of a subsequent gate window during which the opposite data condition is sensed. The latching output mode is useful for engagement of a diverter mechanism, as in "train" logic applications, or for inhibiting a machine function, as in "no can/no fill" and die protection applications.

The LIM-2, like shift registration, offers a means of coordinating inspection and rejection inputs and outputs, without the affect of time variables. The LIM-2 creates, instead, a relationship between inputs and outputs that is controlled, in most cases, by the relative *mechanical* placement of sensors. Since most repetitive processes start and stop and/or vary in rate, this type of mechanical relationship is almost always preferred over reliance on one or more timing adjustments.

D.18.
LIM-2, Latch output



AND Logic

The MICRO-AMP model MA4G (see Figure D.4) monitors up to four inputs and and switches its output only when all inputs are simultaneously in the same state. The MA4G may be programmed to switch its output when all four inputs are "low" (AND logic), when all four inputs are "high" (NOR logic), or when all four inputs are *either* simultaneously "low" *or* "high" (Exclusive NOR or XNOR logic).

The MA4G may be used as a two, three, or four-input gate. Unused inputs are simply tied "low" (to dc common) or left unconnected ("high"). The MA4G has complementary outputs, and any number of modules may be cascaded for monitoring more than four inputs. A basic four-input AND gate, model AG-4, is also offered in the PLUG LOGIC product line. AND gate logic modules are useful in inspection or positioning applications when checking for "all parts present".

Anti-bounce Logic

PLUG LOGIC model AB-2 is designed for buffering of count inputs. The AB-2 is used when counting objects that are occasionally unstable as they pass a sensor, like cans or bottles on a conveyor. The AB-2 requires two sensors that are mounted adjacent to each other. The AB-2 processes the inputs from the two sensors and will produce an output pulse to a counter only when an object has entered and then left the fields of both sensors in the proper direction. Objects that bounce slightly backwards or that "dance" in front of the sensors will not register more than a single count.

Dual Channel Inverter

PLUG LOGIC model BN2-2 offers two separate channels, each of which will combine two "high" inputs to switch its output "on". The BN2-2 may be used to simply invert a signal from "high" to "low" or vice-versa. This is often necessary in more complex logic systems in order to inhibit or gate other sensors or logic modules. Its two channels may also be interconnected to create other logic functions, including OR logic and complementary AND logic.

Notes Regarding Logic Module Inputs

The inputs of MAXI-AMP CL Series, MICRO-AMP logic, and PLUG LOGIC modules accept the output of any device that will provide a current path to ground. This includes the current sinking (NPN) outputs of dc sensors, plus the contact closures of sensors or other devices with electromechanical output relays.

Also, the inputs and outputs of all logic modules are compatible. This allows nearly any logic sequence, no matter how complex, to be created by using modules as logic "building blocks". There is, of course, a point in the complexity of a sensing system where logic control by a PLC is economically justified. Banner sensors are designed for interfaceability to all types of PLCs, computers, and other logic circuitry (see Section C).

Section C: Interfacing

A key step in any sensor selection process is to analyze the *load* to which the sensor or sensing system will interface. Here, the term "load" is used in a general sense to describe electromechanical devices (solenoids, clutches, brakes, contactors, etc.) and resistive loads (lamps, heaters, etc.) in addition to solid-state circuit inputs (counters, programmable logic controllers, Banner logic modules, etc.).

The first step in analyzing a sensor-to-load interface is to determine whether the load requires a switched signal or an analog signal from the sensor. In other words, is the sensing system to switch a load "on" and "off" with a digital signal, or will the sensor provide a meter or a control circuit with an analog signal?

The output of an *analog* sensor (Figure C.1) varies over a range of voltage (or current) and is proportional to some sensing parameter. Analog photoelectric sensors, e.g. analog OMNI-BEAMs, produce an output that varies with received light intensity. Analog ultrasonic sensors, like 923 Series ULTRA-BEAMs, generate an output that varies with the distance from the sensor to the target. A *digital* output has only two states: "on" or "off" (Figure C.2). The output of most sensors and sensing systems is digital.

Figure C.1 Analog output.

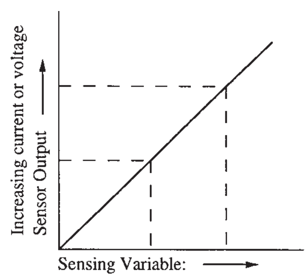
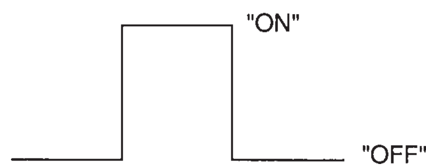


Figure C.2 Digital output.



SWITCHED OUTPUTS

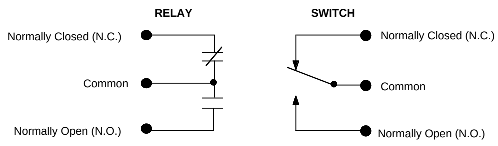
All sensors with digital outputs have an output switch of one type or another, which interfaces the sensor to a load. An understanding of the configuration and the capabilities of each type of switch is important in the sensor selection process. The major divison in switch types is between *electromechanical* and *solid-state.*

Automated factories have adopted the programmable logic controller (PLC) to direct process control. Today's sensor is more likely used to supply data to a computer or controller than to perform an actual control funtion. For applications like these, the benefits of solid-state relays, such as reliability and speed, become important (see Table C-1). Because of this, the output device of most self-contained photoelectric controls is a solid-state relay.

Electromechanical Relays (Table C-2)

An electromechanical relay is useful as the output device of a self-contained sensor whenever the sensor provides direct control of a load that draws *more* current than can be handled by any of the solid-state relays offered within the family of sensors being applied. This situation is most common in control applications where sensors directly switch start, stop, and divert mechanisms such as clutches, brakes and solenoids at (or adjacent to) the point of sensing.

Figure C.3. Single-pole, double-throw (SPDT) contacts (complementary switching).



Electromechanical relays with one or more double-throw contacts are very useful in interfaces that require complementary switching (e.g. SPDT relays, Figure C.3). Also, electromechanical relays are convenient to use when a string of sensor outputs are wired together in series for **AND** logic, as in "all parts present" sensing applications. However, whenever multiple sensor AND logic is required, the system is best engineered by first evaluating the options that are available using sensors with solid-state outputs (see Multiple Sensor Hookup, pages D-1 through D-3).

Electromechanical relays are often used simply because they are easiest to understand. When interfacing to a circuit input that has unknown voltage and current characteristics, it is easiest to use a "hard contact" for switching. Electromechanical relays offer hard contacts. However, not all electromechanical relays are designed to switch low-level signals, and the "unknowns" may still lead to intermittent trouble. Measuring the voltage and current between the points where a contact is to be connected (e.g. with a VOM) is an easy way to define the input configuration.

The products listed in Table C-2 have electromechanical relays as their output switches. The major difference between relay types is their ability to switch low current level signals. The key to this difference is the relay contact material. Gold flashing on the contacts of the MAXI-AMP relays allows relatively small signals to be reliably conducted.

Gold flash is quickly burned off by arcing caused by switching a large load and/or an inductive load. Once a gold-flashed contact has been used to switch a large load or an inductive load of any size, it cannot be used to reliably switch a low-level signal.

TABLE C-1. Comparison of Electromechanical and Solid-state Relays*

ELECTROMECHANICAL RELAYS	SOLID-STATE RELAYS
Contacts are forgiving to temporary overload	(Contacts may be destroyed by overload; additional protection circuitry is required)
Immune to false trips from electrical "noise"	(Sensitive to some forms of EMI and/or RFI)
Positive audible switching	(Silent switching)
Little or no voltage drop across contact	(On-state voltage drop across contact)
No restrictions on series or parallel connections	(Some designs cannot be wired in series; and some designs have restrictions on parallel connection)
Contacts generate little or no heat	(Contacts dissipate heat energy)
Relatively low cost for high-capacity switching	(High capacity switches are expensive)
(Low capacity switches are relatively expensive: require gold-flashed contacts)	Low capacity switches are inexpensive
(Speed is limited by mechanical design)	Fast switching speeds
(Mechanical life expectancy: contact life is limited by demand of load)	Infinite life, high reliability
(Typically require 50mA or more to energize)	Require very little power to energize
(Contact arcing is common with inductive and some capacitive and resistive loads)	No contact arcing: contacts produce little or no switching "noise"
(Contact "bounce" may cause erratic operation with fast-reacting loads, e.g.- electronic counters)	Positive switching: no contact "bounce"
(Can only be sealed; hermetically sealed relays are expensive)	Can be encapsulated; tolerant of shock, vibration, and hostile environments.

NOTE: relative disadvantages *are indicated by parentheses ( ).*

Table C-2 clearly suggests that the relay in VALU-BEAM 915 Series sensors and in MULTI-BEAM powerblocks should *only* be used for loads that demand more current than can be handled by the solid-state equivalents in each family. These relays should *never* be used to switch low-level logic signals.

The silver-nickel alloy contacts of the relay in the MAXI-BEAM, ULTRA-BEAM, OMNI-BEAM, Q85 Series, and MICRO-AMP products are somewhat more reliable with smaller loads. These contacts may be used for some solid-state interfaces. For example, these relays will reliably interface to a 120Vac (or higher voltage) input of a PLC. Keep in mind that a contact of any electromechanical relay should not be used for logic-level switching after it has been used to switch a large load or any inductive load.

While silver alloy contact materials are resistant to oxidation, they are prone to sulfidation, which can increase contact resistance. Contact arcing, if held to a controlled level, can prevent the buildup of sulfidation on contacts and can actually help to extend useful contact life.

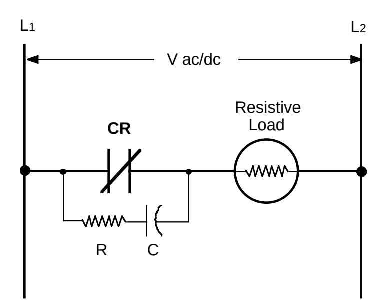
Table C-2. Sensors with Electromechanical Output Relays

Banner Product with Electromechanical Relay	Sensor Operating Voltage	Contact Configura-tion	Contact Material	Maximum Load (Resistive Load)	Minimum Load	Response Time on/off (milli-seconds)	Mechanical Life Expectancy (switching cycles, no load)
MULTI-BEAM 2PBR Power Block	105-130Vac	SPST	Silver oxide complex alloy	5A @ 250Vac 250V ac max. 30V dc max.	1 Amp @ 5 volts	20 close 20 release	10,000,000
MULTI-BEAM 2PBR2 Power Block		SPDT					
VALU-BEAM 915 Series	12-28V ac/dc, 90-130V ac, or 210-250V ac (depending on model)	SPDT			100mA @ 24 volts		
OTB/LTB Optical Touch Button	105-130Vac, 210-250V ac, 10-30V dc, depending on model	SPDT		7A @ 120Vac 250V ac max. 30V dc max.	100mA @ 24 volts		50,000,000
Q85 Series	12-240V dc or 24-240V ac	SPDT	Silver nickel alloy	3A @ 250Vac 250V ac max. 30V dc max.	10mA @ 5 volts		50,000,000
MAXI-BEAM RPBR Power Block	12-30V dc or 12-250V ac	SPST		5A @ 120Vac 250V ac max. 30V dc max.	100mA @ 5 volts		10,000,000
MAXI-BEAM RPBR2 Power Block	12-30V dc or 12-250V ac	SPDT					
ULTRA-BEAM 925 Series	105-130V ac or 210-260V ac (depending on model)				10mA @ 24 volts		
MICRO-AMP MPS-15 Chassis	105-130V ac or 210-250V ac (depending on model)						
E Series OMNI-BEAM	24-36V dc or 24-250V ac						
Sonic OMNI-BEAM	105-130V ac			7A @ 120Vac 250V ac max. 30V dc max.	10mA @ 5 volts		50,000,000
MAXI-AMP CD, CL, CM, CP, & CR models with electromechanical relay	12 to 28V dc (all models), plus 105-130V ac or 210-250V ac (varies w/model)	SPDT	Gold-flashed silver Cadmium oxide	5A @ 250V ac 250V ac max. 24V dc max.	1 mA @ 2 volts	10 close 10 release	20,000,000

At voltage and current levels that are too small to produce an arc, a capacitive discharge occurs between separating contacts that may be sufficient to prevent sulfidation build-up on the contacts. For large loads and inductive loads, arcing should be controlled to prolong contact life.

For large *resistive loads*, where arcing occurs, a series resistor and capacitor combination (R-C network) is placed in parallel with the contacts (Figure C.4). When the contacts open, the capacitance shunts the voltage away from the contacts. The resistor prevents the capacitor from dumping its charge onto the contacts when they close. The resistance limits capacitor current, but it also reduces the capacitor's effectiveness. As a result, an arc may still occur, but it will be of short duration.

Figure C.4. R-C "Snubber".



The following formulas may be used for the approximate values of R and C:

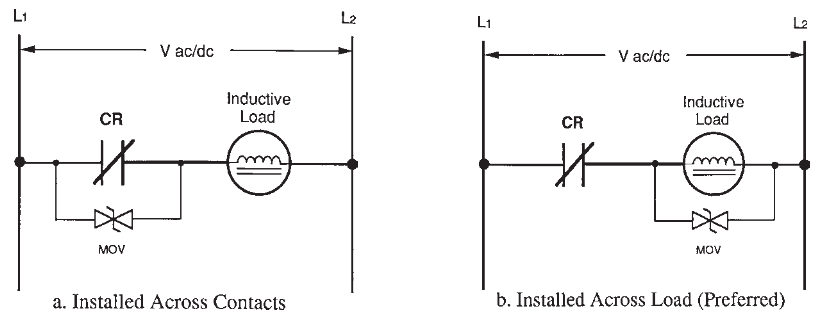
$$R = \frac{E}{10(I^x)} \text{ ohms} \qquad \text{Where, } x = \left(1 + \frac{50}{E}\right) \qquad C = \frac{I^2}{10} \text{ microfarads}$$

Where: E = Voltage across the contacts when open I = Holding current of the load (amps).

The resistor should be 1/2-watt or larger. The working voltage of the capacitor should exceed **E**. R-C networks, also called "snubbers", are available as single components. Paktron (Vienna, VA, U.S.A.) offers a series of Quencharc® R-C networks which are sold by electronic component dealers and distributors.

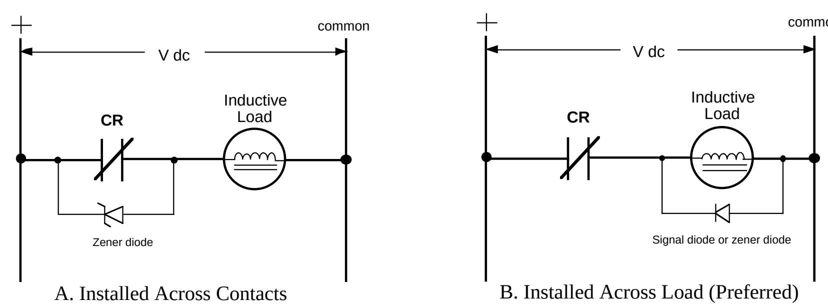
When interfacing to an *inductive load*, the best method of arc suppression is a clamping device such as a diode (for dc loads) or varistor (for ac or dc loads) connected in parallel with either the contacts or the load (Figure C.5). Metal oxide varistors (MOVs) are manufactured by General Electric, Mepco, and others. When voltage spikes occur, the impedance of the MOV changes from very high to very low, clamping the transient voltage to a protective level. The excess energy of the high voltage pulse is absorbed by the MOV. MOVs are rated by their *clamping voltage* and by their *peak pulse current capacity*.

Figure C.5. Clamping device for inductive loads: metal oxide varistor (MOV).



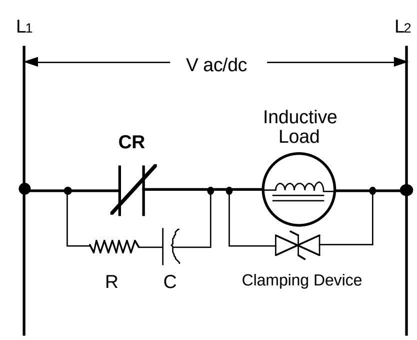
Diodes are generally used for arc suppression with low voltage dc loads. The diode is placed across the inductive load or across the contacts with its cathode tied to the positive side (Figure C.6). A clamping diode should be sized to handle the load current and *twice* the supply voltage. MOVs for low voltage are manufactured, but are less common than those for high voltage.

Figure C.6. Diode used for clamping in dc circuits with inductive loads.



A high-current arc may be drawn at voltages below the clamping point as contacts open or bounce. Because of this, it is good insurance to also install an R-C network across contacts that switch an inductive load to limit low voltage arcing until the clamp turns on (Figure C.7).

Figure C.7. Best method for arc suppression with inductive loads: install a clamping device and an R-C "snubber".



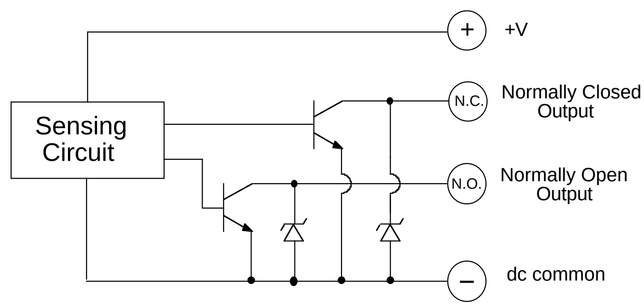
Arc suppression also helps minimize EMI (electromagnetic interference). Electromechanical relay contact arcing is a primary cause of false triggering of logic circuitry. When one-shot pulse or off-delay logic is used, it is particularly important to suppress arcing of the relay in the MAXI-AMP module and in OMNI-BEAM, MAXI-BEAM, and MULTI-BEAM power blocks. These products are designed for EMI noise immunity, but the relay contacts are so close to the amplifier and logic circuitry that false triggering from contact arcing is possible.

Solid-state Relays

The output switch of most self-contained sensors is a solid-state relay. Solid-state relays are divided between those designed to switch loads that operate on dc voltage and those designed to switch ac loads. There are a few solid-state relays that are able to switch either ac or dc loads. (See MULTI-BEAM power blocks and MAXI-AMP modules with solid-state output option in the Banner product catalog.)

All solid-state relays are SPST switches. The output of a sensor is usually programmable for either normally open or normally closed operation. When there is no timing logic involved, programming of the sensor output switch is accomplished by selecting the light operate or the dark operate sensing mode (where selection is possible). Some dc sensors offer multiple solid-state outputs. For example, SM512, S18, and Q19 Series sensors and MICRO-AMP modules offer two solid-state output switches configured so that one is normally open and one is normally closed. This arrangement, called a *complementary output*, is the solid-state equivalent of an SPDT form 1C relay contact (Figure C.8).

Figure C.8. Example of solid-state complementary output.



A. Interfacing DC Sensors to DC Loads (Table C-3)

DC sensors and dc component amplifiers use a transistor for their output switch. There are three output configurations:

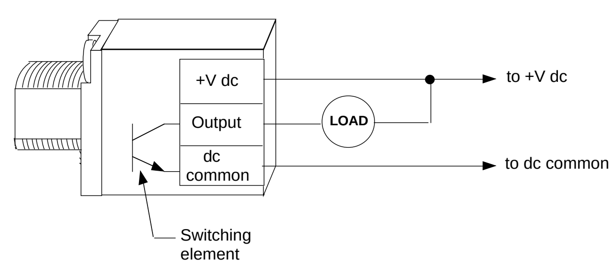
1) Open collector NPN - current sinking,
2) Open collector PNP - current sourcing,
3) Isolated NPN - current sinking *or* sourcing.

Most simple resistive and electromechanical dc loads will interface to any of these three configurations. However, the inputs of logic circuitry dictate the requirement for either a sinking or a sourcing input device. To determine the input requirement for a particular circuit, it may be helpful to investigate the following:

a) The specifications for the input requirements may define a logic "1" and a logic "0". If a logic "1"is defined as a high voltage (i.e. the sensor supply voltage), then a sensor with a sourcing output is usually required. If a low voltage (usually near zero volts) is required for a logic "1", then a sensor with a sinking output is needed for the input. (A logic "1" may sometimes be called a logic "TRUE".)

b) If a connection diagram for the circuit shows a switch connected between the input and another connection point, find out what the voltage is at the connection point, relative to the dc common of the circuit. This can sometimes be discovered from a schematic diagram of the circuit, or it can be measured with a dc voltmeter (e.g. a VOM). If the connection point measures positive with respect to dc common, then a sensor with a sourcing output is usually required for the input. If the connection point is in continuity with dc common of the circuit, then a sensor with a sinking output device is needed for the circuit input.

Figure C.9. Current sinking output.



Current Sinking Outputs

Current sinking devices are those that switch ground (dc common of the sensor supply voltage) or -V to a load. The load is connected between the output of the sensor and the positive side of the power supply (Figure C.9). Most dc sensors have at least one current sinking output (Table C-3).

In the most straightforward interfaces, the sensor supply voltage is the same as the load supply voltage. A current sinking output can also be used to interface to a load that operates at a lower voltage than the sensor supply voltage. The ground (or -V) of the sensor supply should be tied to the ground of the load supply, so that both supplies have a common voltage reference.

A current sinking output can drive the input to a logic circuit that requires a current source with the addition of a *pullup resistor* (Figure C.10a). This scheme inverts the actual input state. The "on" condition of the sensing system becomes the "off" condition as seen by the solid-state input, and vice versa. Again, the ground of the sensor supply should be common to the ground of the logic circuit supply.

Table C-3. Sensors Powered by DC Voltage with Solid-state Output Switches for DC Loads

DC Sensor Model	Sensor Operating Voltage	Output Switch Configuration	Output Switch (Transistor) Type	Output Switch Capacity	Overload Protection	On-state Saturation Voltage (at signal levels)
OMNI-BEAM OPBT, OPBTQD, & OPBTQDH Power Blocks	10-30V dc	SPST	One NPN (sinking) or PNP (sourcing) (Bi-Modal™)	100mA	Yes	<1.0V
SM30 Series				250mA		
MULTI-BEAM PBT Power Block			One NPN (sinking)		No	<0.5V (TTL compatible)
MULTI-BEAM PBT48 Power Block	44-52V dc					
MULTI-BEAM PBT2 Power Block	10-30V dc	SPDT	Two NPN (sinking); one N.O. and one N.C. (complementary)	250mA (each output)	No	
SM512 Series					Yes	<1.0V
MICRO-AMP MA3 & MA3-4				150mA (each output)		<0.5V (TTL compatible)
MULTI-BEAM PBP Power Block		SPST	One PNP (sourcing)	250mA	No	<1.0V
MULTI-BEAM PBP48 Power Block	44-52V dc					
MICRO-AMP MA3P and MA3-4P	10-30V dc	SPDT	Two PNP (sourcing); one N.O. and one N.C. (complementary)	150mA (each output)	Yes	
MULTI-BEAM LS10R	12-24V dc	DPST	One NPN (sinking) plus one PNP (sourcing); (bipolar)	125mA (each output)		<0.2V (TTL compatible)
MAXI-BEAM RPBT Power Block	10-30V dc			250mA (each output)		
VALU-BEAM SM912 Series						
MINI-BEAM SM312 Series				150mA (each output)		
ECONO-BEAM SE612 Series						
MAXI-AMP CD, CL, CM, CR; models with solid-state output option	12-28V dc	SPST	One isolated NPN (sinking or sourcing)	50mA	No	<1.0V

Table C-3. Sensors Powered by DC Voltage with Solid-state Output Switches for DC Loads (continued)

DC Sensor Model	Sensor Operating Voltage	Output Switch Configuration	Output Switch (Transistor) Type	Output Switch Capacity	Overload Protection	On-state Saturation Voltage (at signal levels)
C3Ø Series QØ8 Series	10-30V dc	SPDT	One NPN (sinking) or PNP (sourcing)	150mA	No	<0.2V (TTL compatible)
S18 Series Q19 Series	10-30V dc	SPDT	Two NPN (sinking) or two PNP (sourcing); complementary	150mA (each output)	Yes	<1.0V

Connection of a current sinking output to 5 volt TTL (transistor-transistor logic) is an example of a sensor-to-logic circuit interface (Figure C.10b). TTL inputs require that the current sinking output "pull low" to within about 600 millivolts (0.6 volts) of dc common.

