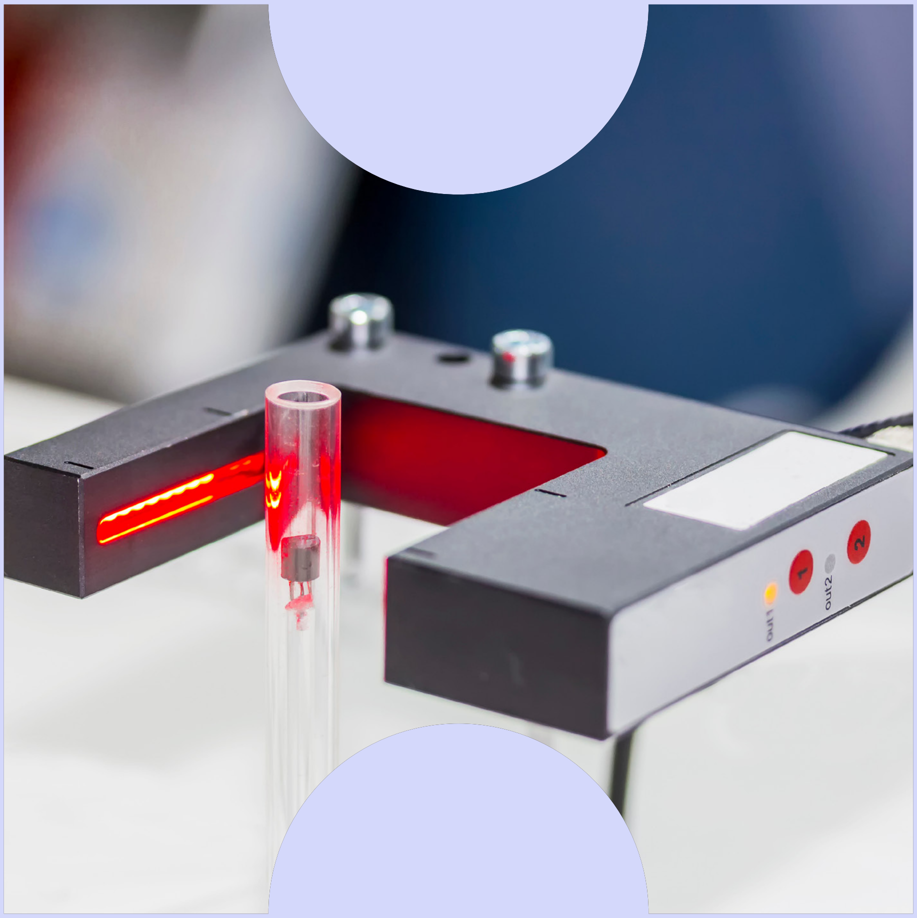
We get technical

Optimizing industry 4.0 Communication architectures using multi-protocol I/O hubs and converters

Sorting through proximity and distance sensor technology choices

How sensor fusion enables AMRs to maneuver around factory floors efficiently

Remote I/O devices optimize automation control systems



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contents

Editor's note

Welcome to the Industrial Sensors eMagazine, where we dive into the cutting-edge technologies that are transforming the world of industrial automation and communication. This issue will delve into some of the most crucial advancements that are optimizing efficiency, reliability, and flexibility across the industry.

As Industry 4.0 continues to revolutionize manufacturing and automation, the focus on optimizing communication architectures takes center stage. We explore how multi-protocol I/O hubs and converters are streamlining data exchange, making systems more agile and interoperable. This technology is crucial for building smart factories capable of seamlessly integrating diverse devices and protocols.

We also take a close look at proximity and distance sensor technology, breaking down how these sensors are evolving to meet the demands of modern automation. Whether it's enhancing machine vision or improving precision, these sensors are playing a pivotal role in applications ranging from robotics to quality control.