The current sinking outputs of some sensors do not *saturate* below about 1 volt. This is acceptable for most loads, but an *on-state saturation voltage* of 1 volt is not low enough to energize TTL inputs. Table C-3 lists the on-state saturation voltage for each family of dc sensors specified at *signal* levels of load current. When saturation voltage is specified at 0.5V dc or less, a direct interface to TTL circuits is usually possible. Sensor outputs that saturate above 0.6V dc require use of an interposing relay, like model OC-12, for interfacing to TTL (see Figure C.11).

If the sensor and the load do not share the same power supply, *and* if a common cannot be established between the two supplies, then an interface device *must* be added between the sensor and the load. Model OC-12 is an optically-isolated solid-state relay that is used to interface a dc sensor to a dc logic circuit. The OC-12 can be used to source or sink up to 50 mA at up to 30V dc to a circuit. It may be run by either a sinking or a sourcing sensor (Figure C.11). The OC-12 is packaged in a standard octal-plug relay housing, and may be conveniently wired by using a model OS-8 octal socket.

Models PD-28 and PD-90 are interface devices used to switch dc loads which demand more current than the dc sensing system can

Figure C.10a. Hookup of a current sinking output to a logic input requiring a current source, using a pullup resistor.

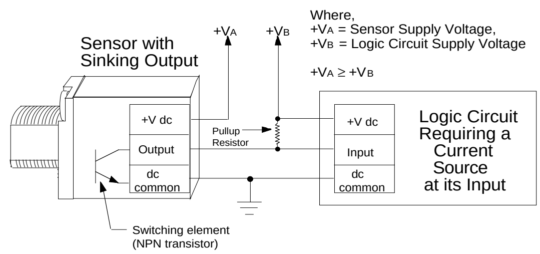


Figure C.10b. Hookup of a current sinking output to a TTL gate.

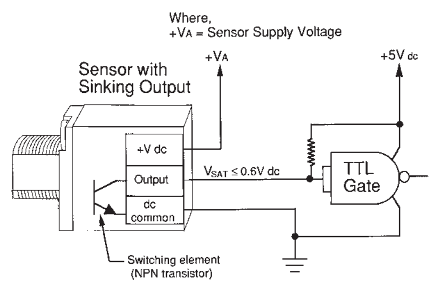
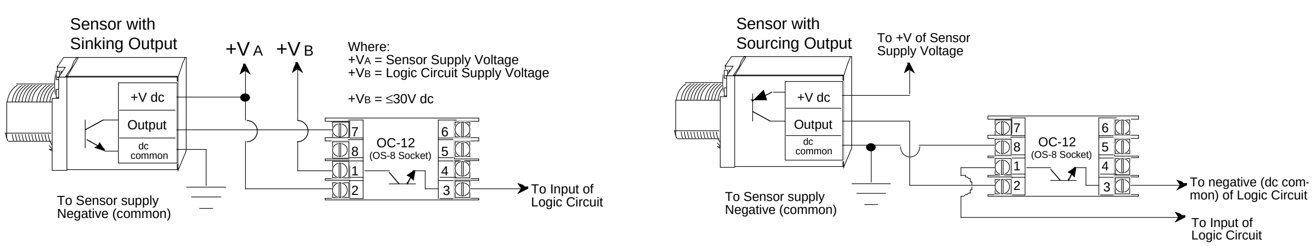


Figure C.11. Optical coupler interfacing: dc sensor to dc logic circuit where voltage isolation is required.

To logic requiring a current source: *To logic requiring a current sink:*



handle. Model PD-28 can operate loads up to 30V dc at 3/4 amp. Model PD-90 can switch loads up to 200V dc at 1/4 amp. These solid-state relays may be run by either sinking or sourcing sensors. They are useful for meeting the current demands of fast-response dc clutches, brakes, and large solenoids. PD-28 and PD-90 relays require that the ground of the sensor supply be tied to the ground of the load supply (Figure C.12).

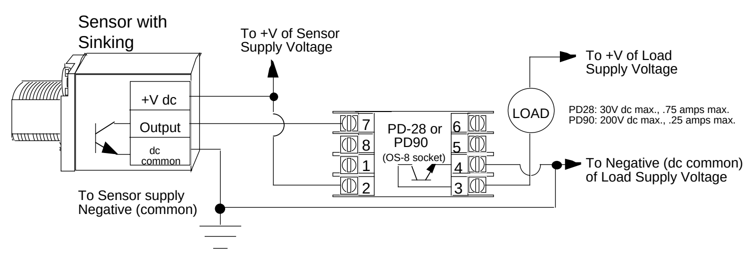
Current Sourcing Outputs

Current sourcing output devices are those that switch positive dc to a load. The load is connected between the output of the sensor and the negative (common) side of the power supply (Figure C.13). The voltage that the sensor switches to the load is the sensor supply voltage. As in all dc interfaces, if at all possible, the negative of the sensor power supply should be common to the negative of the load power supply.

Sourcing outputs are becoming increasingly important as more and more solid-state controls are designed to require sourcing devices as inputs. The dc versions of the VALU-BEAM SM912 Series, MINI-BEAM SM312 Series, ECONO-BEAM SE612 Series, and the MAXI-BEAM sensor family all offer two output switches: one sinking and one sourcing. This arrangement, called a *bipolar output*, is the solid-state equivalent of a DPST relay for most loads (Figure C.14a). A bipolar output will satisfy the input of almost any dc logic circuit. The patented *Bi-Modal*™ output design of OMNI-BEAM dc power blocks and SM30 Series sensors also satisfies requirements for either a sinking or a sourcing interface (Figure C.14b).

A bipolar output configuration usually can be converted to a complementary output with the addition of either a pullup or a pulldown resistor. To convert a bipolar to a complementary current sinking output, a pulldown resistor is added from the sourcing output to ground (Figure C.15). To convert a bipolar output to a complementary current sourcing output, a pullup resistor is added from the sinking output to +V of the load power supply.

Figure C.12. Hookup of PD28 and PD90 power driver relays.



Isolated Transistor Output

MAXI-AMP modules with solid-state relay option offer an NPN transistor output switch that is isolated from the module supply voltage. It may be treated like a polarity-sensitive SPST contact for either sourcing *or* sinking interfaces. Its maximum current switching capacity is 50 mA. For this reason, it may be interfaced directly only to logic circuit inputs. Figure C.16 shows the general wiring scheme for a sourcing or sinking interface to a PLC. It is also possible to wire the isolated transistor output of multiple MAXI-AMP modules together in series. (Most other dc sensors and sensing systems have the emitter of the output transistor tied to +V or to common. As a result, they *cannot* be wired in series with other dc sensors. See 3-wire DC Sensors, pages D-2 and D-3).

Figure C.13. Current sourcing output.

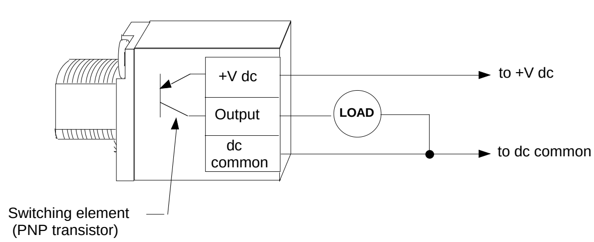


Figure C.14a. Example of a solid-state bipolar output.

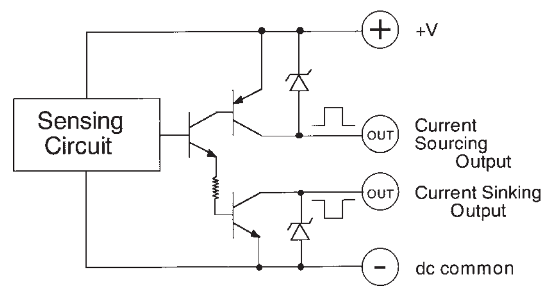


Figure C.14b. Example of solid-state Bi-Modal™ output.

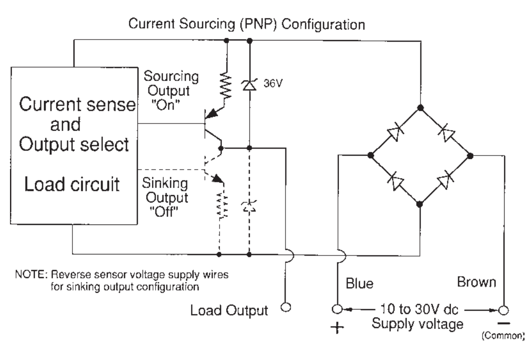


Figure C.15. Conversion of a bipolar output to a current sinking complementary output, using a pulldown resistor.

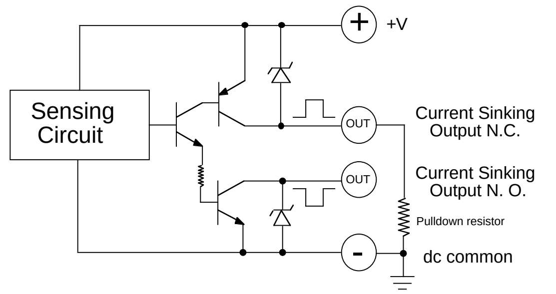


Figure C.17. Powering a MAXI-AMP module with a dc voltage and switching an ac load.

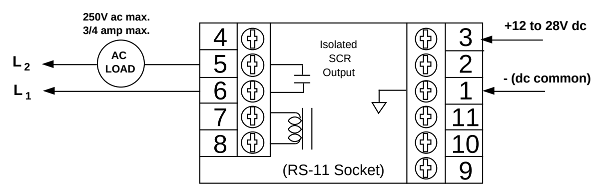
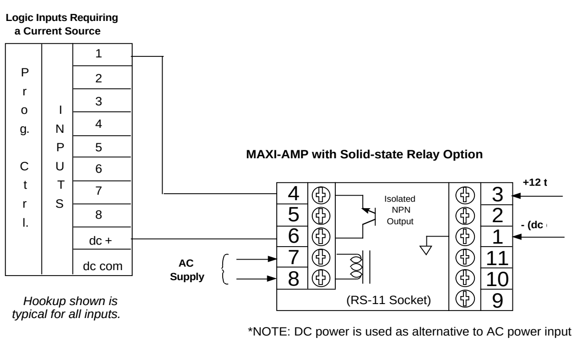


Figure C.16. MAXI-AMP modules with isolated solid-state output: sourcing & sinking hookups to PLC

Hookup for current sourcing:



Hookup for current sinking:

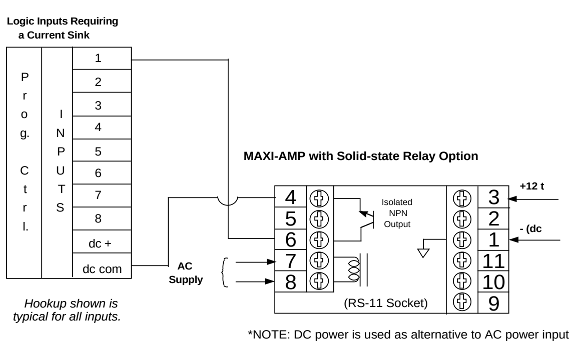


Figure C.18. Interfacing dc outputs to ac loads using BTR-1A solid-state relay.

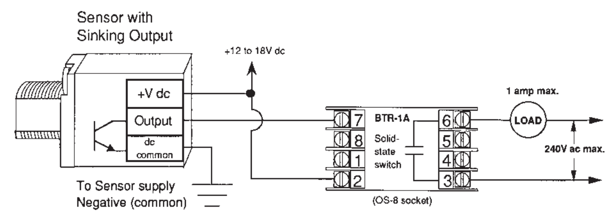
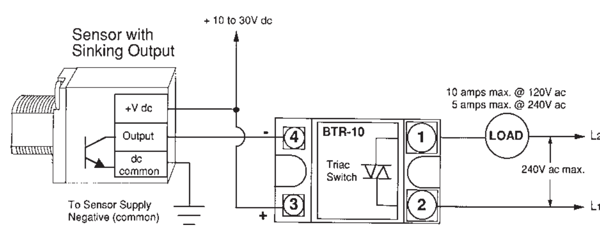


Figure C.19. Use of BTR-10 triac to switch large ac loads.



B. Interfacing DC Sensors to AC Loads

MAXI-AMP modules with the *solid-state output option* offer a way to power the module with low voltage dc and switch an ac load (Figure C.17). All other dc sensors and component amplifiers require an external interface relay to accomplish ac switching.

Loads up to 1 amp at up to 240V ac may be switched using the model BTR-1A ac output module. Its low 0.1 mA off-state leakage current makes it the ideal interface device to use between a dc sensor and a 120V ac PLC input. Note, however, that the BTR-1A's input will work only in 12 to 18V dc systems (Figure C.18).

Model BTR-10 is a triac that will switch loads up to 10 amps at 120V ac or 5 amps at 240V ac. The BTR-10 has too much off-state leakage current to interface to logic circuits and other light loads. It should be used *only* for large loads with current demand in excess of 1 amp (Figure C.19).

C. Interfacing AC Sensors to AC Loads (Table C-4)

The output switch configuration of most ac sensors consists of an SCR and bridge rectifier combination, protected from line transients by an MOV. Some designs also include an R-C snubber to prevent the SCR from false switching due to quick voltage changes (dV/dt).

Sensors that are designed to switch ac loads have one of three wiring configurations:

2-wire design,
3-wire design, or
4-wire design.

2-wire Sensors

2-wire designs predominate among self-contained ac sensors. The simplicity of installation that is associated with 2-wire sensors is a big advantage. However, 2-wire sensors carry a few application warnings.

A 2-wire sensor remains powered by a residual current which flows through the load when the load is "off" (Fig. C.20). This residual current is called the sensor's *off-state leakage current* (I_{off}). The effect of this leakage current depends upon the characteristics of the load. The voltage that appears across the load in the off-state is equal to the leakage current of the sensor multiplied by the resistance of the load: $V_{off} = I_{off} \times R_{Load.}$

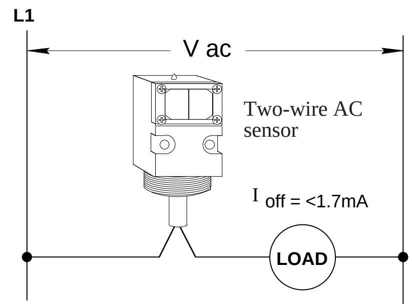
If this resultant off-state voltage is less than the guaranteed turn-off voltage of the load, then the interface is direct. If the off-state voltage causes the load to stay "on", an artificial load resistor must be connected in parallel with the load to lower the effective resistance of the load. Leakage current is *additive* when multiple sensors are wired in parallel to a single load.

The off-state leakage current of MULTI-BEAM 2-wire sensors is only 1 milliamp. The maximum leakage current of all other 2-wire sensors is 1.7 milliamps, which is too low to cause a problem with most loads, including ac inputs to most PLCs.

MULTI-BEAM 2-wire powerblocks do not successfully wire together in series. This is also true of MAXI-BEAM powerblocks. VALU-BEAM 2-wire sensors *do* wire together in series, as do MINI-BEAM and SM3Ø Series sensors, but there is a significant additive voltage drop (see reference hookup information on pages C-27, -30, and -36).

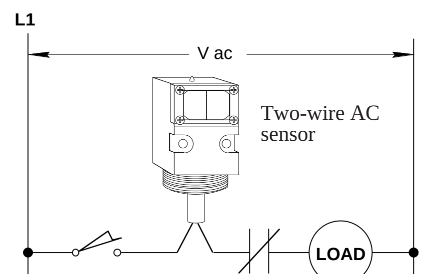
Also, when 2-wire sensors are wired in series or in parallel with the "hard" contacts of switches or electromechanical relays, the delay time required by the sensor's false-pulse protection circuitry may become an important factor. When wired with series contacts (Figure C.21), the 2-wire sensor will receive power to operate only when all of the contacts are closed. The false-pulse protection circuitry will cause up to a 0.3 second delay between the time that the last contact closes and the time that the load can energize (see individual sensor specifications).

Figure C.20. Off-state leakage current of 2-wire sensors.



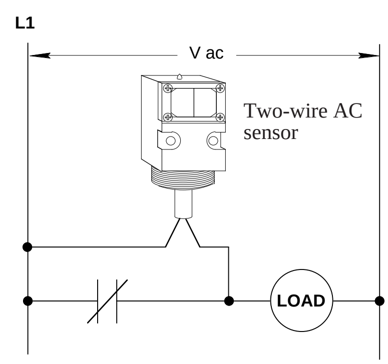
The sensor remains powered when the load is "off" by a residual current which flows through the load.

Figure C.21. 2-wire sensor with series contacts.



Sensor receives power to operate after the last contact closes. This causes up to a 0.3 second delay before the load can energize

Figure C.22. 2-wire sensor with parallel contacts.



The sensor loses the current it needs to operate when the contact is closed. When the contact opens, the load may drop out for up to 0.3 seconds.

When a 2-wire sensor is wired in parallel with contacts (Figure C.22), the load will energize when *any* of the contacts close or the sensor output is energized. When a contact is closed, it shunts the operating current away from the 2-wire sensor. As a result, whenever all of the contacts open, the sensor's power-up delay may cause a drop-out of the load for up to 0.3 seconds.

Table C-4. Sensors Powered by AC Voltage with Solid-state Output Switches for AC Loads

AC Sensor Model	Sensor Operating Voltage	Output Switch Configuration	Output Switch Type	Output Switch Capacity: Load Voltage Range	Output Switch Capacity: Maximum Load Current	Off-state Leakage Current
OMNI-BEAM OPBA2, OPBA2QD, & OPBA2QDH Power Blocks	105-130V ac	SPST	SCR plus bridge rectifier 3- and 4-wire hookup	11-250V ac	1/2 amp 7 amp inrush	<0.1mA
OMNI-BEAM OPBB2, OPBB2QD, & OPBB2QDH Power Blocks	210-250V ac			11-250V ac		
S18 Series	20-250V ac			20-250V ac	300 mA 1 amp inrush	<0.05 mA
MULTI-BEAM 2PBA Power Block	105-130V ac		SCR plus bridge rectifier 2-wire hookup	105-130V ac	3/4 amp 10 amp inrush	<1.0mA
MULTI-BEAM 2PBB Power Block	210-250V ac			210-250V ac		
MULTI-BEAM 2PBD Power Block	22-28V ac			22-28V ac		
MAXI-BEAM R2PBA Power Block	105-130V ac			105-130V ac		<1.7mA
MAXI-BEAM R2PBB Power Block	210-250V ac			210-250V ac		
VALU-BEAM SM2A912 Series	24-250V ac			24-250V ac	1/2 amp 4 amp inrush	
MINI-BEAM SM2A312 Series	24-240V ac			24-240V ac	300mA 3 amp inrush	
SM2A30 Series					500mA 4 amp inrush	
MULTI-BEAM PBA Power Block	105-130V ac	*Power block **PBAQ** has a normally closed output. It is used in applications where a load must be de-energized for a timed pulse. SPST	SCR plus bridge rectifier 3- & 4-wire hookup	11-250V ac Sensor power and output power must share a common neutral.	3/4 amp 10 amp inrush	<0.1mA
MULTI-BEAM PBAQ Power Block*						
MULTI-BEAM 3GA5-14 Edgeguide System						
MULTI-BEAM PBB Power Block	210-250V ac					
MULTI-BEAM 3GB5-14 Edgeguide System						
MULTI-BEAM PBD Power Block	22-28V ac					
MULTI-BEAM PBD-2 Power Block	11-13V ac					
MAXI-BEAM RPBA Power Block	105-130V ac			11-130V ac		
MAXI-BEAM RPBB Power Block	210-250V ac			11-250V ac		
MAXI-AMP CD, CL, CM, CR models with solid-state output option	105-130V ac or 210-250V ac (depending on model)	SPST	Isolated SCR	11-250V ac	3/4 amp 10 amp inrush	

3-wire Sensors

Three-wire ac sensors are powered directly from the ac line (Figure C.23), and do not depend on leakage current through the load for operation. The off-state leakage current of S18 Series ac sensors is only 50 *microamps* (.05 milliamps). Consequently, interfacing to any ac load or PLC input is always direct, and many 3-wire ac sensors may be connected in parallel to a single PLC input without problems.

However, as with 3-wire dc sensors, it is not practical to connect 3-wire ac sensors together in a series configuration. Whenever a series hookup of ac sensors is required, 4-wire sensors should be considered.

4-wire Sensors

OMNI-BEAM, MULTI-BEAM and MAXI-BEAM sensors offer ac power blocks for 3 or 4-wire hookup. When the sensor and the load share a common voltage source, the power block can be jumpered for 3-wire connection (Figure C.24). The output of 4-wire power blocks is isolated from the sensor's power supply circuitry. This allows the load to be powered from a different voltage, as long as both ac circuits share a common neutral (Fig. C.25).

Connection of 4-wire power blocks together in series is straightforward, with less than 3 volts of voltage drop per sensor (Figure C.26). Off-state leakage current is very low (less than 0.1 mA), allowing many 4-wire sensor connections in parallel to a single load or PLC input. Also, 4-wire sensors can be powered continuously, and there are no complications associated with load response when they are connected in series or in parallel with "hard" contacts.

D. Interfacing AC Sensors to DC Loads (Table C-5)

MULTI-BEAM sensors offer 4-wire power blocks that allow the sensor to be powered by ac line voltage, and have its output interface to a dc load. Power block models PBAT and PBBT use a transistor and bridge rectifier combination to switch dc loads. Actually, the output switch has the ability to switch either a dc *or* an ac load (Figure C.27). The output switch has a current handling capacity of 100 mA, and no ability to handle inrush current. For this reason, PBAT and PBBT powerblocks are recommended for interfacing to logic circuitry only. However, *small* inductive dc loads, such as small electromechanical relays, can be switched reliably.

Power block models PBO and PBOB have an optically-isolated transistor switch. This switch is recommended for dc logic interfaces only. These power blocks allow the MULTI-BEAM to be powered by ac line voltage and to input to Banner logic modules, like CL Series MAXI-AMP modules or LIM-2 or LSR-64 Plug Logic modules (Figure C.28).

Model PBAM is a special-purpose power block designed to drive dc annunciators, like low-voltage Sonalerts (Figure C.29, page C-14). MULTI-BEAMs using the PBAM power block are most often used in doorway sensing applications.

MAXI-AMP modules with the solid-state output option provide a way to power the sensing system with ac line voltage, and to switch a dc load with their isolated NPN output (see Figure C.16). This

Figure C.23. 3-wire ac sensor hookup.

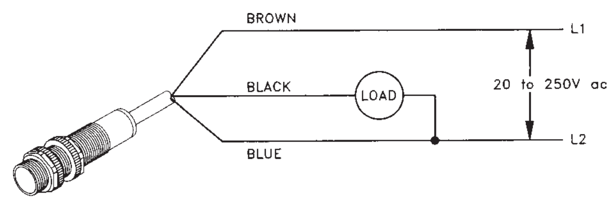
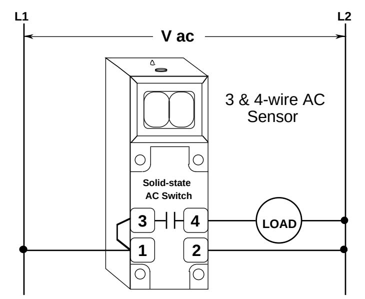
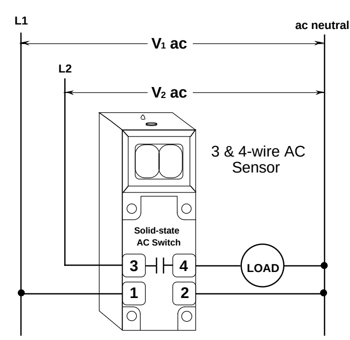


Figure C.24. 4-wire ac sensors: 3-wire hookup.



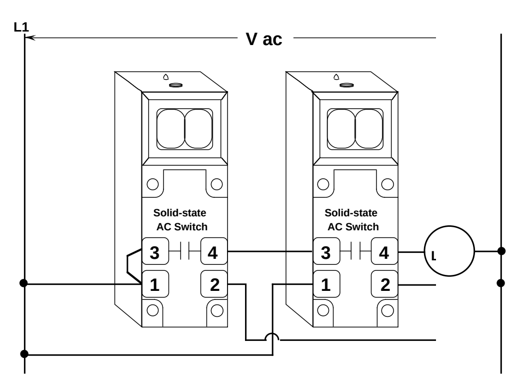
3-wire hookup: sensor and load share a common power

Figure C.25. 4-wire ac sensors: 4-wire hookup.



4-wire hookup: sensor and load are powered by different

Figure C.26. Connection of multiple 4-wire sensors in series.



Series connection of multiple 4-wire sensors is straight

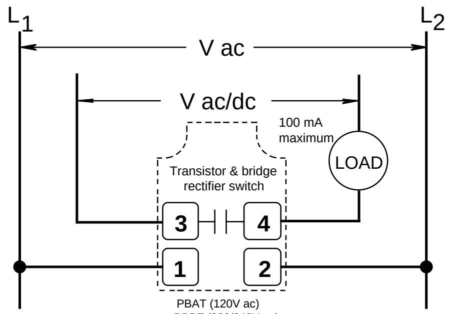
Table C-5.
Sensors Powered by AC Voltage with Solid-state Output Switches for DC Loads

AC Sensor Model	Sensor Operating Voltage	Output Switch Configuration	Output Switch Type	Output Switch Capacity	
				Load Voltage Range	Maximum Load Current
MULTI-BEAM PBAT Power Block	105-130V ac	SPST	One transistor plus bridge rectifier[1]	10-200V dc, 10-140V ac	100mA[2]
MULTI-BEAM PBBT Power Block	210-250V ac			10-350V dc, 10-250V ac	
MULTI-BEAM PBO Power Block	105-130V ac	SPST	One optically-isolated transistor	1-30V dc	50mA
MULTI-BEAM PBOB Power Block	210-250V ac				
MULTI-BEAM PBAM Power Block	105-130V ac	SPST	One transistor[3]	8V dc (approx.)	8mA
MAXI-AMP CD, CL, CM, CR models with solid-state output option	105-130V ac or 210-250V ac (depending on model)	SPST	One isolated NPN transistor (sinking or sourcing)[4]	1-30V dc	50mA

NOTE 1: Approximately 2 volts on-state voltage drop. Do not use to interface low voltage logic circuits like TTL (use PBO or PBOB).
NOTE 2: No tolerance for inrush current: do not use for ac inductive loads.
NOTE 3: Designed to interface with Sonalert type annunciators.
NOTE 4: Models without timing logic have an additional transistor output for logic-level interfaces (10mA maximum).

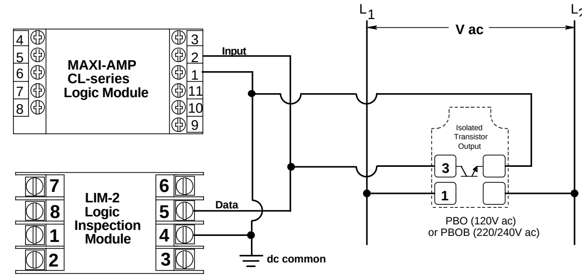
solid-state relay can switch loads of up to 50 mA at up to 30V dc. It is no coincidence that the MAXI-AMP has been mentioned so often in this section on interfacing. The MAXI-AMP allows the sensing system to be powered by either ac or dc and also has an output for either ac or dc . From the standpoint of interfacing, the MAXI-AMP is the most versatile sensing system product ever developed.

Figure C.27. MULTI-BEAM power block models PBAT and PBBT: ac input, ac or dc output.



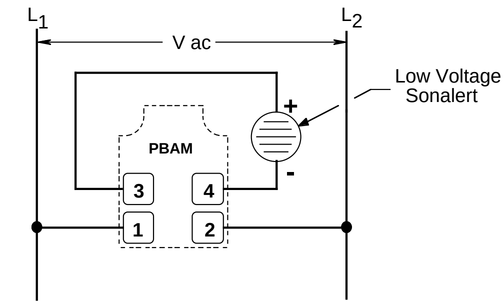
MULTI-BEAM power block models PBAT and PBBT operate the sensor with AC line voltage and switch either AC or DC loads.

Figure C.28. MULTI-BEAM power block models PBO and PBOB: ac input, low voltage dc output.



MULTI-BEAM power block models PBO and PBOB operate the sensor with AC line votage and interface to low-voltage DC logic inputs.

Figure C.29.
MULTI-BEAM power block model PBAM: ac input, output drives dc sonalert.



MULTI-BEAM power block model PBAM operates the sensor with AC line voltage and switches low-voltage DC annunciators.

ANALOG OUTPUTS

Sensors with *analog* outputs are useful in many process control applications where it is necessary to monitor an object's position or size or translucency and to provide a control signal for another analog device such as a motor speed control. Standard analog interfaces involve either a variable source of dc voltage from the analog sensor or control by the analog sensor of the current flow from an external voltage source. Sensors with analog outputs are offered in three product families:

1) Photoelectric: OMNI-BEAM analog sensors
2) Ultrasonic: ULTRA-BEAM 923 Series sensors
3) Ultrasonic: Sonic OMNI-BEAM sensor with analog output

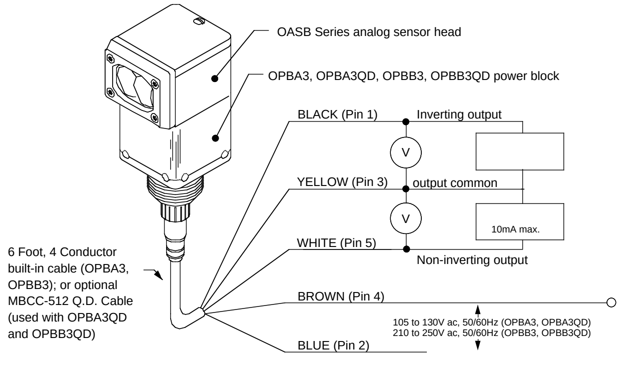
OMNI-BEAM with Analog Output

OMNI-BEAM analog sensors provide a 0 to +10 volt or a +10 to 0 volt dc analog output, either directly or inversely related to the strength of the received light signal. When properly adjusted, these two outputs are mirror images of each other, with their output voltage plots intersecting at 5 volts. Each sensor has multi-turn NULL and SPAN controls to set the minumum and maximum limits of the sensor's voltage sourcing outputs. A convenient 10-element moving-dot LED array gives a visual indication of relative light signal change and power block voltage output to within the nearest volt.

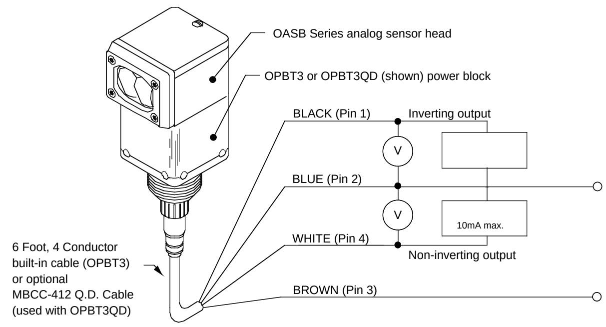
Analog OMNI-BEAM sensors are ordered by specifying an OASB Series sensor head (diffuse, convergent, or plastic or glass fiber optic) and an OPBA3, OPBB3, or OPBT3 power block (choice of ac or dc operation).

Figure C.30. Interfacing for OMNI-BEAM analog photoelectric sensors.

Hookup Information: OPBA3, OPBA3QD, OPBB3, OPBB3QD AC Input Analog Output Power Blocks



Hookup Information: OPBT3 and OPBT3QD DC Input Analog Output Power Blocks



NOTE: If both outputs are used simultaneously, the maximum total load may not exceed 10 mA.

ULTRA-BEAM Ultrasonic Sensor with Analog Output

(Sensing range: 20 inches to 20 feet)

See page C-39 for hookup information on switched output models.

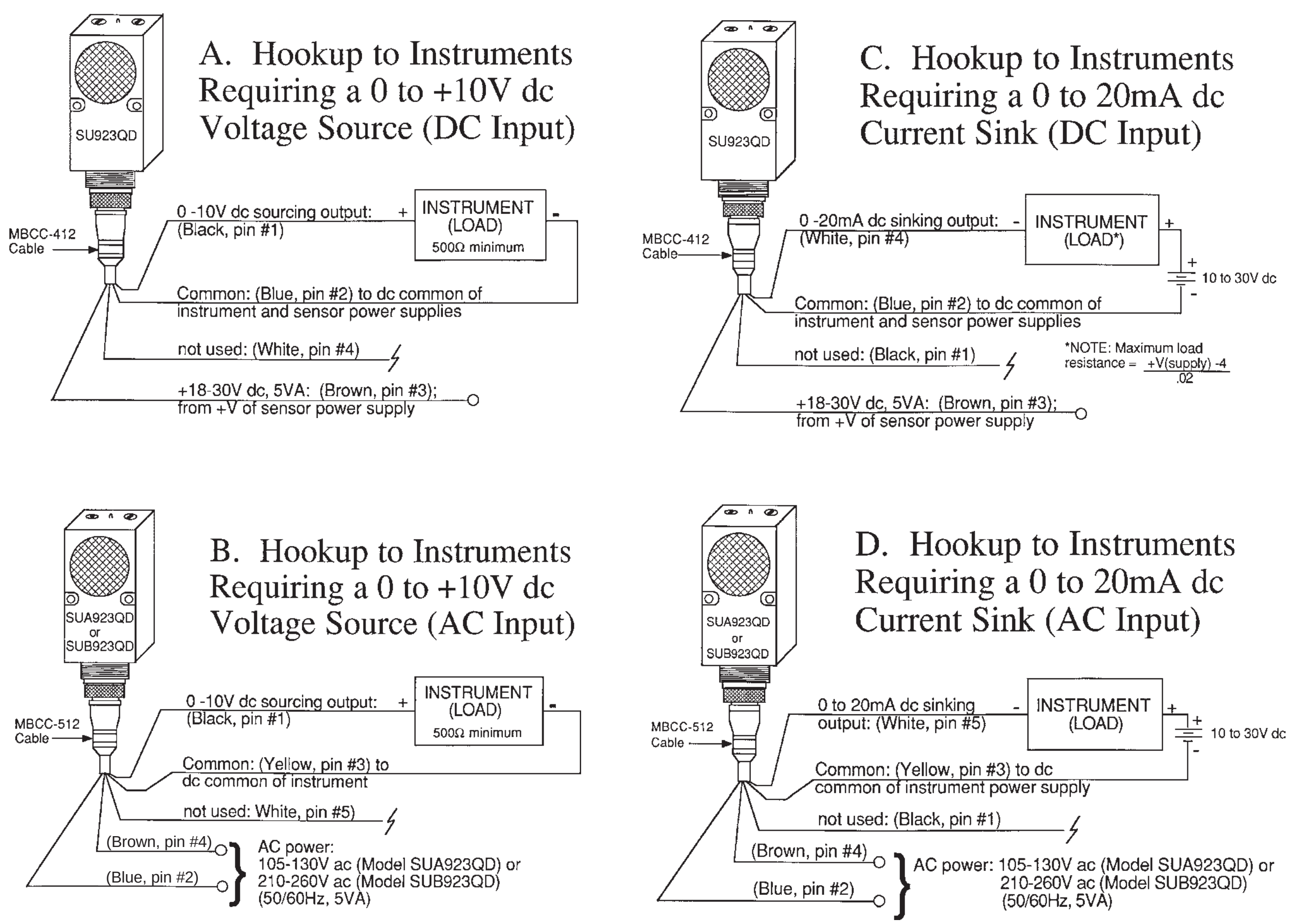
The ULTRA-BEAM 923 Series is the analog version of the long-range ULTRA-BEAM ultrasonic proximity sensor family. Three models offer the choice of 120V ac, 220/240V ac, or 18 to 30V dc for sensor supply voltage. Each model has dual outputs for *either* 0 to 10V dc sourcing *or* 0 to 20 mA sinking interfaces. The analog output of the ULTRA-BEAM is highly linear with changes in distance from the sensor to the object, and can be programmed for *either* increase or decrease of the output level with increasing distance to the target. NULL and SPAN adjustments permit a sensing "window" to be established anywhere within the sensor's 20 foot range. The following diagrams give interfacing information for the four sensor/load combinations (Figure C.31).

ULTRA-BEAM 923 Series Analog Ultrasonic Sensor Models

Model*	Output(s)	Required supply voltage
SU923QD	analog solid-state 0 to +10V voltage sourcing or 0 to 20 mA dc sinking	18 to 30V dc, 5VA
SUA923QD	analog solid-state 0 to +10V voltage sourcing or 0 to 20 mA dc sinking	105 to 130V ac (50/60 Hz), 5VA
SUB923QD	analog solid-state 0 to +10V voltage sourcing or 0 to 20 mA dc sinking	210 to 260V ac (50/60 Hz), 5VA

*All models are equipped with QD (Quick Disconnect) fitting.

Figure C.31. Interfacing for ULTRA-BEAM 923 Series Sensors



See page C-39 for hookup information on switched output models.

Sonic OMNI-BEAM with Analog Output (Sensing range: 4 to 26 inches)

Sonic OMNI-BEAM sensors with analog output use the model OSBUSR sensor head along with one of the following power blocks: model OPBT3 (for +10 to 30V dc supply), OPBA3 (for 105 to 130V ac supply), or OPBB3 (for 210 to 250V ac supply).

All three power blocks provide two analog *sourcing* solid-state outputs: 0 to +10V dc and +10 to 0V dc, with a maximum load of 10mA for each output. This choice of outputs means that the sensor can be connected so that its output will *either* increase *or* decrease with increasing distance to the target object. Both voltage sourcing outputs are highly linear, and are proportional to the distance from the sensor to the object being detected. NEAR and FAR adjustments allow a sensing "window" to be established anywhere within the sensor's 4- to 26-inch range (see Figure B.19).

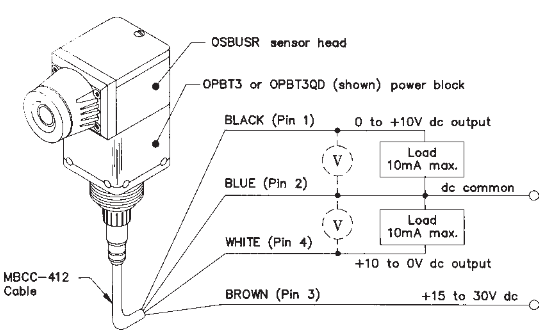
Figure C.32 gives interfacing information for sonic OMNI-BEAM sensors with analog output. Note that the two ac power block models have been combined into a single hookup drawing. Available power blocks are listed below.

Sonic OMNI-BEAM Power Block Models

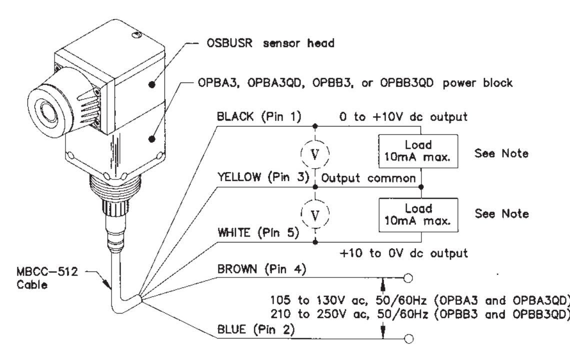
Model	Output(s)	Required supply voltage	Cable Type
OPBA3	analog solid-state voltage sourcing (2)	105 to 130V ac (50/60 Hz)	6-ft. 5-conductor PVC-covered cable
OPBA3QD	analog solid-state voltage sourcing (2)	105 to 130V ac (50/60 Hz)	MBCC-512 cable required (see below)
OPBB3	analog solid-state voltage sourcing (2)	210 to 250V ac (50/60 Hz)	6-ft. 5-conductor PVC-covered cable
OPBB3QD	analog solid-state voltage sourcing (2)	210 to 250V ac (50/60 Hz)	MBCC-512 cable required (see below)
OPBT3	analog solid-state voltage sourcing (2)	+15 to 30V dc, 100mA max.	6-ft. 4-conductor PVC-covered cable
OPBT3QD	analog solid-state voltage sourcing (2)	+15 to 30V dc, 100mA max.	MBCC-412 cable required (see below)

Figure C.32. Interfacing for sonic OMNI-BEAM sensors with analog output.

Hookup Information: OPBT3 and OPBT3QD Analog Output Power Blocks



Hookup Information: OPBA3, OPBA3QD, OPBB3, OPBB3QD Analog Output Power Blocks



NOTE: If both outputs are used simultaneously, the maximum load per output may not exceed 10 mA.

Sensor Hookup Diagrams

Pages C-18 through C-41 contain generalized hookup diagrams for common applications of Banner sensors. If you have any questions about sensor hookup within your particular application, contact your Banner sales engineer or the applications department at the factory (612/544-3164) during normal working hours. Hookup information is organized as follows:

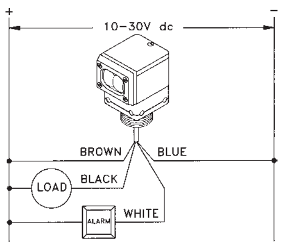
OMNI-BEAM DC Power Blocks

NOTE: output capacity is 100mA maximum, each output.

See page C-14 for analog models and page C-39 for E Series models.

Hookup to a Simple Load
Sinking Outputs

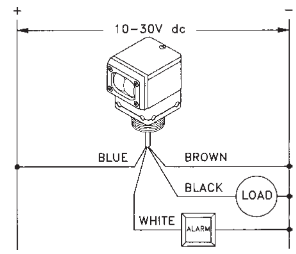
The **Bi-Moda**l output of OMNI-BEAM dc power blocks is configured for current sinking (NPN) by connecting the BROWN supply wire to +V dc, and the BLUE wire to dc common.
Outputs sink 100mA maximum.



Hookup to a Simple Load
Sourcing Outputs

The **Bi-Modal** output of OMNI-BEAM dc power blocks is configured for current sourcing (PNP) by connecting the BLUE supply wire to +V dc, and the BROWN wire to dc common.

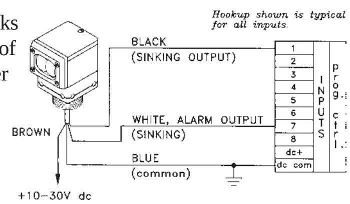
Each output sources up to 100mA.



Hookup to a PLC requiring current sink

OMNI-BEAM dc power blocks interface directly to any type of programmable logic controller or computer dc input.

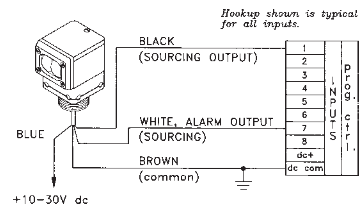
The current sinking configuration (NPN) is shown here.



Hookup to a PLC requiring current source

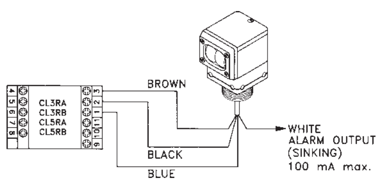
OMNI-BEAM dc power blocks interface directly to any type of programmable logic controller or computer dc input.

The current sourcing configuration (PNP) is shown here.



Hookup to MAXI-AMP Logic

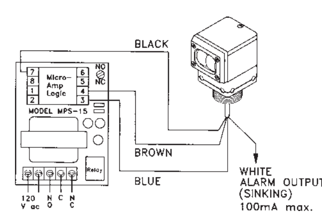
With its power supply wires connected for NPN operation, the **Bi-Modal** output of an OMNI-BEAM connects directly to the input of Banner MAXI-AMP CL Series logic modules. The MAXI-AMP, powered by an ac voltage, offers a dc supply with enough capacity to power an OMNI-BEAM sensor. The OMNI-BEAM may also be connected to the auxiliary input of a CL5 module.



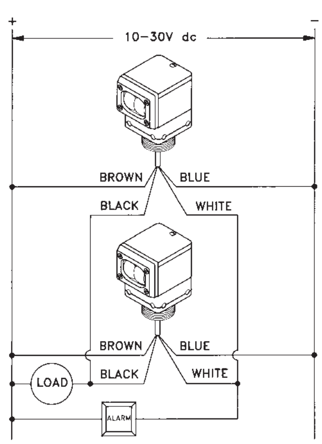
Hookup to MICRO-AMP Logic

With its power supply wires connected for NPN operation, the Bi-Modal output of an OMNI-BEAM connects directly to the input of Banner MICRO-AMP logic-only modules. The following modules may be used:

MA4-2	One-shot
MA5	Delay
MA4G	4-input "AND"
MA4L	Latch



Hookup in Parallel to a Common Load



Any number of OMNI-BEAM DC sensors may be wired in parallel to a common load to create "LIGHT-OR" or "DARK-OR" logic.

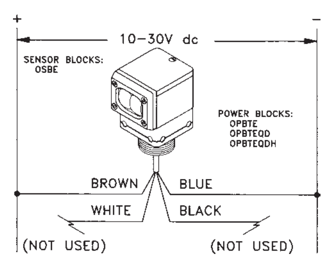
Either the sinking (NPN) or the sourcing (PNP) **Bi-Modal** power supply hookup may be used (sinking hookup is shown).

Series connection of dc OMNI-BEAM outputs is not possible.

Hookup of an Emitter

OMNI-BEAM emitter sensor blocks (models OSBE and OSBEF) simply require supply voltage to operate.

Power blocks *without* output circuitry are available for powering emitters. However, power blocks *with* output circuitry may also be used to power emitters (the power block's output circuitry goes unused).



OMNI-BEAM AC Power Blocks

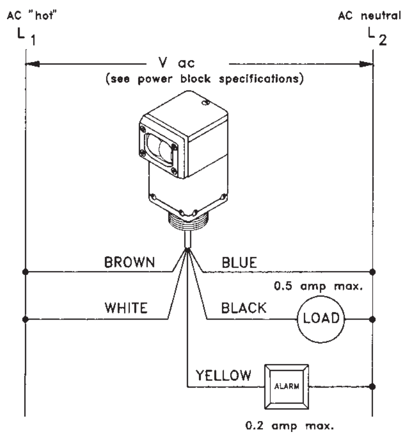
NOTE: output switching capacity is 1/2 amp maximum.

See page C-14 for analog models and page C-39 for E Series models.

Hookup to a Simple Load

OMNI-BEAM ac power blocks have two outputs. The LOAD output is isolated and can switch up to 0.5 amps. The ALARM output is tied internally to ac "hot" and can switch up to 0.2 amps.

The ALARM output may either connect to the system logic controller, or directly switch an alarm.