A key area of growth in automation is the integration of sensor fusion, which is enabling Autonomous Mobile Robots (AMRs) to navigate factory floors with unprecedented autonomy and efficiency. In this issue, we discuss how combining multiple sensor types can provide AMRs with the real-time data they need to maneuver safely and effectively in dynamic environments.

Finally, we examine how remote I/O devices are optimizing automation control systems, allowing for enhanced control, reduced downtime, and greater flexibility in operations. These devices are critical in ensuring that automation systems stay connected and responsive, even in the most challenging environments.

Whether you're an industry veteran or newcomer, this issue offers actionable insights and the latest developments to keep you ahead. We welcome your feedback as we continue exploring technologies shaping the future.

Optimizing industry 4.0 communication architectures using multi-protocol I/O hubs and converters

By Jeff Shepard
Contributed By DigiKey's
North American Editors

Communication protocols are important in supporting real-time data transfers and control in Industry 4.0 and Industrial Internet of Things (IIoT) networks. Sensors, actuators, motor drives, and controllers all have specific communication needs. There's no "one size fits all" communication protocol.

While no single protocol suits every application's requirement, diverse devices often need to be linked. Sensors must be linked to controllers, and controllers must connect with various system elements that use different protocols like IO-Link, Modbus, and multiple forms of Ethernet.

In many instances, the entire machine needs to connect with the Cloud. That results in complex communication architectures with a myriad of protocols. To address that challenge, machine designers can turn to multi-protocol input/output (I/O) masters, hubs, and converters.

This article begins with a review of common Industry 4.0 communication protocols and where they fit into the networking hierarchy. It then presents a series of I/O masters, hubs, and converters from Banner Engineering, reviews their operation, and discusses how they can facilitate complex Industry 4.0 and IIoT communication architectures.

What is the OSI seven-layer model?

Network communication protocols are often described in the context of the Open Systems Interconnection (OSI) seven-layer model. The model starts with three media layers that deal with hardware considerations, such as physical, data link, and network connections.

Data addressing is the focus of the next three layers, which include the transport, session, and presentation processes.

The seventh level of the model is the application layer, which provides the interface between the user and the network. Protocols like Modbus and PROFINET reside in this layer. The OSI model is more loosely related to other protocols like EtherNet/IP.

In the case of EtherNet/IP, the application layer includes processes like web access (HTTP), e-mail (SMTP), file transfers (FTP), etc. The three Host layers implement the Transmission Control Protocol/Internet Protocol (TCP/IP) processes for establishing sessions, making error corrections, etc. The Media layers include the physical 10 Base-T connection and the implementation of the Ethernet data link and network connections (Figure 1).

Where does IO-Link fit in?

IO-Link is a single-drop digital communication interface (SDCI) for small sensors, actuators, and similar devices. It extends bidirectional communications down to individual devices on the factory floor. It's specified in IEC 61131-9 and is designed to be compatible with industrial network architectures based on Modbus, PROFIBUS, EtherNet/IP, etc.

IO-Link uses a Master device to connect IO-Link devices to higher-level protocols like Modbus that provide connections to data-consuming devices like programmable logic controllers (PLCs), human-machine interfaces (HMIs), a cloud data service (CDS), and so on. At the lowest level, IO-Link uses Hubs to aggregate multiple devices and feed the data up to a Master device. In addition, an analog voltage to the IO-Link Converter can be used to add analog sensors to the IO-Link network (Figure 2).