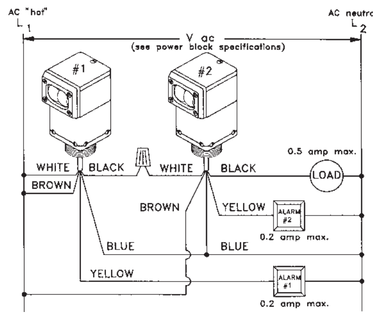


AC Sensors in Series

OMNI-BEAM ac power blocks may be wired together in series with each other for "AND" logic.

The total voltage drop across the series will be the sum of the individual voltage drops across each power block (approximately 3 volts per block).

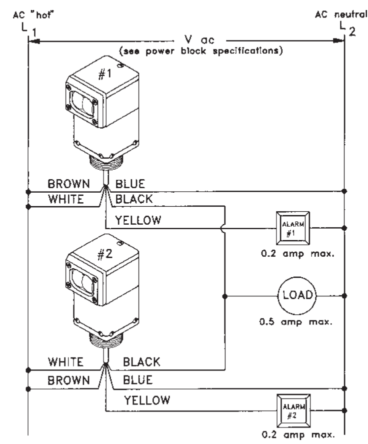
With most loads, 10 or more power blocks may be wired in series.



AC Sensors in Parallel

OMNI-BEAM ac power blocks may be wired together in parallel with each other. This is most often done to obtain "OR" logic (i.e. if an event occurs at either sensor, the load is energized).

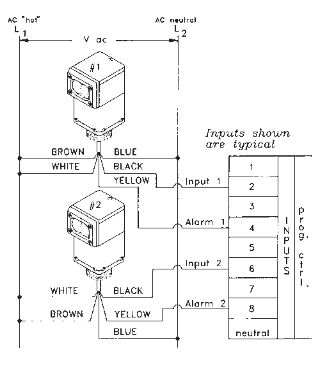
The total off-state leakage current through the load is the sum of the leakage current of the individual power blocks. The maximum leakage current of OMNI-BEAM power blocks is only 100 microamps. As a result, installation of an artificial load resistor in parallel with the load is necessary only for large numbers of sensors wired in parallel to a light load.



Hookup to a Programmable Logic Controller (PLC)

OMNI-BEAM ac power blocks are designed to directly interface to ac inputs of programmable logic controllers.

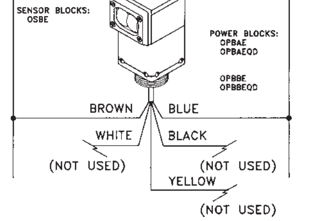
If the ALARM outputs of multiple OMNI-BEAMs are paralleled to a single input, then sensor block programming switch #2 must be in the "on" position (for normally open ALARM output).



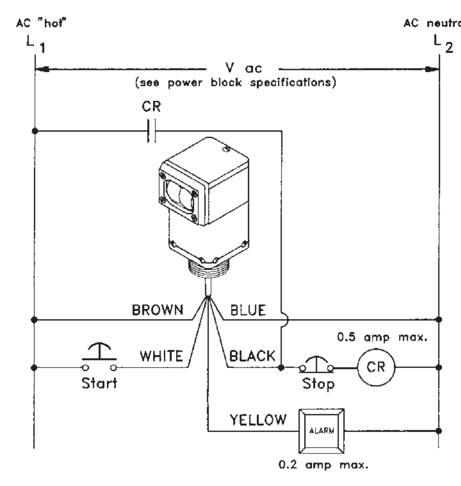
Hookup of Emitter

OMNI-BEAM emitter sensor blocks (model OSBE) simply require supply voltage to operate.

Power blocks *without* output circuitry are available for powering emitters. However, power blocks *with* output circuitry may also be used to power emitters (output circuitry will go unused).



AC Sensor in Series and Parallel with Contacts and Switches



Any number of "hard" contacts may be wired in series or parallel with one or more OMNI-BEAM ac sensors. All models have less than 100 microamps (0.1 milliamp) of off-state leakage current.

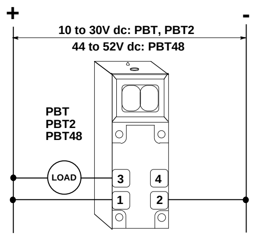
The load (in this case, normally open relay "CR") is energized whenever the "Start" button is closed while the OMNI-BEAM's output is energized. "CR" remains energized until the "Stop" button is pressed (opened).

MULTI-BEAM 3-wire DC Power Blocks

Output capacity: 250mA maximum, each output.

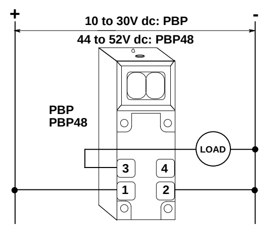
Hookup to a dc Relay or Solenoid (using sinking output)

When using power blocks with current sinking (NPN) outputs, simple loads connect between the power block output (terminal #3) and the positive supply (terminal #1).



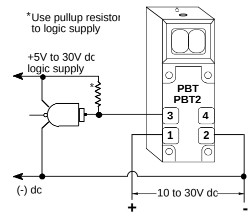
Hookup to a dc Relay or Solenoid (using sourcing output)

When using power blocks with current sourcing (PNP) outputs, simple loads connect between the power block output (terminal #3) and DC common (terminal #2).



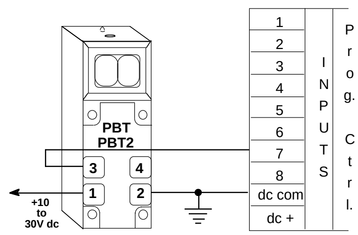
Hookup to a Logic Gate

A logic zero (0 volts DC) is applied to the gate input when the MULTI-BEAM output is energized. When de-energized, a logic one is applied. The logic supply must be common to the MULTI-BEAM supply negative.



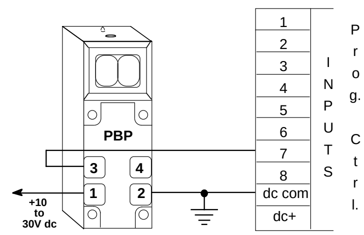
Hookup to a Programmable Logic Controller (PLC) requiring a current sink

Use power blocks with NPN outputs to interface to PLCs and other logic devices requiring a current sink at the inputs. Connect the output of the power block (terminal #3) to any input of the PLC. Also connect the negative of the MULTI-BEAM power supply (terminal #2) to the negative of the PLC power supply.



Hookup to a Programmable Logic Controller (PLC) requiring a current source

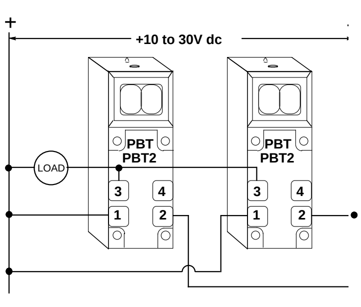
Use power blocks with PNP outputs to interface to PLCs and other logic devices requiring a current source at the inputs. Connect the output of the power block (terminal #3) to any input of the PLC. Also connect the negative of the MULTI-BEAM power supply (terminal #2) to the negative of the PLC power supply.



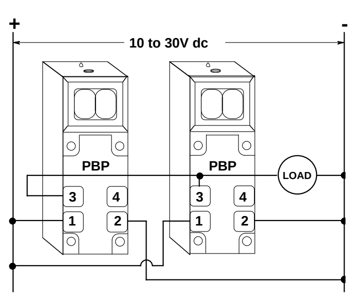
Parallel Hookup to a Common Load

Any number of MULTI-BEAMs may be connected in parallel to one load to create "LIGHT-OR" (light operate mode) or "DARK-OR" (dark operate mode) multiple sensor logic. In most situations, MULTI-BEAM DC power blocks cannot wire in series. However, addition of an interposing relay with a normally closed contact or a Banner logic module will permit "AND" logic with a parallel sensor array (see "SENSOR LOGIC", section D).

To load requiring current sink:



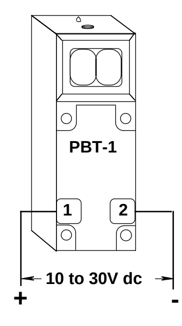
To load requiring current source:



Hookup of a dc Emitter

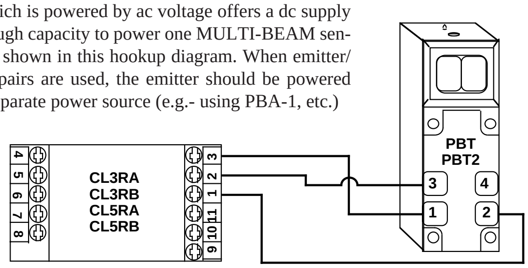
MULTI-BEAM emitter-only scanner blocks use DC power block models PBT-1 or PBT48-1. These power blocks connect directly across the DC supply, as shown.

Emitter models:
SBE
SBED
SBEX
SBEV
SBEXD
SBEF
SBEXF



Hookup to a MAXI-AMP Logic Module

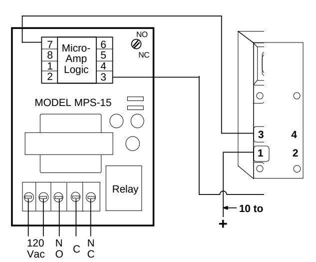
The current sinking output(s) of MAXI-BEAM power block models PBT and PBT2 may be connected directly to the input of CL Series MAXI-AMP modules. A MAXI-AMP which is powered by ac voltage offers a dc supply with enough capacity to power one MULTI-BEAM sensor, as is shown in this hookup diagram. When emitter/receiver pairs are used, the emitter should be powered from a separate power source (e.g.- using PBA-1, etc.)



Hookup to MICRO-AMP Logic (MPS-15 Chassis)

The current sinking output(s) of MULTI-BEAM power block models PBT and PBT2 may be connected directly to the primary input (terminal #7) or the other inputs of MICRO-AMP logic modules. The following logic modules may be used:

MA4-2 One shot
MA5 On/off delay
MA4G 4-input "AND"
MA4L Latch



NOTE: MULTI-BEAM dc power blocks cannot wire in series.

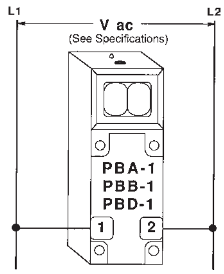
MULTI-BEAM 4-wire AC Power Blocks

NOTE: output switching capacity is 3/4 amp maximum.

Hookup of an ac Emitter

MULTI-BEAM emitter-only ac power blocks connect directly across the ac line, as shown.

Emitter models:
SBE, SBED,
SBEX, SBEV,
SBEXD, SBEF,
& SBEXF.

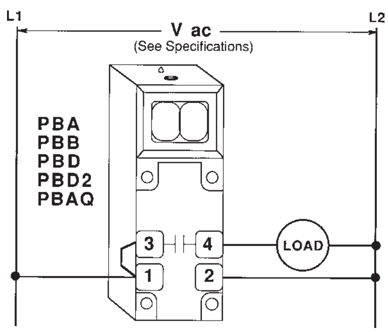


Hookup to a Simple ac Load

AC voltage is connected to terminals #1 and #2 to provide power to the MULTI-BEAM. The solid-state output switch behaves as if there were a contact between terminals #3 and #4. L1 is most conveniently applied to terminal #3 by jumpering terminals #1 and #3 inside the MULTI-BEAM.

The outputs of all five power block models are rated for 250V ac maximum, and can switch an AC voltage which is different from the supply *as long as both AC circuits share a common neutral.* Observe local wiring codes when mixing AC voltages in a common wiring chamber.

Since the output switch is a solid-state device, contact continuity cannot be checked by means of an ohmeter, continuity tester, etc. To check the functioning of the output switch, a load must be installed and tested along with the MULTI-BEAM.

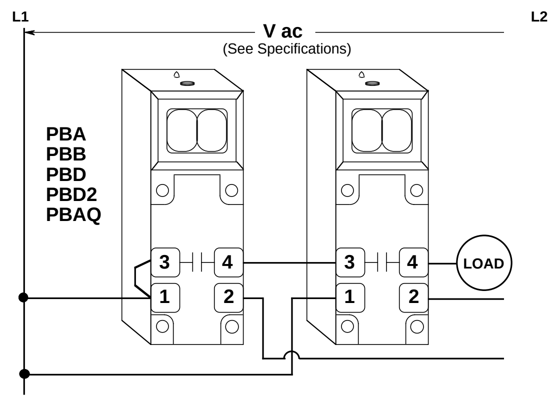


CAUTION: the output switch could be destroyed if the load becomes a short circuit (i.e., if L1 and L2 are connected directly across terminals #3 and #4).

NOTE: this hookup depicts the output switch as a normally open contact. *Model **PBAQ** has a **normally closed** output switch.*

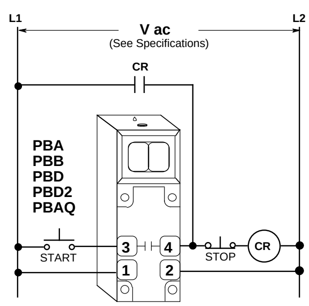
Hookup in Series with other MULTI-BEAMs

MULTI-BEAM 3- & 4-wire ac power blocks may be wired in series with each other for the "AND" logic function. The total voltage drop across the series will be the sum of the individual voltage drops across each power block (approximately 3 volts per block). With most loads, 10 or more power blocks may be wired in series.



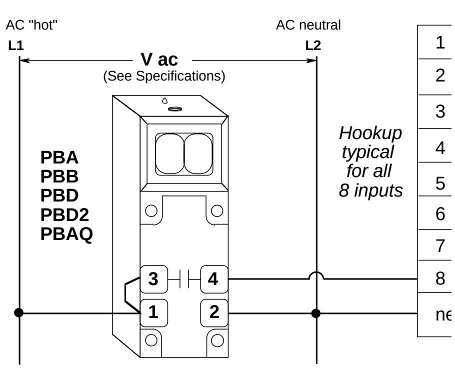
Hookup in Parallel or Series with Contacts or Switches

Any number of "hard" contacts may be wired in parallel or series with one or more MULTI-BEAM 3- & 4-wire power blocks. All models have less than 100 microamps (0.1 milliamp) of off-state leakage current. The load operates when either the contacts close or the MULTI-BEAM output is energized.



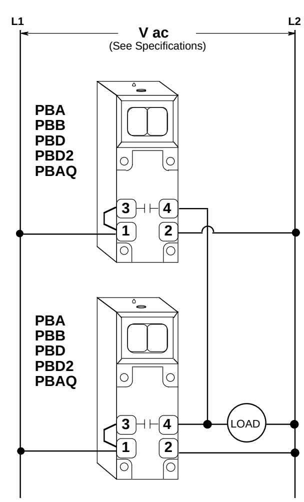
Hookup to a Programmable Logic Controller (PLC)

Interfacing to a PLC I/O is direct with MULTI-BEAM 3- & 4-wire AC power blocks. All models have less than 100 microamps (0.1 milliamp) of off-state leakage current. If you have a question on hookup to a particular brand of PLC, contact the Banner Applications Department during normal business hours.



Hookup in Parallel with other MULTI-BEAMs

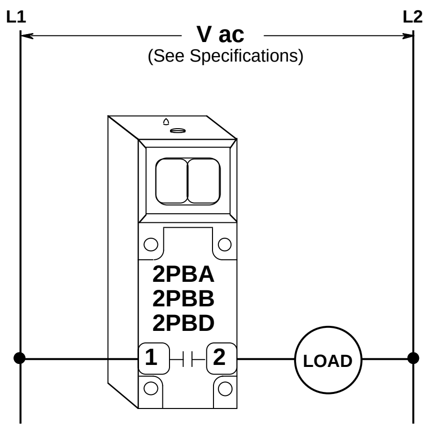
Any number of 3- & 4-wire MULTI-BEAM power block outputs may be connected in parallel to a load. Parallel sensor connection is usually used to yield "OR" logic (i.e., if an event occurs at any sensor, the load is energized). The total off-state leakage current through the load is the sum of the leakage current of the individual power blocks. However, the maximum leakage current of MULTI-BEAM 3- & 4-wire ac power blocks is only 100 microamps. As a result, installation of an artificial load resistor in parallel with the load is necessary only for large numbers of sensors wired in parallel to a light load.



MULTI-BEAM 2-wire AC Power Blocks

NOTE: output has maximum load capacity of 3/4 amp; maximum resistive load 15K ohms, minimum inductive load 1.2 watts (10mA)

Basic Hookup of a 2-wire MULTI-BEAM



MULTI-BEAM 2-wire sensors wire in series with an appropriate load. This combination, in turn, wires directly across the AC line. A 2-wire sensor may be connected exactly like a mechanical limit switch.

The MULTI-BEAM remains powered when the load is "off" by a residual current which flows through the load. This off-state leakage current is always less than 1 milliamp. The effect of this leakage current depends upon the characteristics of the load. The voltage which appears across the load in the off-state is equal to the leakage current of the sensor multiplied by the resistance of the load:

V (off)= 1mA x R(load)

If this resultant off-state voltage is less than the guaranteed turn-off voltage of the load, the interface is direct. If the off-state voltage causes the load to stay "on", an artificial load resistor must be connected in parallel with the load to lower its effective resistance. Most loads, including most programmable logic controller (PLC) inputs, will interface to 2-wire sensors with 1mA leakage current without the need for an artificial load resistor. There is no polarity requirement. Either wire may connect to terminal #1, and the other to terminal #2.

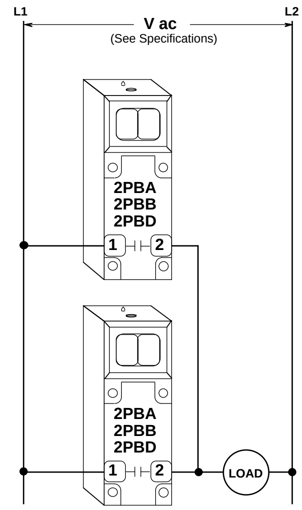
NOTE: all three components of a MULTI-BEAM 2-wire sensor will be destroyed if the load becomes a short circuit!!

2-wire MULTI-BEAMs in Parallel

Multiple 2-wire MULTI-BEAMs may be wired together in parallel to a load for "OR" or "NAND" logic functions. When sensors are wired in parallel, the off-state leakage current through the load is equal to the sum of the leakage currents of the individual sensors. Consequently, loads with high resistance like small relays and electronic circuits may require artificial load resistors.

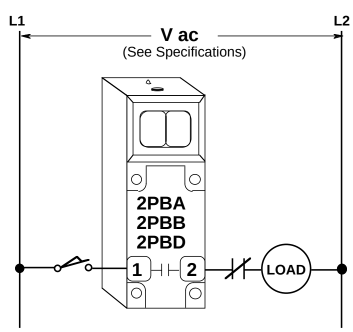
2-wire MULTI-BEAM sensors have a 100 millisecond power-up delay for protection against false outputs. When 2-wire MULTI-BEAMs are wired together in parallel, any power block which has an energized output will rob all of the other power blocks of the current they need to operate. When the energized output drops, there will be a 0.1 second delay before any other MULTI-BEAM can energize. As a result, the load may momentarily drop out.

2-wire MULTI-BEAM sensors cannot wire in series with other 2-wire sensors unless power block model 2PBR is used. If series connection of 2-wire AC sensors is required, consider models within the VALU-BEAM or MINI-BEAM families.



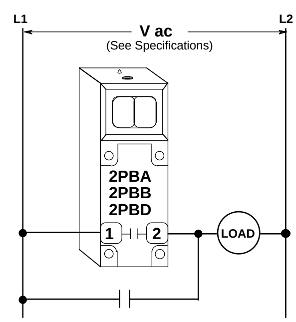
2-wire MULTI-BEAM in Series with Contacts

When 2-wire MULTI-BEAM sensors are connected in series with mechanical switch or relay contacts, the sensor will receive power to operate only when all of the contacts are closed. The false-pulse protection circuit of the MULTI-BEAM will cause a 0.1 second delay between the time that the last contact closes and the time that the load can energize.



2-wire MULTI-BEAM in Parallel with Contacts

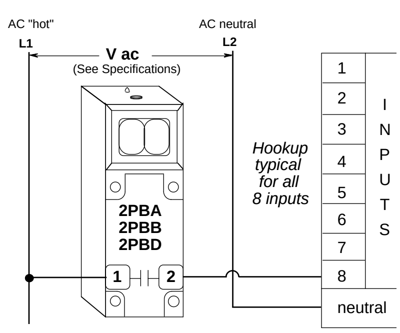
2-wire MULTI-BEAM sensors may be wired in parallel with mechanical switch or relay contacts. The load will energize when any of the contacts close or the sensor output is energized. When a contact is closed, it shunts the operating current away from the MULTI-BEAM. As a result, when all of the contacts are open, the MULTI-BEAM's 0.1 second power-up delay may cause a momentary drop-out of the load.



Hookup of a 2-wire MULTI-BEAM to a Programmable Logic Controller (PLC)

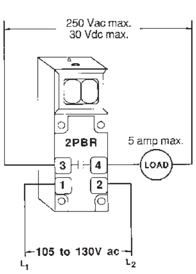
MULTI-BEAM 2-wire sensors operate with very low (1 milliamp) off-state leakage current. As a result, they will interface directly to most PLCs without the need for an artificial load resistor. If the off-state voltage (1mA x input resistance of the PLC) is higher than the PLC sensing threshold, install a 10KΩ to 15KΩ, 5-watt resistor for each 2-wire sensor. The resistor connects between the input terminal and AC neutral.

If you have a question on hookup to a specific brand of PLC, contact the Banner Applications Department during normal business hours.



Hookup of a 2PBR Power Block

Model 2PBR actually requires a 4-wire hookup, even though it only works with 2-wire scanner blocks and logic modules. It is powered by 120V ac across terminals #1 and 2, and offers a SPST "hard" relay contact between terminals #3 and 4. This configuration allows a MULTI-BEAM sensor to directly interface large loads which draw more than 3/4 amp like clutches, brakes, large contactors, and small motors. The 2PBR also eliminates the problem of voltage drop from series strings of sensors operating low voltage ac loads.

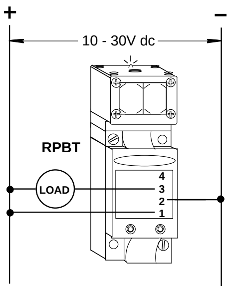


MAXI-BEAM DC Power Blocks

NOTE: Each output has a maximum load capacity of 250mA.

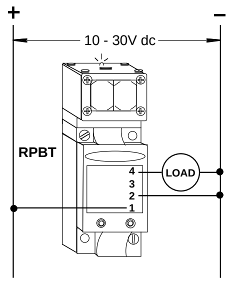
Hookup to a dc Relay or Solenoid (using sinking output)

When using the current sinking (NPN) output, simple loads connect between terminal #3 and the positive supply (terminal #1).



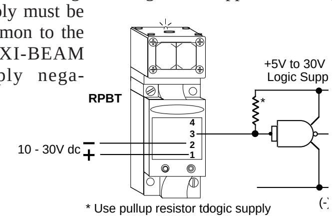
Hookup to a dc Relay or Solenoid (using sourcing output)

When using the current sourcing (PNP) output, simple loads connect between terminal #4 and the DC common (terminal #2).



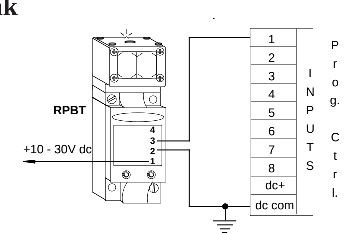
Hookup to a Logic Gate (using sinking output)

A logic zero (0 volts dc) is applied to the GATE input when the MAXI-BEAM sinking output is energized. When de-energized, a logic one is applied. The logic supply must be common to the MAXI-BEAM supply negative.



Hookup to a Programmable Logic Controller (PLC) requiring a current sink

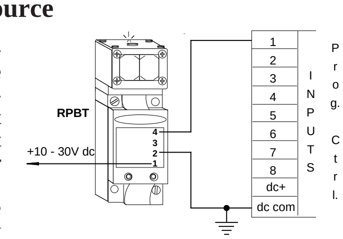
Use MAXI-BEAM NPN output (terminal #3) to interface to PLCs and other logic devices requiring a current sink at the inputs. Connect terminal #3 of the power block to any input of the PLC. Also connect the negative of the MAXI-BEAM power supply (terminal #2) to the negative of the PLC power supply.



The hookup shown is typical for all inputs.

Hookup to a Programmable Logic Controller (PLC) requiring a current source

Use MAXI-BEAM PNP output (terminal #4) to interface to PLCs and other logic devices requiring a current source at the inputs. Connect terminal #4 of the power block to any input of the PLC. Connect the negative of the MAXI-BEAM power supply (terminal #2) to the negative of the PLC power supply.

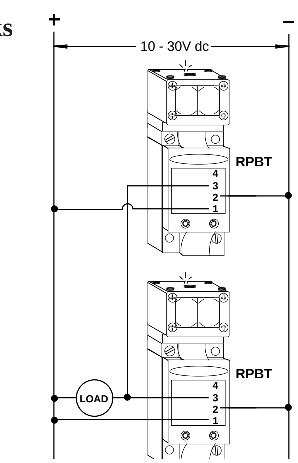


The hookup shown is typical for all inputs.

Parallel Hookup of RPBT Power Blocks to a Common Load

Any number of MAXI-BEAMs may be connected in parallel to a load to create "LIGHT-OR" (light operate mode) or "DARK-OR" (dark operate mode) multiple sensor logic. The diagram at the right shows the current sinking outputs of two MAXI-BEAMs connected in parallel to control a load which requires a current sink (power block terminal #3). For loads requiring a current source, connect the wires from the load instead between terminals #4 and #2 (common).

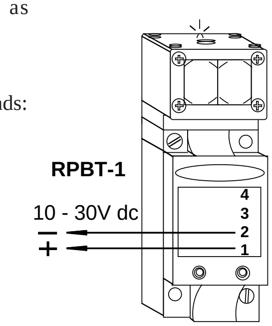
NOTE: series connection of DC MAXI-BEAM sensors may be accomplished using power block model RPBR (see page C-25, bottom right).



Hookup of RPBT-1 (with RSBE Sensor Head)

MAXI-BEAM emitter only sensor heads use dc power block model RPBT-1, which connects directly across the dc supply as shown.

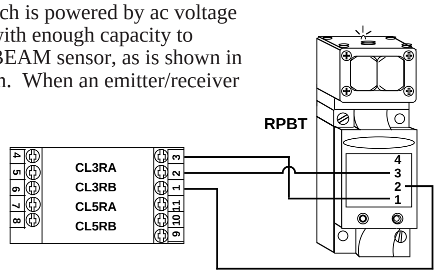
Emitter sensor heads:
RSBE
RSBESR
RSBEF



Hookup to a MAXI-AMP Logic Module

The current sinking output of MAXI-BEAM power block RPBT may be connected directly to the input of CL Series MAXI-AMP modules.

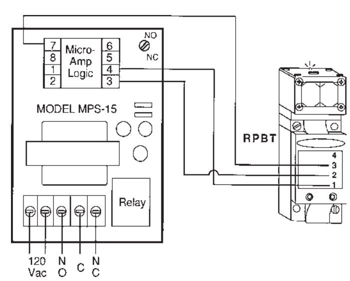
A MAXI-AMP which is powered by ac voltage offers a dc supply with enough capacity to power one MAXI-BEAM sensor, as is shown in this hookup diagram. When an emitter/receiver pair is used, the emitter should be powered from a separate power source (e.g. use power block RPBA-1, etc.).



Hookup to MICRO-AMP Logic (MPS-15 Chassis)

The current sinking output of an RPBT power block may be connected directly to the primary input (terminal #7) or the other inputs of MICRO-AMP logic modules. The following logic modules may be used:

MA4-2 One shot
MA5 On/off delay
MA4G 4-input "AND"
MA4L Latch

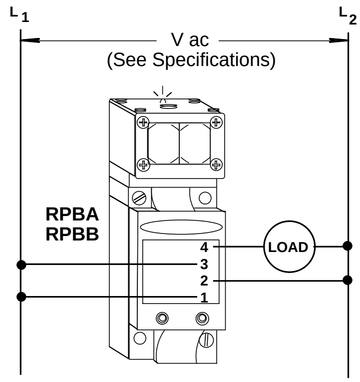


MAXI-BEAM 4-wire AC Power Blocks

NOTE: Output switching capacity is 3/4 amp., maximum.

Hookup to a Simple Load

AC voltage is connected to terminals #1 and #2 to provide power to the MAXI-BEAM. The solid-state output switch behaves as if there were a contact between terminals #3 and #4. L1 is most conveniently applied to terminal #3 by jumpering terminals #1 and #3 inside the wiring base.

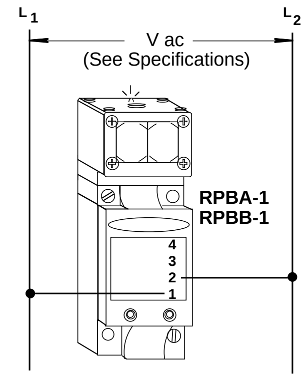


CAUTION: the output switch will be destroyed if the load is shorted.

Hookup of an ac Emitter

MAXI-BEAM emitter-only power blocks connect directly across the line, as shown.

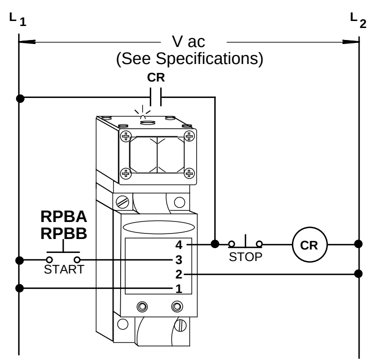
Emitter sensor heads:
RSBE
RSBESR
RSBEF



Hookup in Parallel or Series with Contacts or Switches

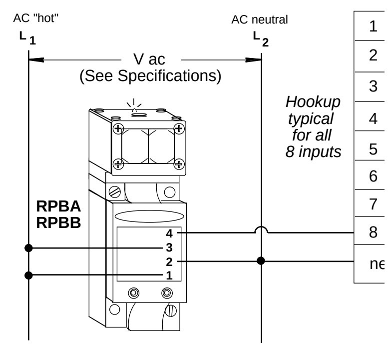
Any number of "hard" contacts may be wired in series or in parallel to MAXI-BEAMs which use power block model RPBA or RPBB.

This circuit illustrates a start-stop function in which CR can be energized only when the MAXI-BEAM output is energized. Once energized, CR is latched ON by its normally open contact. CR is reset by depressing the STOP switch



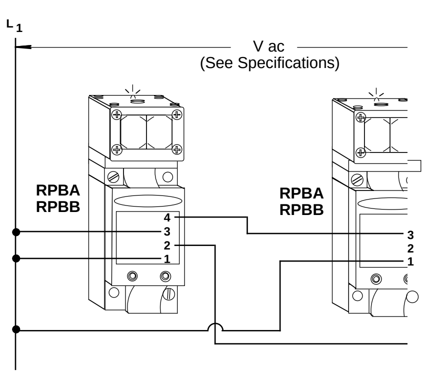
Hookup to a Programmable Logic Controller (PLC)

Interfacing to a PLC I/O is direct with MAXI-BEAMs which use RPBA or RPBB. The off-state leakage current is only 100 microamps (0.1 milliamp) maximum.



Hookup in Series with other MAXI-BEAMs

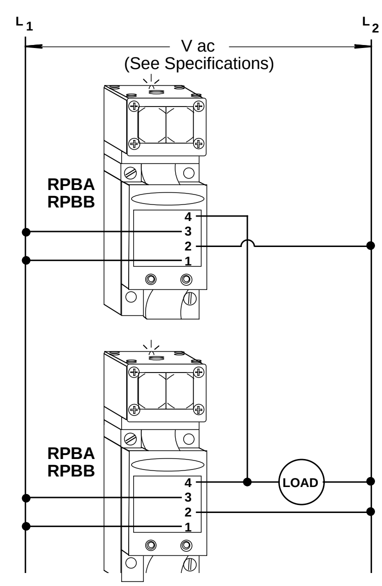
MAXI-BEAMs which use RPBA or RPBB power blocks may be wired in series for the "AND" logic function. The total voltage drop across the series will be the sum of the individual voltage drops across each power block (approximately 3 volts per block). With most loads, 10 or more sensors may be wired together in series.



Hookup in Parallel with other MAXI-BEAMs

Any number of MAXI-BEAMs using RPBA or RPBB power blocks may be wired together in parallel to a load. Parallel sensor connection is usually used to yield "OR" logic (i.e. if an event occurs at any sensor, the load is energized).

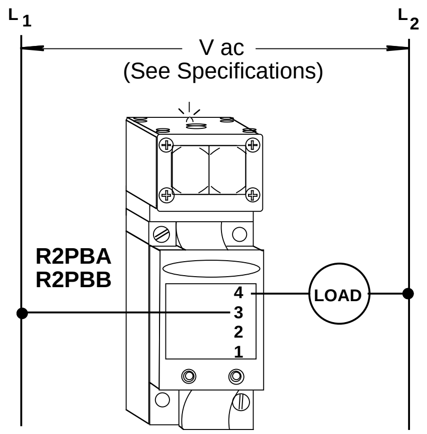
The total off-state leakage current through the load is the sum of the leakage currents of the individual power blocks. However, the maximum leakage current of MAXI-BEAM RPBA or RPBB power blocks is only 100 microamps. As a result, the installation of an artificial load resistor in parallel with the load is necessary only for very large numbers of sensors wired in parallel to a light (i.e. high impedance) load.



MAXI-BEAM 2-wire AC and RPBR Power Blocks

NOTE: Output switching capacity is 3/4 amp., max.

Basic 2-wire Hookup



MAXI-BEAM sensors using power block R2PBA or R2PBB wire in series with an appropriate load. This combination, in turn, wires directly across the ac line. A 2-wire sensor may be connected exactly like a mechanical limit switch.

The MAXI-BEAM remains powered when the load is OFF by a residual current which flows through the load. This off-state leakage current is always less than 1.7 milliamps. The effect of this leakage current depends upon the characteristics of the load. The voltage which appears across the load in the OFF state is equal to the leakage current of the sensor multiplied by the resistance of the load:

V (off) = 1.7mA x R(load).

If this resultant OFF state voltage is less than the guaranteed turn-off voltage of the load, then the interface is direct. If the OFF state voltage causes the load to stay ON, then an artificial load resistor must be connected in parallel with the load to lower its effective resistance. Most loads, including most programmable logic controller (PLC) inputs, will interface to 2-wire sensors with 1.7mA leakage current, without the need for an artificial load resistor.

There is no polarity requirement. either wire may be connected to terminal #3, and the other to terminal #4.

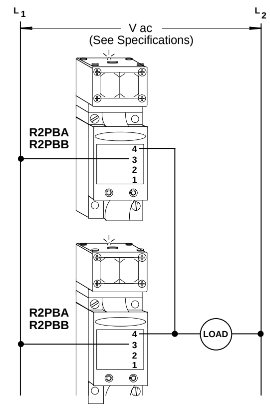
CAUTION: all components of a MAXI-BEAM 2-wire sensor assembly will be destroyed if the load becomes a short circuit.

2-wire MAXI-BEAMs in Parallel

Multiple 2-wire MAXI-BEAMs may be wired together in parallel to a load for "OR" or "NAND" logic functions. When sensors are wired in parallel, the off-state leakage current through the load is equal to the sum of the leakage currents of the individual sensors. Consequently, loads with high resistance like small relays and electronic circuits may require artificial load resistors.

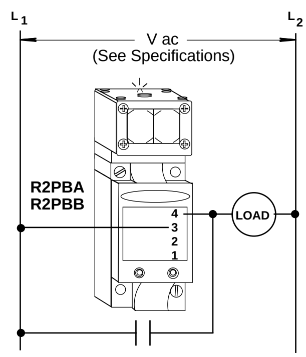
MAXI-BEAM sensors have a 100 millisecond power-up delay for protection against false outputs. When 2-wire MAXI-BEAMs are wired together in parallel, any power block which has an energized output will rob all other 2-wire power blocks of the voltage needed to operate the sensor. When the energized output drops, there will be a 0.1 second delay before any other MAXI-BEAM can energize. As a result, the load may momentarily drop out.

2-wire MAXI-BEAM sensors cannot wire in series with other 2-wire sensors. If series connection of 2-wire ac sensors is required, consider models within the VALU-BEAM or MINI-BEAM sensor families. 4-wire ac power blocks *can* wire in series (see RPBA, RPBB).



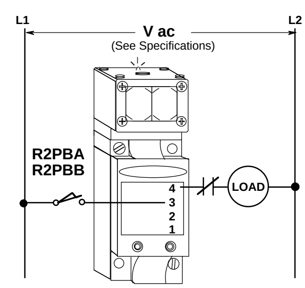
2-wire MAXI-BEAMs with Parallel Contacts

2-wire MAXI-BEAM sensors may be wired in parallel with mechanical switch or relay contacts. The load will energize when either a contact closes or the sensor output is energized. When a contact is closed, it shunts the operating current away from the MAXI-BEAM. As a result, when all of the contacts open, the MAXI-BEAMs 0.1 second power-up delay may cause a momentary drop-out of the load.



2-wire MAXI-BEAMs with Series Contacts

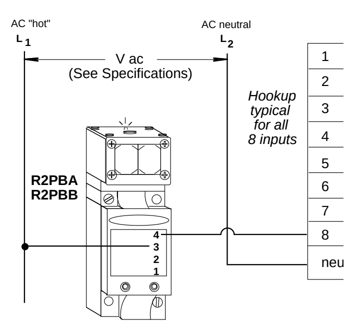
When 2-wire MAXI-BEAM sensors are connected in series with mechanical switch or relay contacts, the sensor will receive power to operate only when all of the contacts are closed. The false-pulse protection circuit of the MAXI-BEAM will cause a 0.1 second delay between the time that the last contact closes and the time that the load can energize.



Hookup of 2-wire MAXI-BEAMs to a Programmable Logic Controller (PLC)

MAXI-BEAM 2-wire sensors operate with low (1.7mA) off-state leakage current. As a result, they will interface directly to most PLCs without the need for an artificial load resistor. If the off-state voltage (1.7mA x input resistance of PLC) is higher than the PLC sensing threshold, install a 10KΩ to 15KΩ, 5 watt resistor for each 2-wire sensor. The resistor connects between the input terminal and ac neutral.

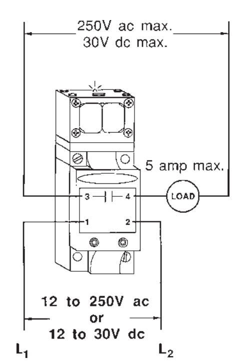
If you have a question on hookup to a specific brand of PLC, contact the Banner Applications Department during normal business hours.



RPBR Power Block Hookup

Model RPBR operates the MAXI-BEAM with either ac or dc supply voltage. It offers an SPST "hard" contact which allows the MAXI-BEAM to directly interface with large loads that draw more than 3/4 amp, like clutches, brakes, large contactors, and small motors. It also allows series connection ("AND") logic without the problem of voltage drop.

Contacts are not gold-flashed, so interfacing to low voltage circuitry is not recommended. A transient suppressor (MOV) should be installed across the contact if it switches an inductive load.



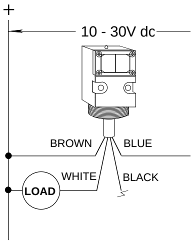
Relay specifications are:
CONTACT RATING: 250V ac max., 30V dc max., 5 amps max. (resistive load)
CLOSURE TIME: 20 milliseconds max.
RELEASE TIME: 20 milliseconds max.
MECHANICAL LIFE: 10,000,000 operations

DC VALU-BEAM SM912 Series Sensors

NOTE: each output has a maximum load capacity of 250mA.

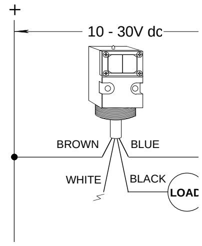
Hookup to a dc Relay or Solenoid (using sinking output)

The diagram below shows hookup of a dc VALU-BEAM to a dc load using the sensor's *sinking* output, which is rated at 250mA maximum. The BLACK wire is not used.



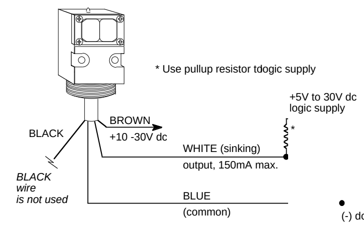
Hookup to a dc Relay or Solenoid (using sourcing output)

The diagram below shows hookup of a dc VALU-BEAM to a dc load using the sensor's *sourcing* output, which is rated at 250mA maximum. The WHITE wire is not used.



Hookup to a Logic Gate

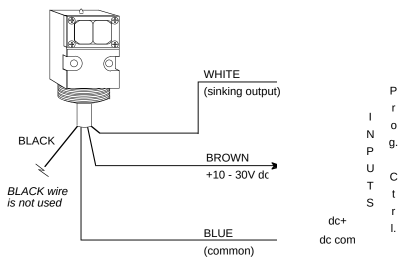
The diagram below shows hookup of a dc VALU-BEAM to a logic gate. A logic zero (0 volts dc) is applied to the gate input when the VALU-BEAM output is energized. When de-energized, a logic one is applied. The logic supply negative must be common to the VALU-BEAM supply negative.



Hookup to a Programmable Logic Controller (sinking output)

This diagram shows hookup of a dc VALU-BEAM to a programmable controller requiring a current sink, using the sensor's *sinking* output. The BLACK wire is not used.

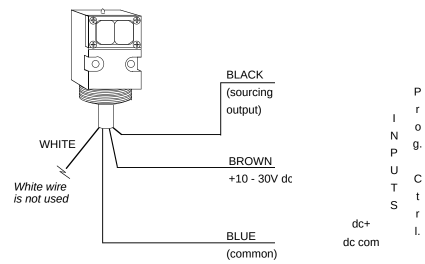
Hookup shown is typical for all inputs.



Hookup to a Programmable Logic Controller (sourcing output)

This diagram shows hookup of a dc VALU-BEAM to a programmable controller requiring a current source, using the sensor's *sourcing* output. The WHITE wire is not used.

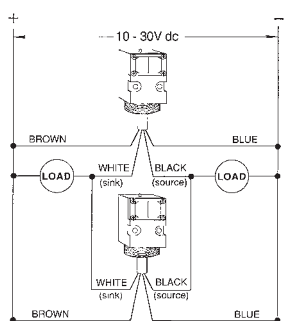
Hookup shown is typical for all inputs.



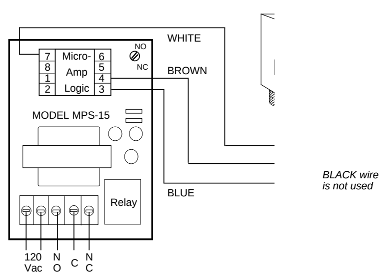
Parallel Hookup with other SM912 Series dc VALU-BEAMs

Any number of SM912 series dc VALU-BEAM sensors may be wired in parallel to a common load to create "LIGHT-OR" or "DARK-OR" logic.

Either the sinking outputs or the sourcing outputs (or both) are tied together. Unused output wires should be cut off or tied back and insulated. Series connection of sensor outputs is not possible.



Hookup to MICRO-AMP Logic

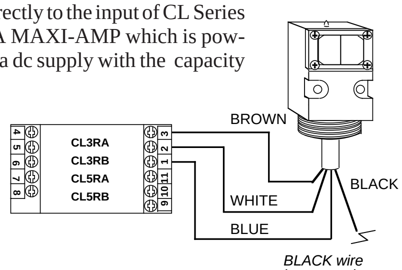


The current sinking (white) output of the VALU-BEAM is shown connected to the primary input (pin #7) of a MICRO-AMP logic module. It may be connected, instead, to the other inputs (see logic module description). The following logic modules may be used:

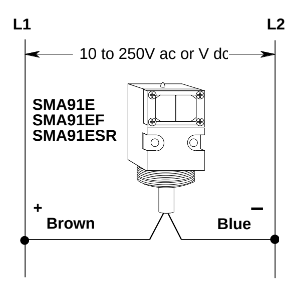
MA4-2	One-shot
MA5	On/off delay
MA4G	4-input "AND"
MA4L	Latch

Hookup to a MAXI-AMP Series Logic Module

The current sinking output(s) of VALU-BEAM sensors may be connected directly to the input of CL Series MAXI-AMP modules. A MAXI-AMP which is powered by ac voltage offers a dc supply with the capacity to power one VALU-BEAM sensor (see hookup diagram). When emitter/receiver pairs are used, the emitter should be powered from a separate power source.



Emitter Hookup



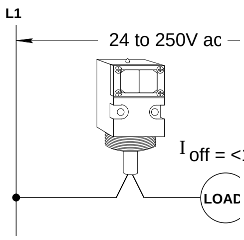
NOTE: Observe polarity for dc hookup

AC VALU-BEAM SM2A912 Series Sensors

NOTE: Output switching capacity is 500mA, maximum.

Basic ac Hookup

VALU-BEAM 2-wire ac sensors wire in series with an appropriate load. This combination, in turn, wires across the ac line.



These sensors operate in the range of 24 to 250V ac, and may be programmed for either normally open (N.O.) or normally closed (N.C.) operation by way of the light-dark operate switch on the back of the sensor. A 2-wire ac sensor may be connected exactly like a mechanical limit switch.

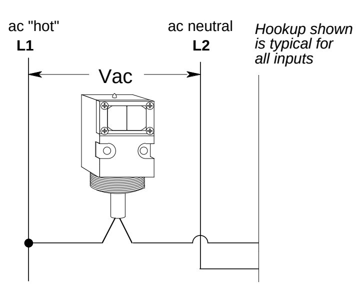
The sensor remains powered when the load is "off" by a residual current which flows through the load. The off-state leakage current (**I**off) is always less than 1.7mA. The effect of this leakage current depends on the characteristics of the load. The voltage which appears across the load in the off-state is equal to the leakage current of the sensor multiplied by the resistance of the load:

V(off) = 1.7mA x R(load).

If this resultant off-state voltage is less than the guaranteed turn-off voltage of the load, then the interface is direct. If the off-state voltage causes the load to stay "on", then an artificial load resistor must be connected in parallel with the load to lower the effective resistance. Most loads, including most programmable controller inputs, will interface to 2-wire sensors with 1.7mA leakage current without an artificial load resistor. *These sensors are not polarity sensitive: all hookups are without regard to wire color.*

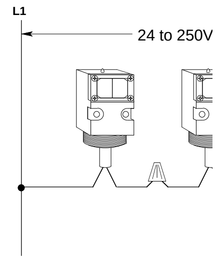
WARNING: VALU-BEAM 2-wire ac sensors will be destroyed if the load becomes a short circuit!!

Connection to a Programmable Logic Controller



AC Sensors in Series

Multiple 2-wire ac VALU-BEAMs may be wired together in series for "AND" or "NOR" logic functions. The maximum number of sensors which may be wired in series to a load depends upon the level of the line voltage and the switching characteristics of the load. Each sensor connected in series adds an amount of voltage drop across the load. The amount of voltage drop that each sensor adds depends upon the current demand of the load. Each sensor in series adds approximately 5 volts drop across a 500mA load. A 15mA load will see about a 10 volt drop from each sensor added in series. To determine compatibility, compare the resultant on-state voltage across the load against the load's guaranteed turn-on voltage level (from the manufacturer's specifications).