The Open Systems Interconnection (OSI) model

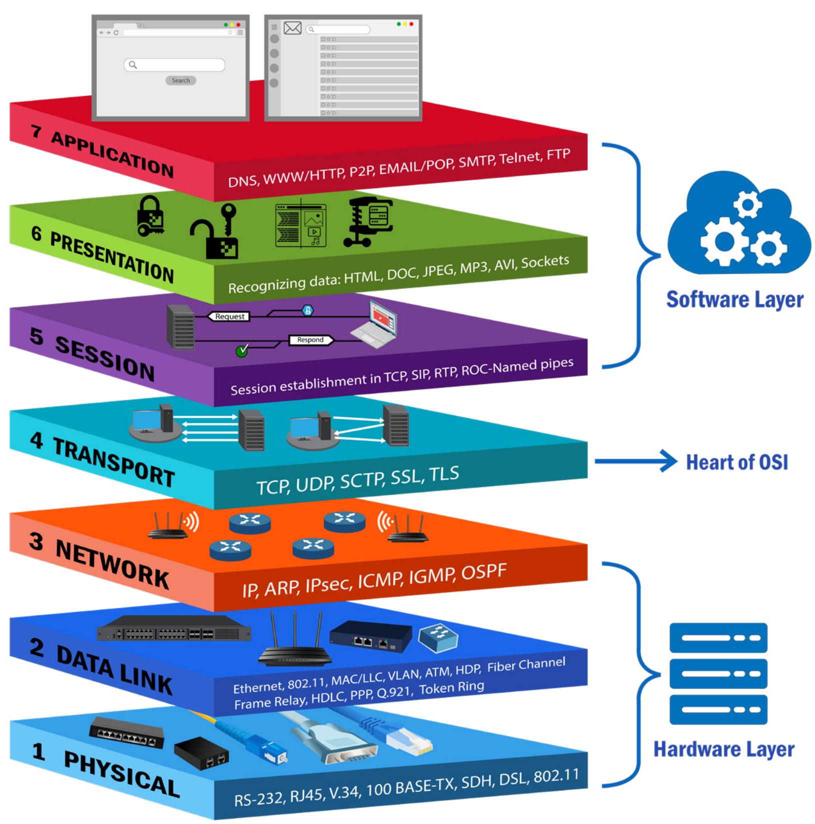


Figure 1: How EtherNet/IP relates to the OSI seven-layer model.

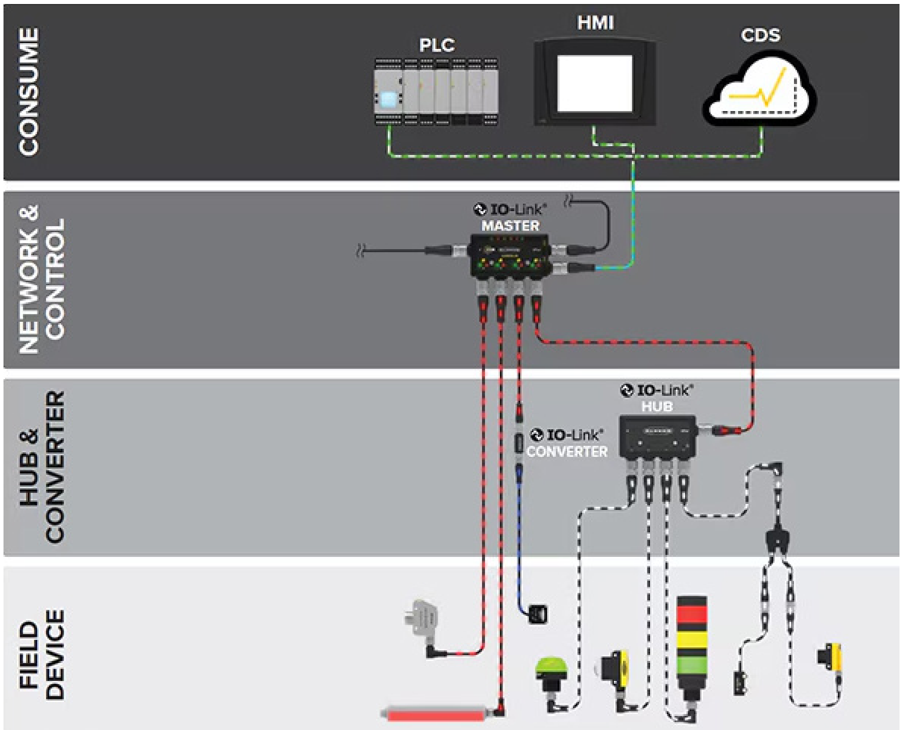


Figure 2: IO-Link converters, hubs, and masters can collect data from field devices and push it up to data consumers like PLCs, HMIs, and CDS. (Image source: Banner Engineering)

Why combine IO-Link with other protocols?

Mass customization and flexible production processes are distinguishing characteristics of Industry 4.0. Combining IO-Link with other protocols can increase the flexibility and versatility of Industry 4.0 factories. Beneficial characteristics of IO-Link include:

Modbus has limited support for analog devices like certain sensors, while IO-Link is compatible with both digital and analog devices.

Increased factory automation and expansion can be facilitated using a gateway that supports both IO-Link and higher-level protocols like Modbus TCP or EtherNet/IP and can function as a bridge between a field-level sensor network and an industrial network communications backbone.

IO-Link increases operational efficiency by providing a standardized, uniform configuration process for all sensors, and it can be used to replace defective sensors automatically when an identical model is used.

The data collection and communication capabilities of IO-Link provide increased visibility into the operation of individual sensors, as well as dispersed sensor networks, and speed the data up to a PLC and the Cloud.

How do you combine Modbus and IO-Link?

One of the first tools to consider is a hybrid I/O Modbus hub like the 8-port bimodal to Modbus R95C-8B21-MQ. This discrete bimodal to Modbus hub connects two discrete channels to each of the eight unique ports, providing access to monitor and configure those ports via Modbus registers.

Hybrid I/O Modbus hubs are available with four configurable analog inputs (voltage or current) and four analog outputs, plus eight configurable PNP (sourcing) or NPN (sinking) discrete inputs and outputs for increased application flexibility.

DXMR90-X1 industrial controllers can be used as a platform for IIoT solutions. They can consolidate data from multiple sources for local data processing and accessibility. The DXMR90 contains individual Modbus clients supporting simultaneous communication to up to five independent serial networks.

The DXMR90-X1 includes one female M12 D-Code Ethernet connector and four female M12 connections for Modbus master connections. Other DXMR90 models are available with two female M12 D-Code Ethernet connectors and four female M12 connections for Modbus client connections or with one female M12 D-Code Ethernet connector and four female M12 connectors for IO-Link master connections.

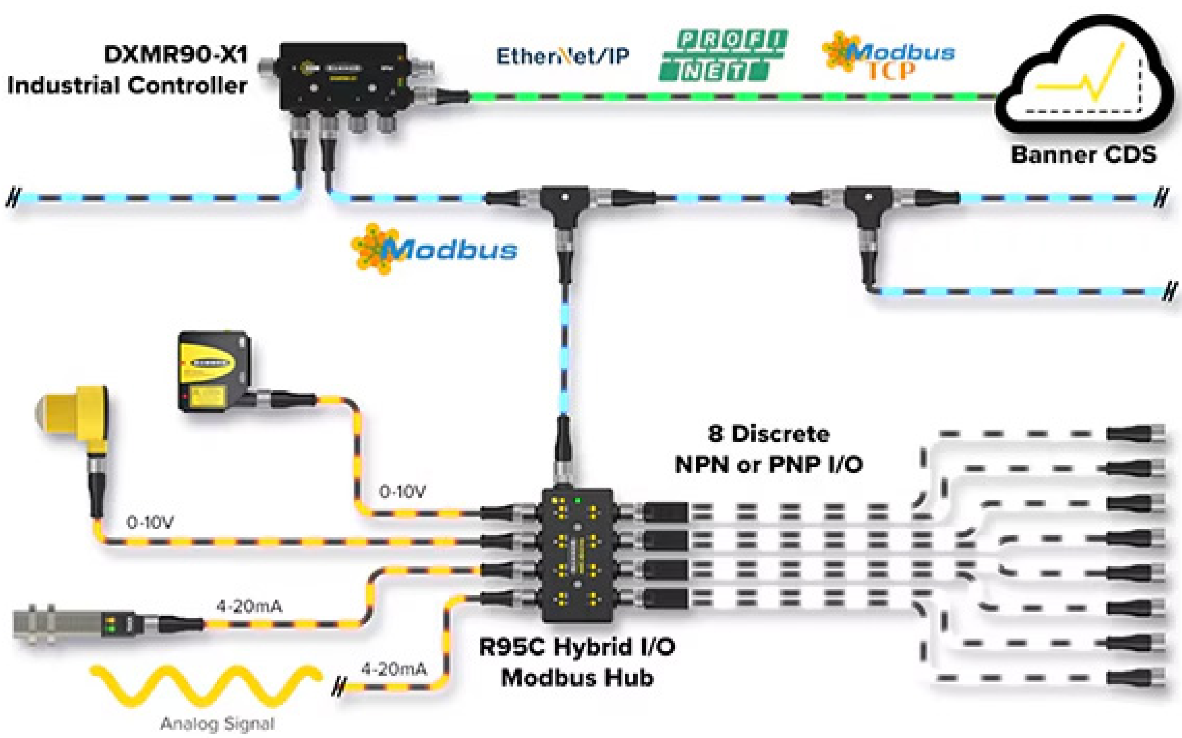
All DXMR90 controllers also include one male M12 (Port 0) for incoming power and Modbus RS-485 and one female M12 for daisy chaining Port 0 signals. Additional features of the DXMR90-X1 include (Figure 3):