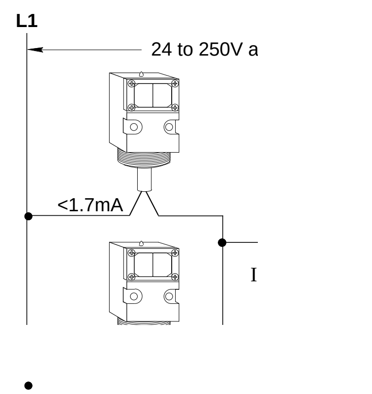


Most non-compatibility of series-connected sensors with loads occurs in low-voltage applications (e.g. 12, 24, or 48V ac circuits) where the on-state voltage drop across the load is a significant percentage of the supply voltage. The power-up inhibit time for the system (up to 300 milliseconds per sensor) is also additive.

AC Sensors in Parallel

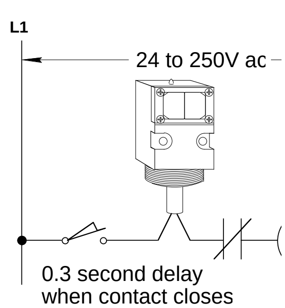
Multiple 2-wire ac VALU-BEAMs may be wired in parallel to a load for "OR" or "NAND" logic functions. With sensors wired in parallel, the off-state leakage current through the load is equal to the sum of the leakage currents required by the individual sensors. Consequently, loads with high resistance like small relays and solid state inputs may require artificial load resistors.

AC VALU-BEAMs wired together in parallel will *not* cause momentary drop-out of the load, as is experienced when wiring in parallel with contacts (see below). However, it is likely that the power-up delay feature *will* cause a momentary drop-out of the load if an ac VALU-BEAM is wired in parallel with a different brand or model of 2-wire sensor. Contact the Banner applications department to verify compatibility.



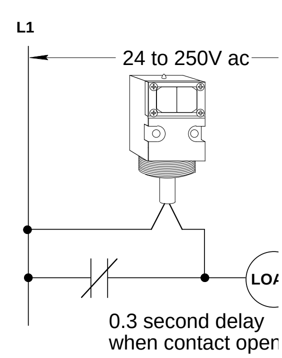
AC Sensors with Series Contacts

When 2-wire ac sensors are connected in series with mechanical limit switch or relay contacts, the sensor will receive power to operate only when all of the contacts are closed. The false-pulse protection circuit of the sensor will cause a 0.3 second delay between the time the contacts close and the time that the load can energize.



AC Sensors with Parallel Contacts

When 2-wire ac sensors are connected in parallel with mechanical switch or relay contacts, the sensor loses the current it needs to operate while any contact is closed. When all of the contacts open, the sensor's 0.3 second power-up delay may cause a momentary drop-out of the load.

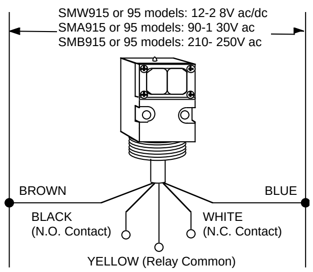


VALU-BEAM 915 and 990 Series Sensors

VALU-BEAM 915 Series Sensors with Relay Output

The 915 Series has an SPDT form 1C output relay. This relay does not have gold-flashed contacts, and should not be used for interfaces to logic inputs. A transient suppressor (MOV) should be installed across the contacts if they are used to switch inductive loads.

NOTE: Interfacing of VALU-BEAM 915 Series sensors to low-voltage logic circuits is **not** recommended.



NOTE: relay contacts are rated at 5 amps maximum (resistive load) at 250V ac max or 30V dc max. Install MOV across contact or across load if switching an inductive load.

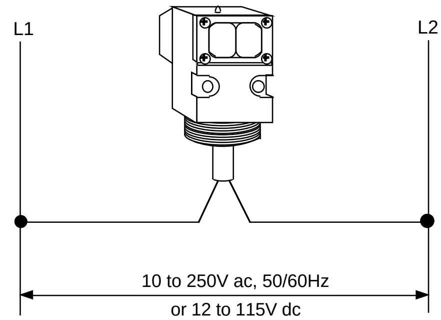
Relay specifications are:

CONTACT RATING: 250V ac max., 30V dc max., 5 amps max. (resistive load)
CLOSURE TIME: 20 milliseconds max.
RELEASE TIME: 20 milliseconds max.
MECHANICAL LIFE: 10,000,000 operations

VALU-BEAM 990 Series Sensors with Built-in Totalizing Counter

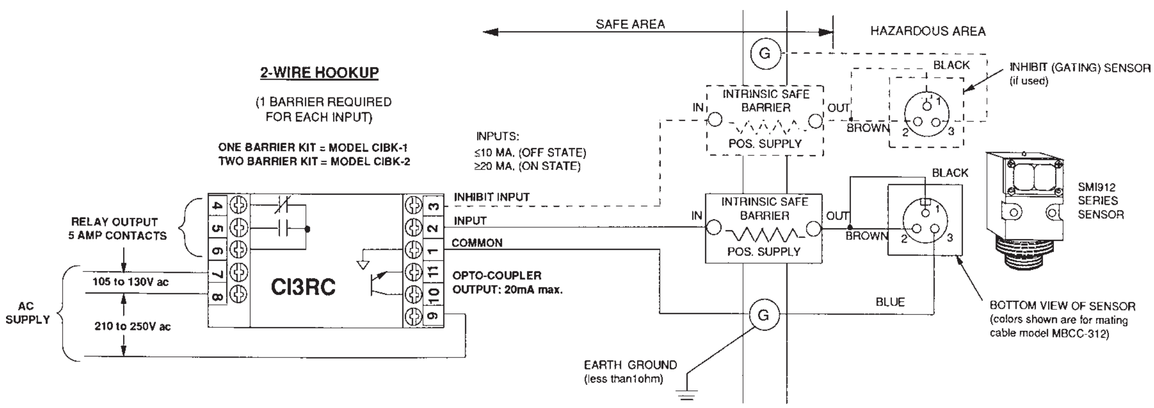
VALU-BEAM 990 Series sensors wire directly across the voltage supply line, as shown. They are not polarity sensitive in dc applications.

Hookup is without regard to wire color

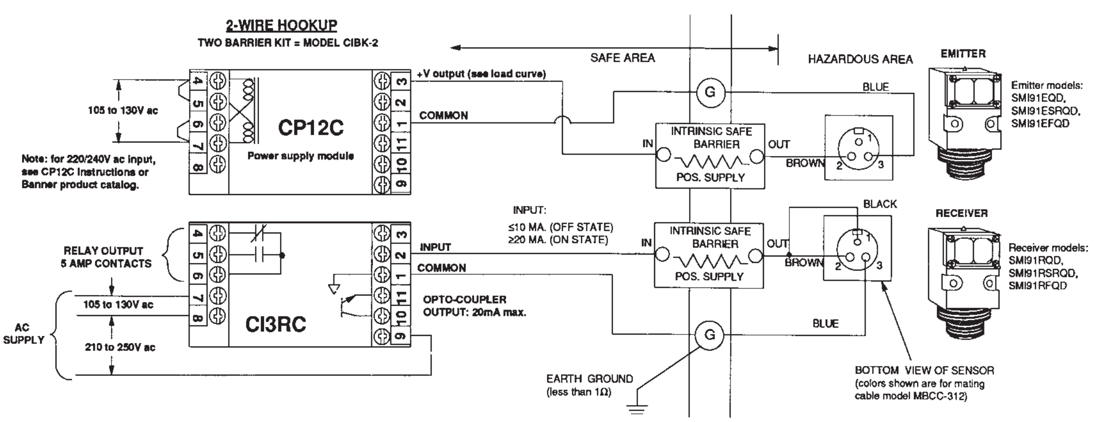


VALU-BEAM SMI912 Series Intrinsically Safe DC Sensors

HOOKUP DIAGRAM A: SMI912 Series Sensor Hookup to CI3RC



HOOKUP DIAGRAM B: SMI91 Series Emitter/Receiver Hookup

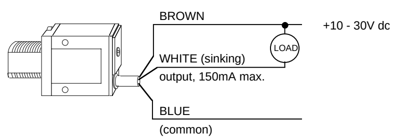


DC MINI-BEAM SM312 Series Sensors

NOTE: maximum capacity of each output is 150mA at 25°C, derated to 100mA at 70°C.

Hookup to a dc Relay or Solenoid (using sinking output)

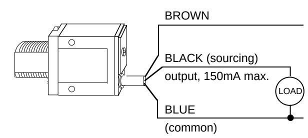
The diagram below shows hookup of a dc MINI-BEAM to a dc load using the sensor's *sinking* output, which is rated at 150mA maximum. The BLACK wire is not used.



BLACK wire is not used

Hookup to a dc Relay or Solenoid (using sourcing output)

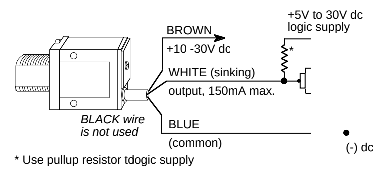
The diagram below shows hookup of a dc MINI-BEAM to a dc load using the sensor's *sourcing* output, which is rated at 150mA maximum. The WHITE wire is not used.



WHITE wire is not used

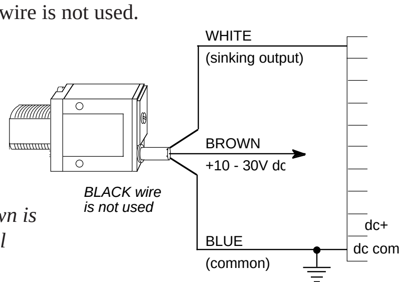
Hookup to a Logic Gate

The diagram below shows hookup of a dc MINI-BEAM to a logic gate. A logic zero (0 volts dc) is applied to the gate input when the MINI-BEAM output is energized. When de-energized, a logic one is applied. The logic supply negative must be common to the MINI-BEAM supply negative.



Hookup to a Programmable Controller requiring a current sink

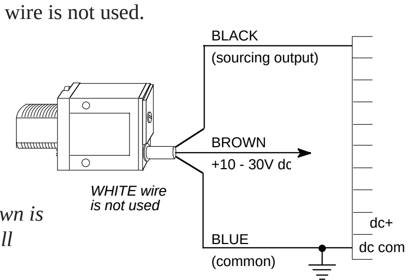
This diagram shows hookup of a dc MINI-BEAM to a programmable controller requiring a current sink, using the sensor's *sinking* output. The BLACK wire is not used.



Hookup shown is typical for all inputs.

Hookup to a Programmable Controller requiring a current source

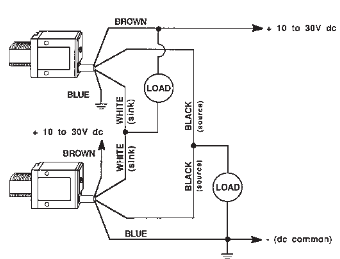
This diagram shows hookup of a dc MINI-BEAM to a programmable controller requiring a current source, using the sensor's *sourcing* output. The WHITE wire is not used.



Hookup shown is typical for all inputs.

Hookup in Parallel with other SM312 Series MINI-BEAMs

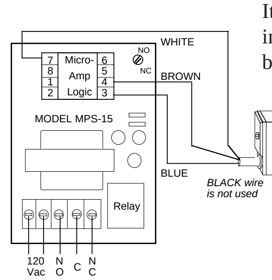
Any number of SM312 series MINI-BEAM sensors may be wired in parallel to a common load to create "LIGHT-OR" or "DARK-OR" logic. LIGHT and DARK operate are switch-selectable.



Either the sinking outputs or the sourcing outputs (or both, as shown here) are tied together. Unused output wires should be cut off or tied back and insulated. Series connection of sensor outputs is not possible.

Hookup to MICRO-AMP Logic (MPS-15 Chassis)

The current sinking output (white wire) of the MINI-BEAM is shown connected to the primary input (pin #7) of a MICRO-AMP logic module.



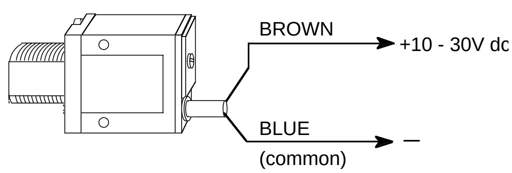
It may be connected, instead, to the other inputs. The following logic modules may be used:

MA4-2	One shot
MA5	On/off delay
MA4G	4-input "AND"
MA4L	Latch

Additional logic may be added using model RS-8 socket.

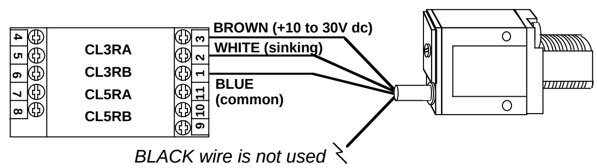
Hookup of a dc Emitter

Emitters connect directly to the supply voltage. Emitter models are: SM31E and SM31EL



Hookup to a MAXI-AMP Logic Module

In this diagram, the sinking output of a MINI-BEAM sensor is shown connected to the input (terminal #2) of a Banner MAXI-AMP "CL" series module.

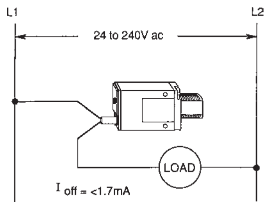


AC MINI-BEAM SM2A312 Series Sensors

NOTE: output has a maximum load capacity of 300mA. Minimum load is 5mA.

Basic ac Hookup

MINI-BEAM 2-wire ac sensors wire in series with an appropriate load. This combination, in turn, wires across the ac line.



These sensors operate in the range of 24 to 240V ac, and may be programmed for either normally open (N.O.) or normally closed (N.C.) operation by way of the light-dark operate switch on the back of the sensor. A 2-wire ac sensor may be connected exactly like a mechanical limit switch.

The sensor remains powered when the load is "off" by a residual current which flows through the load. The off-state leakage current (I) is always less than 1.7mA. The effect of this leakage current depends on the characteristics of the load. The voltage which appears across the load in the off-state is equal to the leakage current of the sensor multiplied by the resistance of the load:

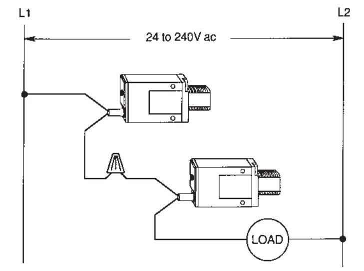
V(off) = 1.7mA x R(load).

If this resultant off-state voltage is less than the guaranteed turn-off voltage of the load, then the interface is direct. If the off-state voltage causes the load to stay "on", then an artificial load resistor must be connected in parallel with the load to lower the effective resistance. Most loads, including most programmable controller inputs, will interface to 2-wire sensors with 1.7mA leakage current without an artificial load resistor. *These sensors are <u>not</u> polarity sensitive: all hookups are without regard to wire color.*

WARNING: MINI-BEAM 2-wire ac sensors will be destroyed if the load becomes a short circuit!!

AC Sensors in Series

Multiple 2-wire ac MINI-BEAMs may be wired together in series for "AND" or "NOR" logic functions. The maximum number of sensors which may be wired in series to a load depends upon the level of the line voltage and the switching characteristics of the load. Each sensor connected in series adds an amount of voltage drop across the load. The amount of voltage drop that each sensor adds depends upon the current demand of the load. Each sensor in series adds approximately 5 volts drop across a 300mA load. A 15mA load will see about a 10 volt drop from each sensor added in series. To determine compatibility, compare the resultant on-state voltage across the load against the load's guaranteed turn-on voltage level (from the manufacturer's specifications).

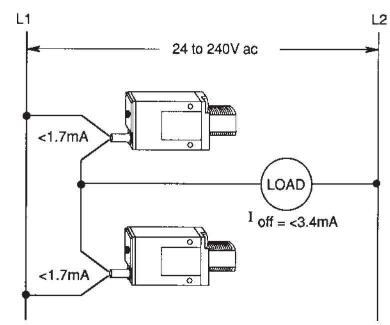


Most non-compatibility of series sensors with loads occurs in low-voltage applications (e.g. 12, 24, or 48V ac circuits) where the on-state voltage drop across the load is a significant percentage of the supply voltage.

The power-up inhibit time (up to 300 milliseconds per sensor) is also additive.

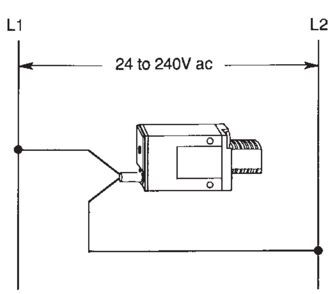
AC Sensors in Parallel

Multiple 2-wire ac MINI-BEAMs may be wired in parallel to a load for "OR" or "NAND" logic functions. With sensors wired in parallel, the off-state leakage current through the load is equal to the sum of the leakage currents required by the individual sensors. Consequently, loads with high resistance like small relays and solid state inputs may require artificial load resistors.



AC MINI-BEAMs wired together in parallel will *not* cause momentary drop-out of the load, as is experienced when wiring in parallel with contacts (see below). However, it is likely that the power-up delay feature *will* cause a momentary drop-out of the load if an ac MINI-BEAM is wired in parallel with a different brand or model of 2-wire sensor. Contact the Banner applications department to verify compatibility.

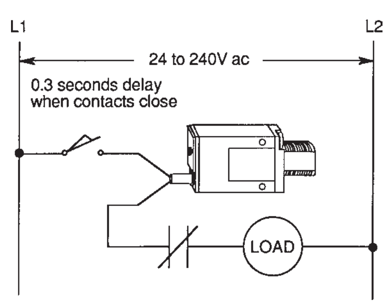
Hookup of an ac Emitter



***Hookup for emitters SMA31E and SMA31EL.** Emitters connect directly across the ac line, without regard to wire color.*

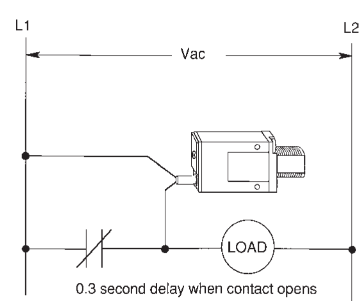
AC Sensors with Series Contacts

When 2-wire ac sensors are connected in series with mechanical limit switch or relay contacts, the sensor will receive power to operate only when all of the contacts are closed. The false-pulse protection circuit of the sensor will cause a 0.3 second delay between the time the contacts close and the time that the load can energize.



AC Sensors with Parallel Contacts

When 2-wire ac sensors are connected in parallel with mechanical switch or relay contacts, the sensor loses the voltage it needs to operate while any contact is closed. When all of the contacts open, the sensor's 0.3 second power-up delay may cause a momentary drop-out of the load.

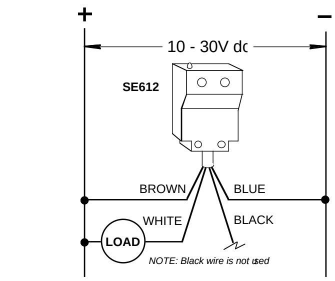


ECONO-BEAM Miniature Self-contained DC Sensors

NOTE: the maximum load capacity of each output is 150 milliamps. Both outputs may be used at the same time to run separate loads.

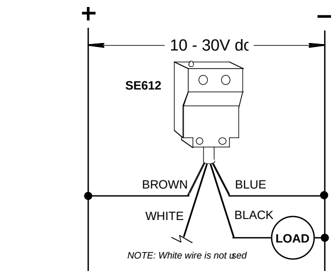
Hookup to a dc Relay or Solenoid (sinking output)

This diagram shows the hookup to a simple dc load, using the sensor's NPN (current sinking) output.



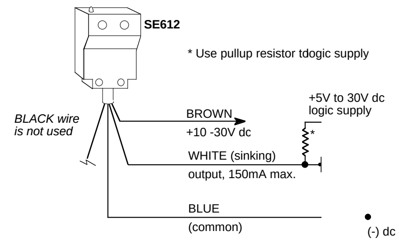
Hookup to a dc Relay or Solenoid (sourcing output)

This diagram shows the hookup to a simple dc load, using the sensor's PNP (current sourcing) output.

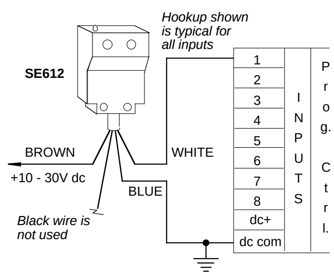


Hookup to a Logic Gate

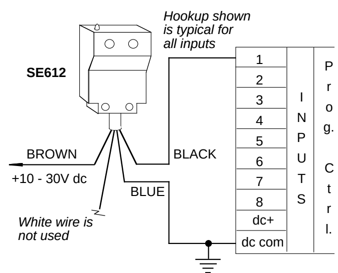
The NPN (current sinking) output is used to interface the ECONO-BEAM with a logic circuit. The logic supply negative must be common to the sensor's supply. Output on = logic "0"; off = logic "1".



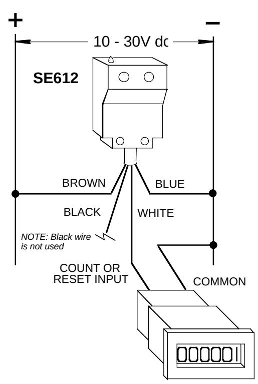
Hookup to a PLC
(programmable Logic Controller) requiring a current sink



Hookup to a PLC
(programmable Logic Controller) requiring a current source



Hookup to a Counter



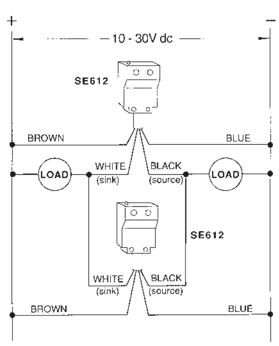
Most counters, totalizers, rate meters, etc., including battery-powered LCD types, accept the NPN (current sinking) output of ECONO-BEAMs.

An ECONO-BEAM sensor used with an LCD totalizer makes a very cost-effective counting system.

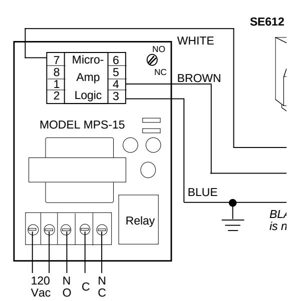
Parallel Hookup to a Common Load

Any number of ECONO-BEAM sensors may be wired in parallel to a common load to create "LIGHT-OR" logic. For "DARK-OR" logic, use ECONO-BEAMs with the model suffix "NC" (e.g. - SE612DNC, etc.).

Either the sinking outputs or the sourcing outputs (or both, as shown here) are tied together. Unused output wires should be cut off or tied back and insulated. Series connection of sensor outputs is not possible.



Hookup to MICRO-AMP Logic (MPS-15 Chassis)



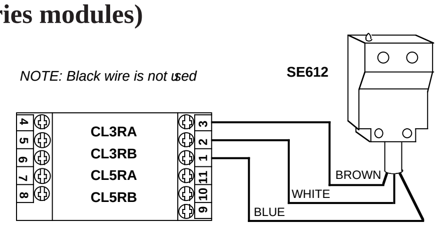
The NPN output of ECONO-BEAMs connects directly to any input of Banner MICRO-AMP logic-only modules.