- Converts Modbus RTU to Modbus TCP/IP, EtherNet/IP, or Profinet
- Internal logic driven by action rules for easy programming, or MicroPython and ScriptBasic for developing more complex solutions
- Support for Internet protocols, including RESTful and MQTT
- Well-suited for IIoT data analytics, condition monitoring, predictive maintenance, overall equipment effective (OEE) analysis, diagnostics, and troubleshooting

What is multi-protocol support?

The DXMR110-8K 8-port IO-Link master is a compact, multi-protocol smart controller that consolidates, processes, and distributes IO-link and discrete data from multiple sources. Connections include:

Figure 3: The DXMR90-X1 controller can be used in conjunction with the R95C hybrid I/O Modbus hub. (Image source: Banner Engineering)



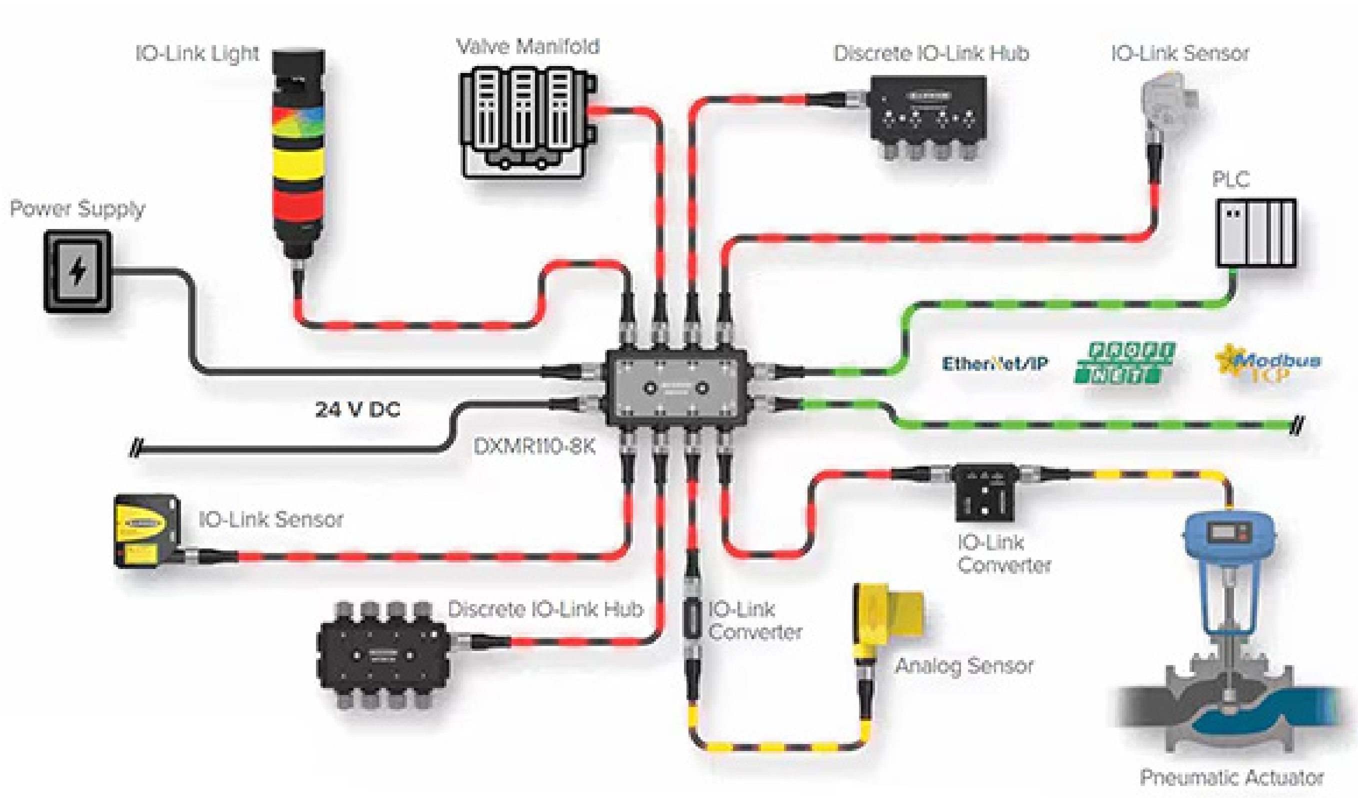


Figure 4: The DXMR110-8K 8-port IO-Link master is a multiprotocol smart controller. (Image source: Banner Engineering)

- Two female M12 D-Code Ethernet connectors for daisy chaining and communication to a higher-level control system
- Eight female M12 connections for IO-Link devices
- One male M12 for incoming power and one female M12 for daisy chaining power

The DXMR110 supports cloud connectivity and includes advanced programming features. ScriptBasic and action rules programming can be used to create and implement custom scripts and logic for optimized automation processes.

The internal processing power of the DXMR110 can be used to move data processing to the edge, minimizing the need for hardware in the control cabinet and eliminating I/O cards on a PLC. Integrated cloud connectivity can make data accessible from anywhere in the world. Finally, the IP67 housing simplifies installation in any location by eliminating the need for a control cabinet (Figure 4).

There's more

The devices presented so far are not the only options for implementing multi-protocol industrial communication solutions. Machine designers can employ a range of Banner Engineering's remote I/O blocks to optimize system design, space efficiency, and performance.

Banner offers in-line converters and masters with over-molded designs that meet the ingress performance (IP) demands of IP65, IP67, and IP68. The R45C series in-line converters and masters provide a gateway for connecting IO-Link devices to an IIoT network or system controllers using the Modbus RTU protocol. Model R45C-2K-MQ connects two IO-Link devices to a Modbus RTU interface.

When analog signals are required, designers can turn to the R45C-MII-IIQ Modbus for a dual analog in-line I/O converter. Functions include:

- Analog in. When the converter receives an analog input, it sends the numerical representation of the value to the corresponding Modbus register. It can accept analog inputs from 0 to 11,000 mV or 0 to 24,000 µA.

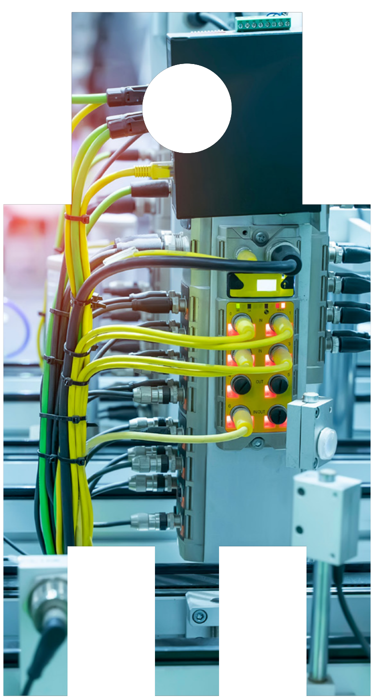


Figure 5: Examples of the form factors and configurations of Banner's remote I/O solutions for IO-Link integration. (Image source: DigiKey)

- Analog out. The converter outputs an analog value corresponding to a numerical input. Analog outputs can range from 0 to 11,000 mV or 0 to 24,000 µA.
- Process data values outside the valid range (POVR) can also be detected and processed, and the converter sends a signal to the system.

When a single analog input needs to be converted to an IO-Link signal, designers can use the S15C-I-KQ. This cylindrical analog current to IO-Link converter connects to a 4 to 20 mA current source and outputs the corresponding value to an IO-Link master.

Banner offers a variety of Modbus RTU I/O blocks that support connections of multiple analog and discrete devices connected to a Modbus or IO-Link network. They can be mixed or matched to support flexible system designs and interoperability (Figure 5).

Can wireless protocols be integrated?

Banner's Sure Cross DSX80 Performance wireless I/O network solution enables wireless connectivity. It can be used independently or connected to a host PLC using Modbus or a personal or tablet computer.

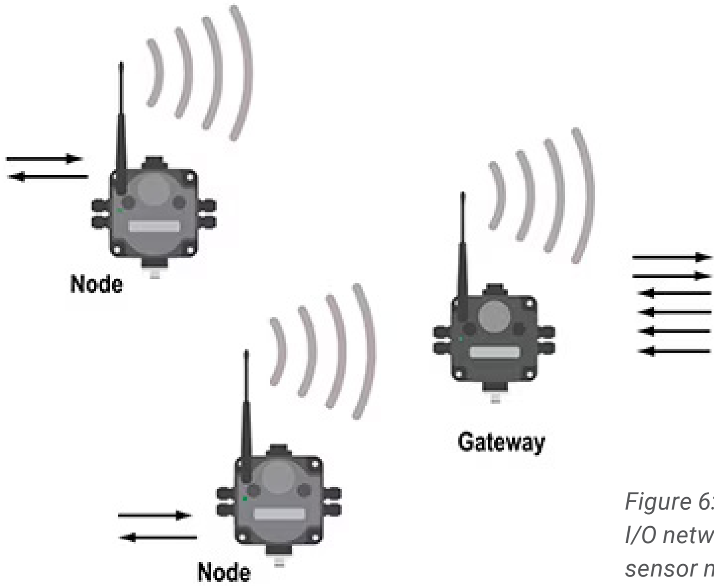


Figure 6: Banner's Sure Cross DSX80 Performance wireless I/O network solution includes a gateway and one or more sensor nodes. (Image source: Banner Engineering)

The basic system architecture comprises a Gateway and one or more Nodes (Figure 6).

Implementing a Sure Cross DX80 Performance wireless network involves three elements: the network topology, master and slave relationships, and the time division multiple access (TDMA) architecture.

A star topology is used where the master maintains a separate connection with each node. If the connection between a node and the master fails, connectivity with the rest of the nodes is unaffected.

A gateway like the DX80G2M6-QC is the master device and initiates all communication with the slave devices. A gateway that uses a Modbus RTU RS-485 connection acts as a slave to a Modbus RTU host controller. A single wireless network can include up to 47 slave nodes.

Slave devices can be wireless nodes like the DX80N9Q45DT dual thermistor temperature sensor node, the DX80N9Q45PS150G pressure sensor node, or vibration and humidity sensors.

Slave devices can't initiate communication with the gateway or communicate with each other. A serial data radio like the DX80SR9M-H can be added to extend network coverage to accommodate physically large installations.

TDMA is the key to combining robust connectivity with minimal energy consumption. The TDMA controller in the gateway assigns each node a specific time to send and receive data. The gateway always has device ID number 0. Nodes may be numbered in any order using device IDs 1 through 47.