The following MICRO-AMP logic modules may be used:

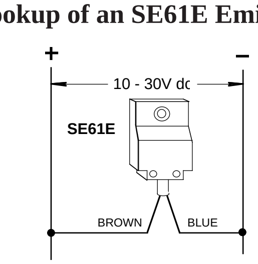
MA4-2	One-shot
MA5	Delay
MA4G	4-input "AND"
MA4L	Latch

Hookup to MAXI-AMP Logic (CL Series modules)

The NPN (current sinking) output of an ECONO-BEAM sensor may be used as an input to Banner MAXI-AMP CL Series logic modules. The MAXI-AMP, which is powered by ac voltage, offers a dc supply with enough capacity to power an ECONO-BEAM sensor. The ECONO-BEAM may also be used as an input to the auxiliary input of a CL5 module.



Hookup of an SE61E Emitter



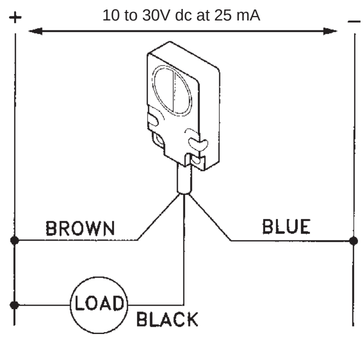
QØ8 Series Low-profile Miniature Self-contained DC Sensors

Maximum load 150 mA. (continuous)

Diffuse Mode Sensor Hookup to Loads Requiring Current Sink

This hookup is for diffuse mode QØ8 Series sensors having NPN (sinking) outputs.

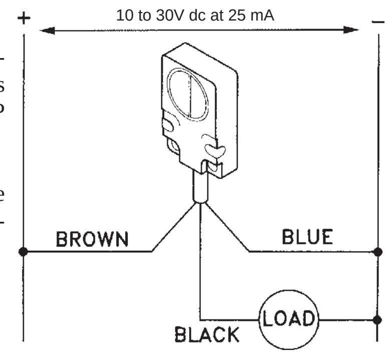
The hookup is the same for both light- and dark-operate sensor models.



Diffuse Mode Sensor Hookup to Loads Requiring Current Source

This hookup is for diffuse mode QØ8 Series sensors having PNP (sourcing) outputs.

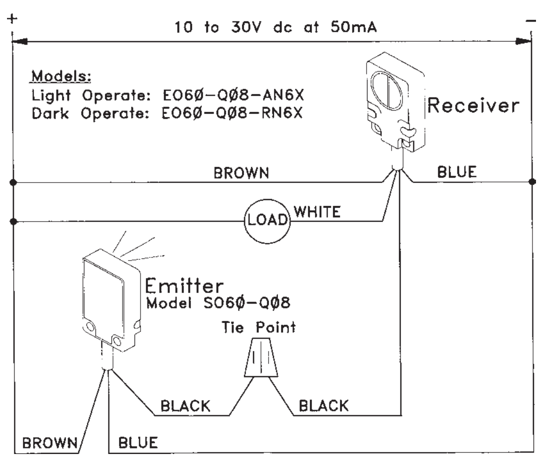
The hookup is the same for both light- and dark-operate sensor models.



Opposed Mode Sensor Hookup to Loads Requiring Current Sink

This hookup is for opposed mode QØ8 Series emitters and receivers with NPN (sinking) outputs.

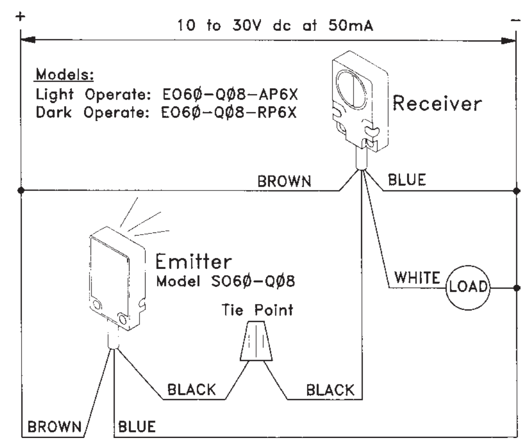
The hookup is the same for both light- and dark-operate sensor models.



Opposed Mode Sensor Hookup to Loads Requiring Current Source

This hookup is for opposed mode QØ8 Series emitters and receivers with PNP (sourcing) outputs.

The hookup is the same for both light- and dark-operate sensor models.



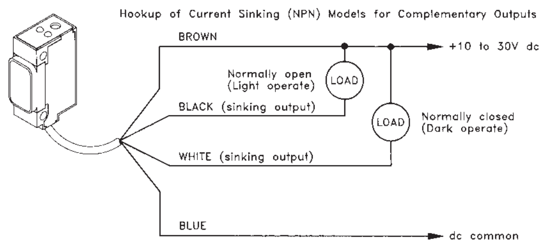
Q19 Series Miniature Self-contained DC Sensors

Maximum load 150 mA. (continuous) each output (standard hookup); 150 mA. (total, both outputs) when alarm hookup is used.

Hookup to Loads Requiring Current Sink (standard hookup)

This hookup is for Q19 Series sensors having complementary NPN (sinking) outputs.

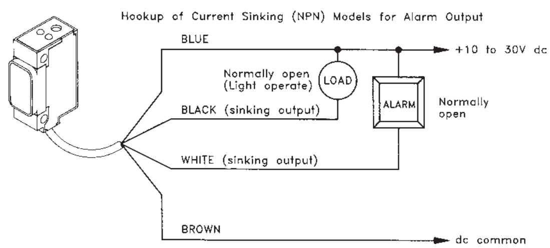
Light- and dark-operate outputs may be used simultaneously. Maximum load is 150 mA each output.



Hookup to Loads Requiring Current Sink (alarm hookup)

This hookup is for Q19 Series sensors having NPN (sinking) outputs.

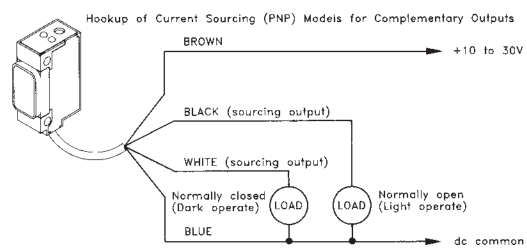
The dark operate output may be wired as a normally open alarm output. When this is done, the maximum *total* load (both outputs together) is 150 mA.



Hookup to Loads Requiring Current Source (standard hookup)

This hookup is for Q19 Series sensors having complementary PNP (sourcing) outputs.

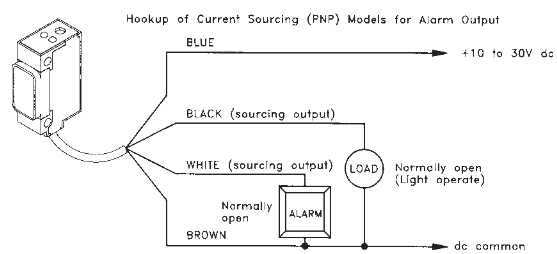
Light- and dark-operate outputs may be used simultaneously. Maximum load is 150 mA each output.



Hookup to Loads Requiring Current Source (alarm hookup)

This hookup is for Q19 Series sensors having PNP (sourcing) outputs.

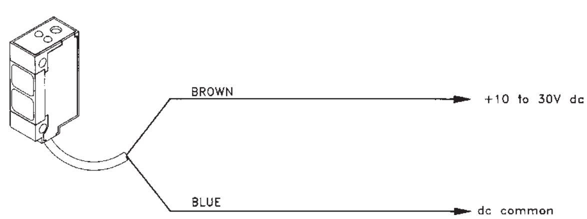
The dark operate output may be wired as a normally open alarm output. When this is done, the maximum *total* load (both outputs together) is 150 mA.



Hookup of Q19 Series Opposed Mode Emitters

Q19 Series opposed mode emitters use this hookup.

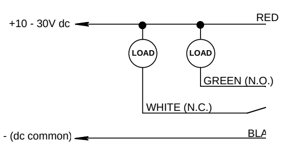
Emitters are connected to power only. They have no output circuits.



SM512 Series Sensors

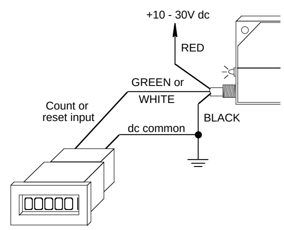
Hookup of an SM512 Series Sensor to a Relay or Solenoid

SM512 Series sensors (including SM51RB and SM502A) offer two open collector NPN outputs in a complementary configuration (one normally open and one normally closed). The green output wire switches the load when the receiver "sees" its modulated light source (LIGHT operate). The white output wire switches in the dark condition (DARK operate). Both output circuits can switch up to 1/4 amp.



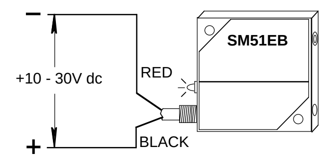
Hookup of SM512 Series Sensor to a Counter

Most counters, totalizers, rate meters, etc. accept either output of the SM512s. Hookup to a battery-powered LCD type is shown here. For other types, follow the counter's hookup instructions for an NPN or current sinking input device.



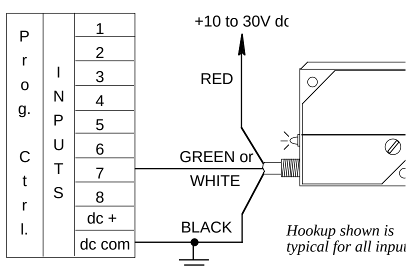
Hookup of an SM51EB Emitter

Emitter model SM51EB connects directly to a dc power supply, as shown.



Hookup of an SM512 Series Sensor to a Programmable Controller requiring a current sink

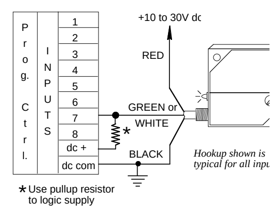
Either sensor output is wired directly to any input of the PLC. Also, connect the negative of the sensor power supply to the negative of the PLC (input card) power supply (if they are separate supplies).



Hookup of an SM512 Series Sensor to a Programmable Controller requiring a current source

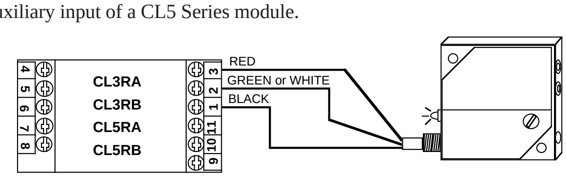
Either sensor output is wired directly to any input of the PLC. An external "pullup" resistor is connected between the input and +V of the PLC (input card) power supply. The value of the resistor is not critical: values from 1KΩ to 10KΩ, 1/4 watt or larger, will satisfy most inputs. Connect the negative of the sensor power supply to the negative of the PLC (input card) power supply (if they are separate supplies).

The wiring scheme inverts the LIGHT and DARK output configuration as seen by the PLC input. The white output becomes LIGHT operate, and the green output is used for DARK operate.



Hookup to MAXI-AMP Logic (CL Series Module)

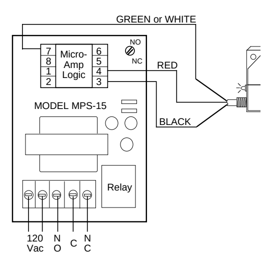
The output of an SM512 Series sensor may be used as an input to Banner MAXI-AMP CL Series logic modules. The MAXI-AMP, when powered by ac voltage, offers a dc supply with enough capacity to power one SM512 Series sensor. An SM512 Series sensor may also be used as an input to the auxiliary input of a CL5 Series module.



Hookup to MICRO-AMP Logic (MPS-15 Chassis)

The output (green or white wire) of SM512 Series sensors connects directly to any input of the following Banner MICRO-AMP logic-only modules:

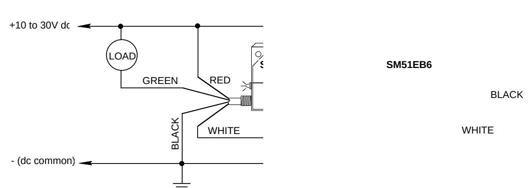
- **MA4-2** One-shot
- **MA5** Delay
- **MA4G** 4-input "AND"
- **MA4L** Latch



Hookup of an SM51EB6 and SM51RB6 High Power Emitter/Receiver Pair

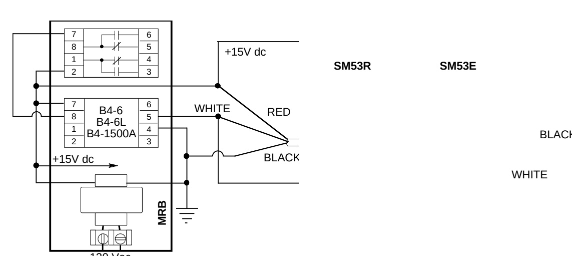
Both the emitter and the receiver have white wires which connect together to sync (lock on) the pair to a narrow frequency bandwidth. There is only one receiver output, which is the same NPN current sinking circuit used in the other SM512 Series sensors.

The output is normally open (or LIGHT operate). For normally closed output, specify model SM51RB6DO ("DO" = Dark Operate).



Hookup of an SM53E and SM53R High Sensitivity Emitter/Receiver Pair

The emitter/receiver pair has an analog output which serves as the input to an ac-coupled amplifier. The hookup shown here is to an ac-coupled B Series amplifier. Note that the white wires from both the emitter and receiver tie together at the amplifier input. This connects together an AGC circuit which regulates the emitter output for constant received light signal strength. The sensors are powered by 12 to 18V dc.



SM30 Series DC Receivers

NOTE: maximum load capacity for dc receivers is 250mA, continuous.
See page C-36 for emitter hookup.

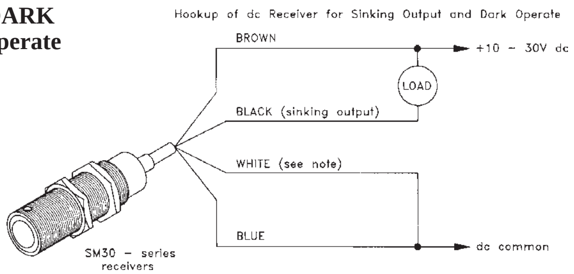
DC Receiver Hookup to a Simple Load

DC SM30 series receivers may be connected for either light- or dark-operate sensing, and for either sinking or sourcing output. *In DARK operate mode, the receiver output conducts when the light beam is blocked; in LIGHT operate, the receiver output conducts when the light beam is unblocked.*

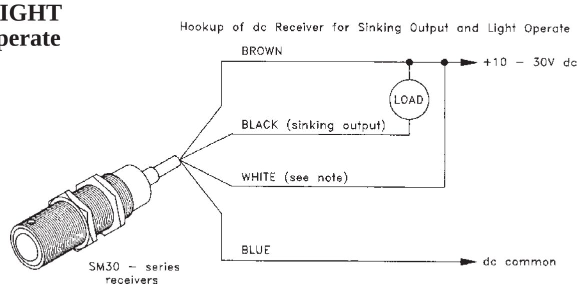
NOTE: For light-operate sensing applications, the white wire is *always* connected to the POSITIVE side of the power supply. For dark-operate sensing applications, the white wire is *always* connected to the DC COMMON side of the power supply. The diagrams below show dc receiver hookup to "simple loads" such as dc relays and solenoids.

SINKING Hookups

DARK operate

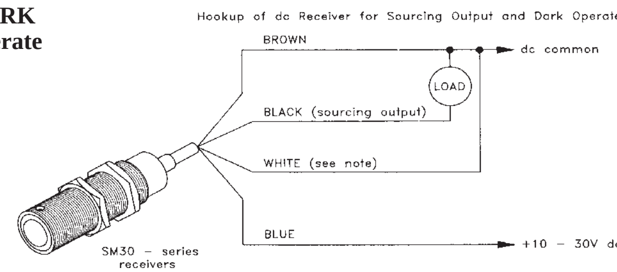


LIGHT operate

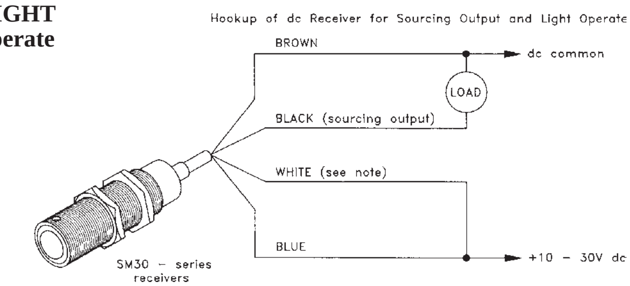


SOURCING Hookups

DARK operate



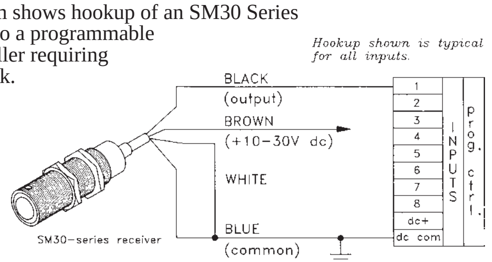
LIGHT operate



Note: contact Applications Group at factory for information on interfacing to TTL circuitry.

DC Receiver Hookup to a Programmable Controller requiring a current sink (DARK operate* shown)

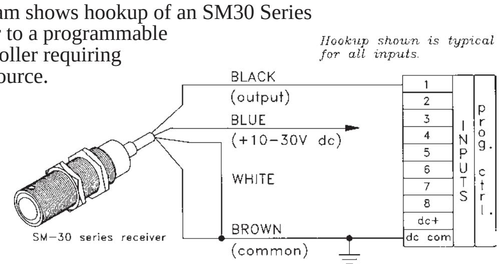
This diagram shows hookup of an SM30 Series dc receiver to a programmable logic controller requiring a current sink.



*For light-operate sensing applications, the white wire is instead connected to "+10 to 30V dc".

DC Receiver Hookup to a Programmable Controller requiring a current source (DARK operate* shown)

This diagram shows hookup of an SM30 Series dc receiver to a programmable logic controller requiring a current source.

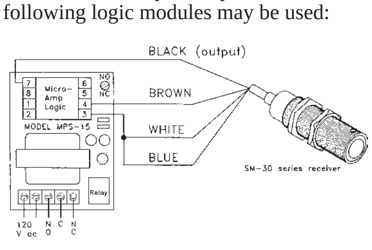


*For light-operate sensing applications, the white wire is instead connected to "+10 to 30V dc".

DC Receiver Hookup to MICRO-AMP Logic (MPS-15 chassis; sinking hookup, DARK operate* shown)

The output of the receiver is shown connected to the primary input (pin #7) of a MICRO-AMP logic module. Alternatively, it may be connected to one of the other inputs. The following logic modules may be used:

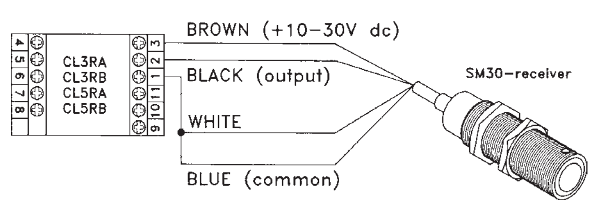
MA4-2	**One-shot**
MA5	**On/off delay**
MA4G	**4-input "AND"**
MA4L	**Latch**



*For light-operate applications, connect the white wire instead to +Vdc (pin #4).

DC Receiver Hookup to a MAXI-AMP Logic Module (Sinking hookup, DARK operate* shown)

In this diagram, the output of an SM30 Series receiver is shown connected to the input (terminal #2) of a Banner MAXI-AMP "CL" series module.

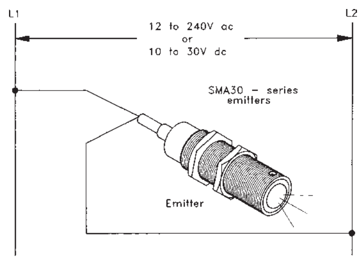


*For light-operate applications, connect the white wire instead to +Vdc (pin #3).

SM30 Series AC Receivers*

NOTE: maximum load capacity for ac receivers is 500mA, continuous.

SM30 Series Emitter Hookup



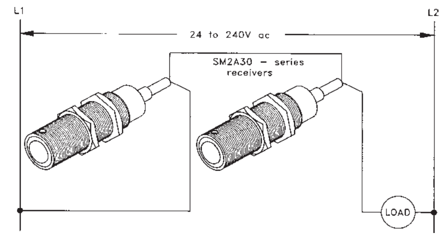
Emitters with stainless steel housing have a third wire that must be connected to *earth ground* whenever the emitter is operated from an **ac** voltage source. The ground wire is the GREEN wire.

Hookup to a **dc** supply is without regard to power supply polarity.

AC Receivers in Series

Multiple SM30 Series ac receivers may be wired together in series for "AND" or "NOR" logic functions. The maximum number of sensors that may be wired in series to a load depends upon the level of the line voltage and the switching characteristics of the load. Each sensor connected in series adds an amount of voltage drop across the load. The amount of voltage drop that each sensor adds depends upon the current demand of the load. Each sensor in series adds approximately 3.5 volts drop across a 500mA load. A 15mA load will see about a 5 volt drop from each sensor added in series. To determine compatibility, compare the resultant on-state voltage across the load against the load's guaranteed turn-on voltage level (from the manufacturer's specifications).

Most non-compatibility of series sensors with loads occurs in low-voltage applications (e.g. 12, 24, and 48V ac circuits) where the on-state voltage drop across the load is a significant percent of the supply voltage.



Basic AC Receiver Hookup

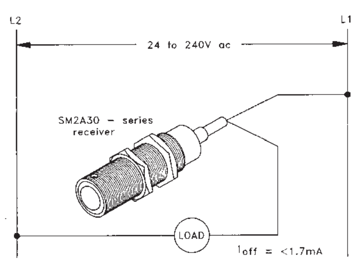
NOTE: AC receivers with stainless steel housing have a third wire (GREEN) that must be connected to *earth ground*.

These receivers operate over a voltage range of 24 to 240V ac (50/60Hz). They wire in series with an appropriate load. This combination, in turn, wires across the line. SM30 Series ac receivers may be connected exactly like a mechanical limit switch.

The sensor remains powered when the load is "off" by a residual current which flows through the load. The off-state leakage current **(I)** is always less than 1.7mA. The effect of this leakage current depends upon the characteristics of the load. The voltage that appears across the load in the off-state is equal to the leakage current of the sensor multiplied by the resistance of the load:

V(off) **= 1.7mA x R**(load).

If this resultant off-state voltage is less than the guaranteed turn-off voltage of the load, then the interface to the load is direct. If the off-state voltage causes the load to stay "on", then an artificial load resistor must be connected in parallel with the load to lower the effective resistance of the load. Most loads, including most programmable controller inputs, interface to 2-wire sensors with 1.7mA of leakage current without an artificial load resistor.

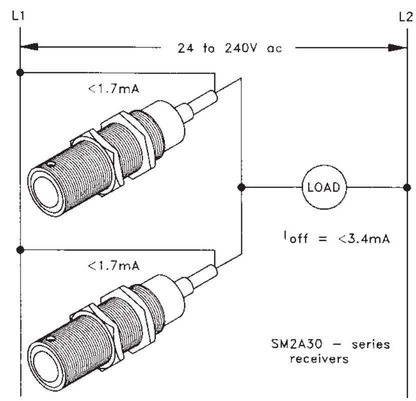


WARNING: SM30 Series 2-wire ac receivers will be destroyed if the load becomes a short-circuit!!

AC Receivers in Parallel

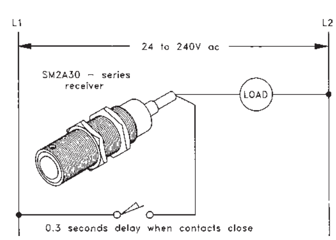
Multiple SM30 Series ac receivers may be wired in parallel to a load for "OR" or "NAND" logic functions. With sensors wired in parallel, the off-state leakage current through the load is equal to the sum of the leakage currents required by the individual sensors. Consequently loads with high resistance, like small relays and solid-state inputs, may require artificial load resistors.

SM30 Series ac receivers wired together in parallel *will not* cause momentary drop-out of the load as is experienced when wiring in parallel with contacts (see below). However, it is likely that the power up delay feature *will* cause a momentary drop-out of the load if an ac SM30 receiver is wired in parallel with a different brand or model of 2-wire ac sensor. Contact the Banner Applications Group to verify compatibility.



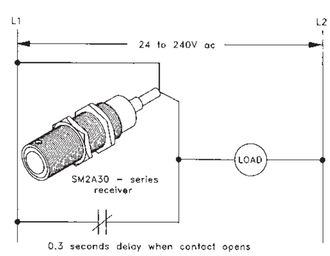
AC Receivers in Series with Contacts

When SM30 Series ac receivers are connected in series with a mechanical limit switch or a contact, the sensor will receive power to operate only when *all* of the contacts are closed. The false-pulse protection circuit of the sensor will cause a 0.3 second delay between the time the contacts close and the time that the load can energize.



AC Receivers in Parallel with Contacts

When SM30 Series ac receivers are connected in parallel with a mechanical limit switch or a relay, the sensor loses the voltage it needs to operate while *any* contact is closed. When all of the contacts open, the sensor's 0.3 second power-up delay may cause a momentary drop-out of the load.



*NOTE: Grounding of AC Stainless Steel Sensors

These sensors are not polarity-sensitive: all ac hookups are without regard to wire color. However, the ground wire of all ac stainless steel SM30 sensors (receivers and emitters) must be connected to earth ground. The ground wire is the GREEN wire.

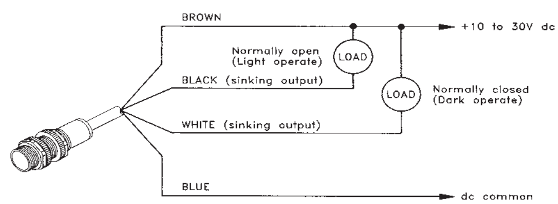
S18 Series DC and AC Sensors

Hookup Diagrams,
DC sensors

S18 Series dc sensors may be purchased with a choice of either NPN (sinking) or PNP (sourcing) complementary outputs, one normally open and the other normally closed. In all models, except emitters, the normally closed output may be wired as a normally open low excess gain alarm output.

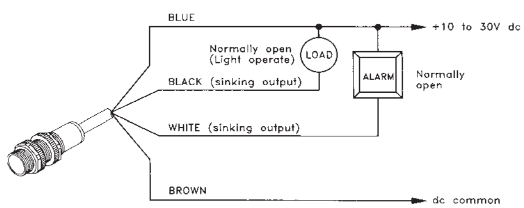
S18 dc sensor outputs in the standard hookup are rated at 150 mA. maximum each (continuous). Output capacity in the alarm hookup is 150 mA. *total*, both outputs. There is a 100 millisecond delay upon power-up.

NPN sinking models, standard hookup



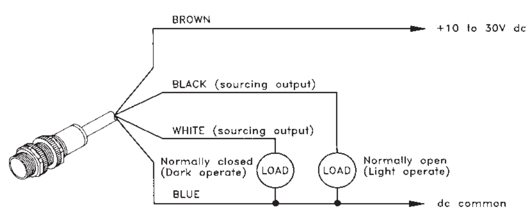
Note: Use model MQDC-415(RA) cable for "Q" model sensors (ordered separately)

NPN sinking models, hookup for alarm output



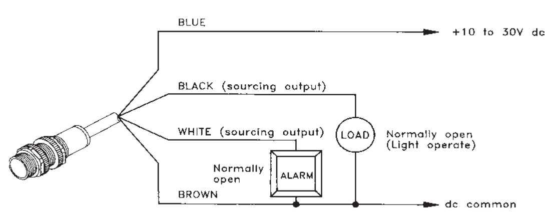
Note: Use model MQDC-415 (RA) cable for "Q" model sensors (ordered separately)

PNP sourcing models, standard hookup



Note: Use model MQDC-415(RA) cable for "Q" model sensors (ordered separately)

PNP sourcing models, hookup for alarm output



Note: Use model MQDC-415(RA) cable for "Q" model sensors (ordered separately)

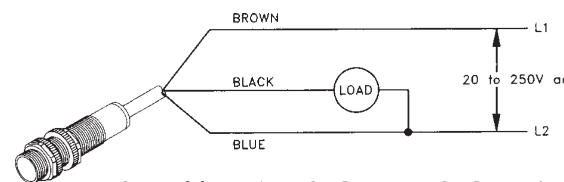
Hookup Diagrams,
AC sensors

S18 Series ac sensors use a three-wire hookup.

S18 ac sensor outputs are rated at 300 mA. maximum (continuous).

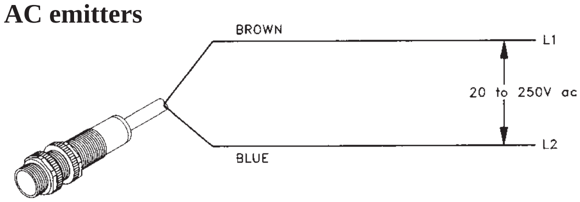
There is a 100-millisecond delay upon power up.

All AC sensors



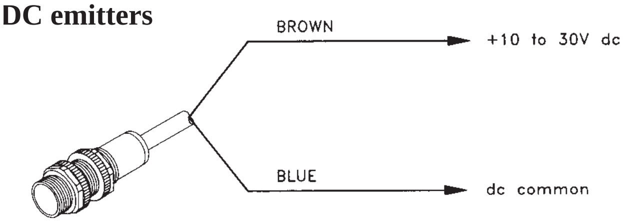
QD models require MQDC-515 or MQDC-515RA cable.

AC emitters



QD models require MQDC-515 or MQDC-515RA cable.

DC emitters



QD style emitters require MQDC-415 or MQDC-415RA mating cable.

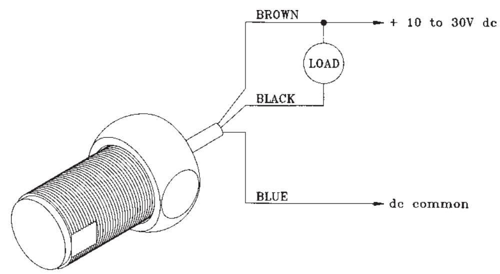
C3Ø Series DC Sensors

Maximum load is 150 mA (continuous).

Hookup to Load Requiring Current Sink (NPN models)

This hookup is for C3Ø Series sensors with NPN (sinking) output.

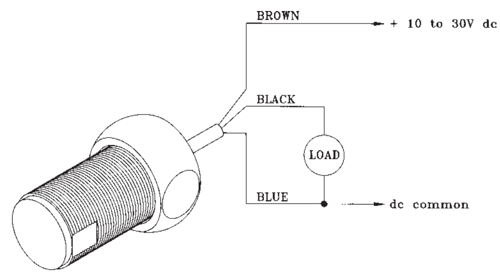
Maximum load is 150 mA (continuous).



Hookup to Load Requiring Current Source (PNP models)

This hookup is for C3Ø Series sensors with PNP (sourcing) output.

Maximum load is 150 mA (continuous).



Q85 Series Sensors

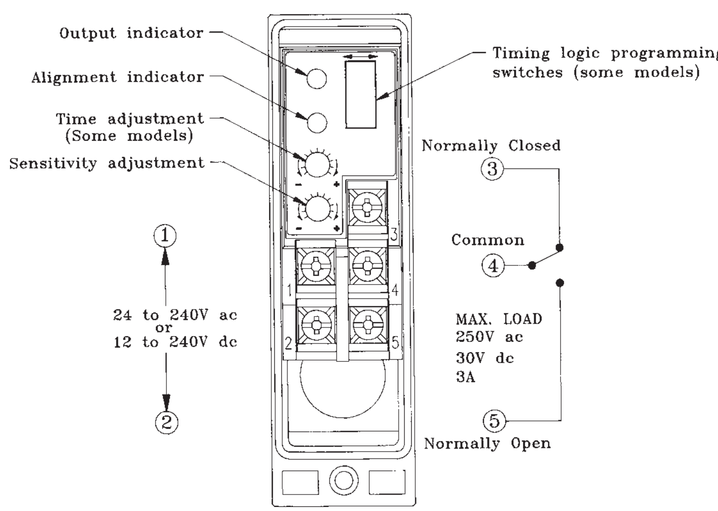
Hookup of Models having Electromechanical Relay Output

Q85 Series Sensors with electromechanical relay output switching device connect to power and load as shown at right. Wiring is done at the five terminals inside the wiring chamber.

These sensors operate from either 24 to 240 Vac or 12 to 240V dc, and there is no polarity required for power supply hookup.

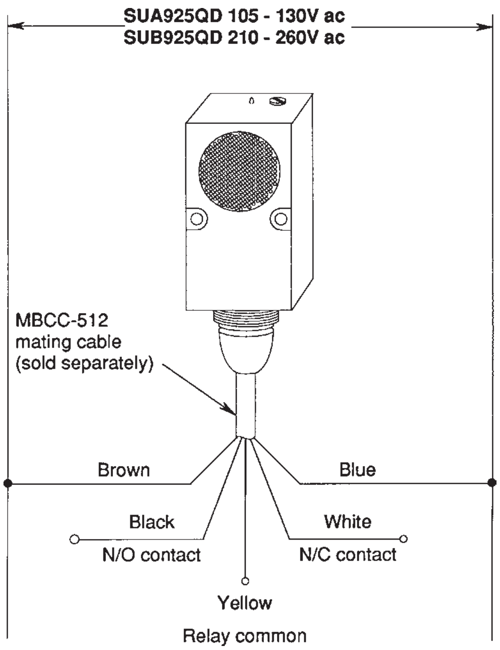
Both normally open and normally closed relay contacts are provided. Maximum (resistive) load is 250V ac, 30V dc, 3A.

Opposed mode emitters use the same ac/dc power hookup (at terminals 1 and 2). Emitters have no output circuitry.



ULTRA-BEAM 925 series Sensors (electromechanical relay output)

See page C-15 for hookup information on analog output models.

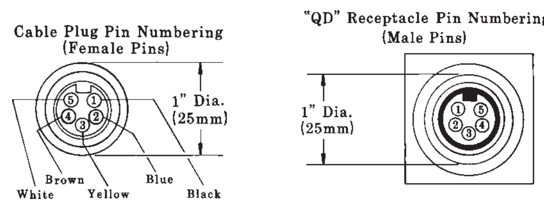


OUTPUT RELAY SPECIFICATIONS: one form "C" SPDT electromechanical relay with silver-nickel alloy contacts.

Capacity: 150 watts or 600VA maximum power (resistive load)
Maximum voltage: 250V ac or 30V dc (resistive load)
Maximum current: 5 amps (resisitive load)
Minimum load: 5V dc @ 100 milliamps
Mechanical life: 10,000,000 operations

Note: install a suitable metal oxide varistor (MOV) across the contact(s) to switch an inductive load.

MBCC-512 Quick Disconnect Cable

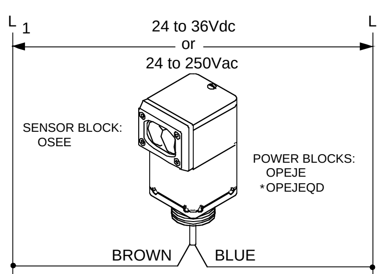


ULTRA-BEAM 925 and Sonic OMNI-BEAM sensors require 5-conductor quick-disconnect (female) SO-type cable. Standard length of model MBCC-512 cable is 12 feet. SO-type cables of other manufacturers may be used.

E Series OMNI-BEAM Sensors

See page C-18 for Standard OMNI-BEAM models.

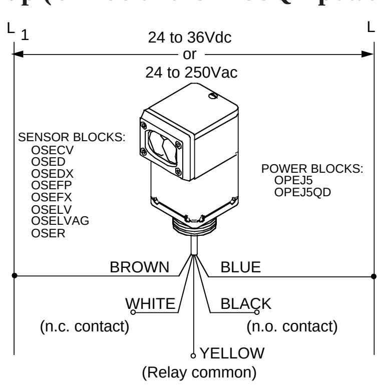
Emitter Hookup (OPEJE and OPEJEQD power blocks):



*Note: cable model MBCC-512 is sold separately for use with powerblock model OPEJEQD. It has five wires. The white, black, and yellow wires have no connection.

E Series dc hookups are without regard to power supply polarity.
Output relay and "QD" cable specifications are same as for 925 Series, above.

Sensor Hookup (OPEJ5 and OPEJ5QD power blocks):



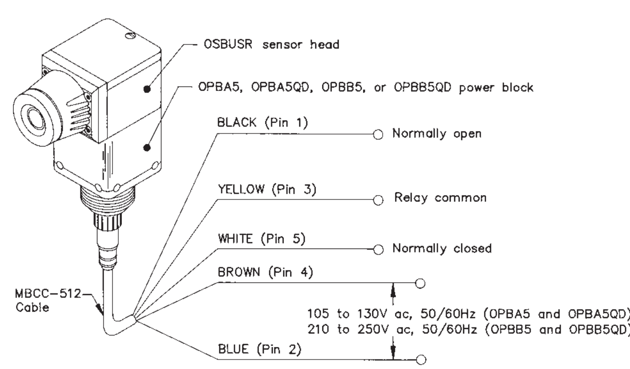
Sonic OMNI-BEAM Sensors

with electromechanical output relay

OUTPUT:
one form "C" SPDT relay, silver nickel alloy contacts.

Maximum voltage: 250V ac or 30V dc (resistive load)
Maximum current: 7 amps (resistive load)
Minimum load: 5V dc at 10 milliamperes
Mechanical life: 50,000,000 operations

Sonic OMNI-BEAM sensors use model MBCC-512 5-conductor SO-type "QD" cable, described above.



See page C-16 for hookup to analog power blocks.

MAXI-AMP Modulated Amplifiers (Electromechanical Output Relay)

MAXI-AMP modules with electromechanical output relay are identified by the letter "R" in the model number suffix. The relay is single-pole double throw (SPDT) with gold-flashed contacts. A transient suppressor (MOV) should be installed across contacts that switch inductive loads.

Relay specifications are:

CONTACT RATING: 250V ac max., 24V dc max., 5 amps max. (resistive load)

CLOSURE TIME: 10 milliseconds max.

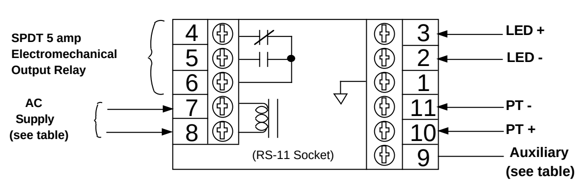
RELEASE TIME: 10 milliseconds max.

MECHANICAL LIFE: 20,000,000 operations

The operating characteristics of Banner MAXI-AMP modulated amplifier modules with electromechanical relay output are summarized in the table at the right.

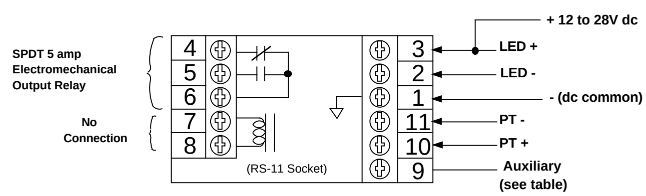
MODULE MODEL	SUPPLY VOLTAGE	USED WITH (INPUT)	OUTPUT CONFIGURATION	LOGIC FUNCTIONS
CD3RA	105-130V ac, or 12-28V dc	CD Series MAXI-AMP modules contain a modulated photoelectric amplifier designed for the **SP12 Series** of preamplified remote barrel sensors.	SPDT electromechanical relay, plus NPN transistor solid-state logic-level dc switch at terminal #9.	ON/OFF Output follows input
CD3RB	210-250V ac, or 12-28V dc			
CD5RA	105-130V ac, or 12-28V dc		SPDT electromechanical relay. (Terminal #9 is reset/inhibit input to logic circuit.)	Selection of 12 programmable functions including: delay, pulse, limit, cycle, and latch.
CD5RB	210-250V ac, or 12-28V dc			
CM3RA	105-130V ac, or 12-28V dc	CM Series MAXI-AMP modules contain a modulated photoelectric amplifier for use with the full line of Banner high-performance modulated remote sensors.	SPDT electromechanical relay, plus NPN transistor solid-state logic-level dc switch at terminal #9.	ON/OFF Output follows input
CM3RB	210-250V ac, or 12-28V dc			
CM5RA	105-130V ac, or 12-28V dc		SPDT electromechanical relay. (Terminal #9 is reset/inhibit input to logic circuit.)	Selection of 12 programmable functions including: delay, pulse, limit, cycle, and latch.
CM5RB	210-250V ac, or 12-28V dc			
CR3RA	105-130V ac, or 12-28V dc	CR Series MAXI-AMP modules contain a modulated photoelectric amplifier especially designed for the **SP100 series** of miniature remote sensors.	SPDT electromechanical relay, plus NPN transistor solid-state logic-level dc switch at terminal #9.	ON/OFF Output follows input
CR3RB	210-250V ac, or 12-28V dc			
CR5RA	105-130V ac, or 12-28V dc		SPDT electromechanical relay. (Terminal #9 is reset/inhibit input to logic circuit.)	Selection of 12 programmable functions including: delay, pulse, limit, cycle, and latch.
CR5RB	210-250V ac, or 12-28V dc			

Hookup for ac-powered Unit



Connect shield wires from remote sensors (if any) to terminal #1.

Hookup for dc-powered Unit



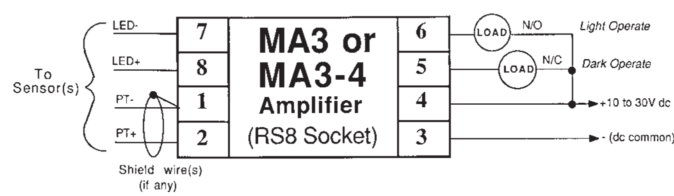
Connect shield wires from remote sensors (if any) to terminal #1.

MICRO-AMP Modulated Amplifiers with Sinking Outputs

Models MA3 and MA3-4 are modulated amplifiers with a complementary NPN sinking output configuration: one output is open while the other is conducting. The output at pin #6 conducts when the remote receiver "sees" its modulated light source. The output at pin #5 conducts in the "dark" state. Both outputs can sink up to 150 milliamps. The power supply is 10-30V dc at 20mA, exclusive of load.

Model MA3 is used with SP100 series miniature remote sensors. Model MA3-4 is a higher-gain amplifier used with high-performance modulated sensors, which includes the following models: LP400; LR & PT200, 250, 300, 400; SP300D; SP300EL/RL; SP300L; SP320D; and SP1000V.

Hookup for Units with Sinking Output



MAXI-AMP Modulated Amplifiers (Solid-state Output Option)

MAXI-AMP modules with the solid-state output option actually offer two SPST relays: one for an ac load, *or* one for a dc load. These contacts share a "common", and so are not normally both connected to loads at the same time. The switch for an ac load is between terminals #5 and #6.

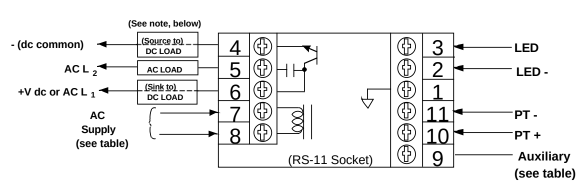
The solid-state ac switch is rated for up to 3/4 amp. The contact design features negligible off-state leakage for direct interfacing to any ac logic input.

The dc switch is an NPN transistor between terminals #4 and #6, It is isolated from the module voltages so that it may be connected for either sourcing or sinking to an input.

The dc switch is rated for 30V dc max., 50mA max., and is recommended for interfacing only to logic circuits.

MODULE MODEL	SUPPLY VOLTAGE	USED WITH (INPUT)	OUTPUT CONFIGURATION	LOGIC FUNCTIONS	FUNCTION OF TERMINAL #9
CD3A	105-130V ac, or 12-28V dc	CD Series MAXI-AMP modules contain a modulated photoelectric amplifier for use with **SP12 Series** preamplified remote barrel sensors.	SPST solid-state contact for switching ac loads of up to 250V ac and up to 3/4 amp. -or- SPST solid-state contact for switching dc circuits of up to 30V dc and up to 50mA. (depending on hookup)	ON/OFF Output follows input	NPN logic level DC output
CD3B	210-250V ac, or 12-28V dc				
CD5A	105-130V ac, or 12-28V dc			Selection of 12 programmable functions including: delay, pulse, limit, cycle, and latch.	Input for inhibit or reset of logic functions (accepts switch to dc common)
CD5B	210-250V ac, or 12-28V dc				
CM3A	105-130V ac, or 12-28V dc	CM Series MAXI-AMP modules contain a modulated photoelectric amplifier for use with the full line of Banner high-performance modulated remote sensors.		ON/OFF Output follows input	NPN logic level DC output
CM3B	210-250V ac, or 12-28V dc				
CM5A	105-130V ac, or 12-28V dc			Selection of 12 programmable functions including: delay, pulse, limit, cycle, and latch.	Input for inhibit or reset of logic functions (accepts switch to dc common)
CM5B	210-250V ac, or 12-28V dc				
CR3A	105-130V ac, or 12-28V dc	CR Series MAXI-AMP modules contain a modulated photoelectric amplifier especially designed for the **SP100 series** of miniature remote sensors.		ON/OFF Output follows input	NPN logic level DC output
CR3B	210-250V ac, or 12-28V dc				
CR5A	105-130V ac, or 12-28V dc			Selection of 12 programmable functions including: delay, pulse, limit, cycle, and latch.	Input for inhibit or reset of logic functions (accepts switch to dc common)
CR5B	210-250V ac, or 12-28V dc				

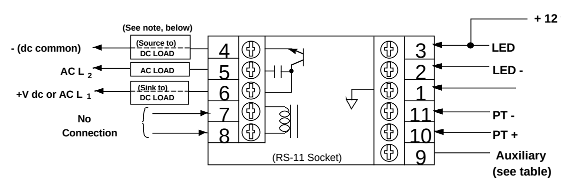
Hookup for ac-powered Unit



Connect shield wires from remote sensors (if any) to terminal #1

NOTE: Output will switch *either* one DC load (30V dc max., 50 mA max.) *or* one AC load (250V ac, 3/4 amp max.), (not both).

Hookup for dc-powered Unit



Connect shield wires from remote sensors (if any) to terminal #1

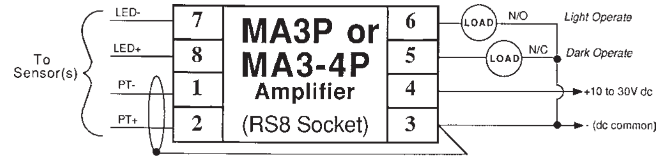
NOTE: Output will switch *either* one DC load (30V dc max., 50 mA max.) *or* one AC load (250V ac, 3/4 amp max.), (not both).

MICRO-AMP Modulated Amplifiers with Sourcing Outputs

Models MA3P and MA3-4P are modulated amplifiers with a complementary PNP sourcing output configuration: one output is open while the other is conducting. The output at pin #6 conducts when the remote receiver "sees" its modulated light source. The output at pin #5 conducts in the "dark" state. Both outputs can source the supply voltage at up to 150 milliamps. The power supply is 10-30V dc at 20mA, exclusive of load.

Model MA3P is used with SP100 series miniature remote sensors. Model MA3-4P is a higher-gain amplifier used with high-performance modulated sensors, which includes the following models: LP400; LR & PT200, 250, 300, 400; SP300D; SP300EL/RL; SP300L; SP320D; and SP1000V.

Hookup for Units with Sourcing Output



NOTE: Connect all sensor shield wires to pin #3.

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