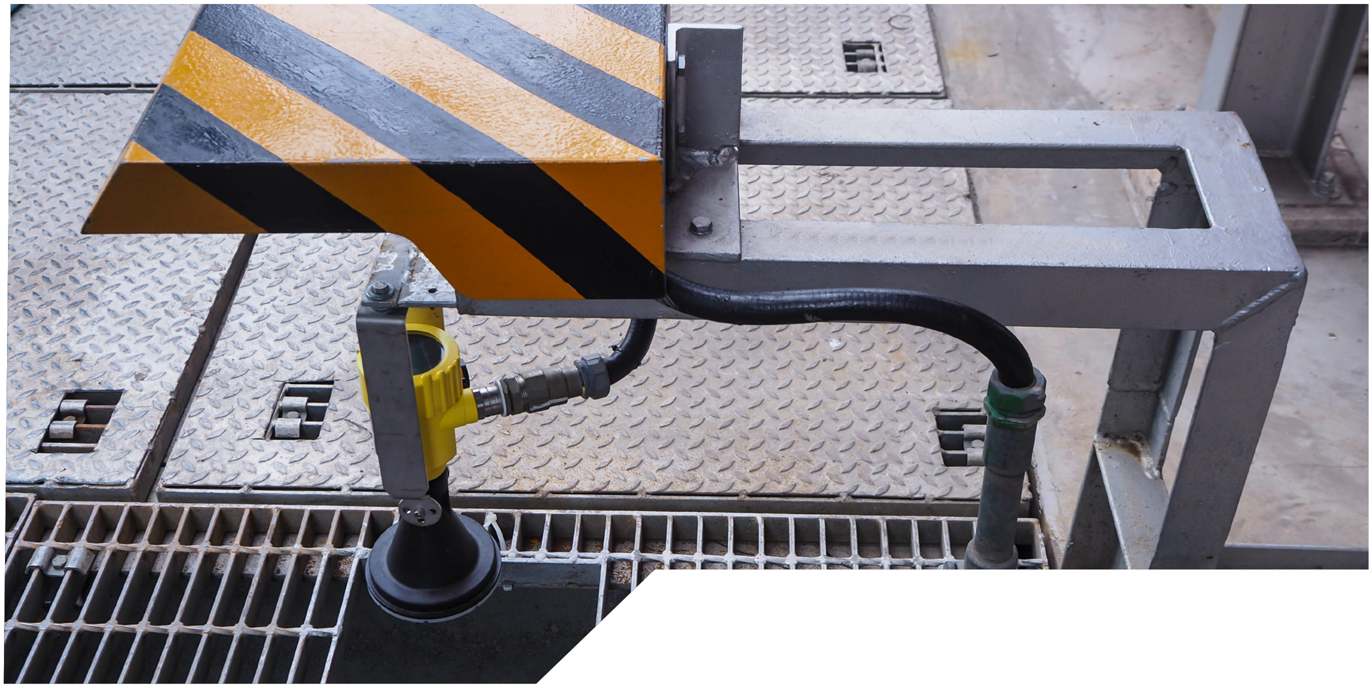
Setting specific communication times for individual nodes optimizes efficiency by eliminating the possibility of conflicts between nodes. It also enables nodes to enter a low-power state between communications, only waking up at the assigned time. Turning off the radio between transmissions conserves power and extends the operating life of battery-powered nodes.

Conclusion

Access to multiple communication protocols, like IO-Link, Modbus, EtherNet/IP, and so on, is necessary to support the efficient operation of Industry 4.0 and IIoT networks. Banner Engineering provides designers with a comprehensive selection of IO-Link hubs, converters, and masters in various form factors to support optimized communication solutions.

How to select and apply radar for sensing in harsh environments

By Kenton Williston
Contributed By DigiKey's
North American Editors



Outdoor and industrial applications and other rugged environments present conditions that can interfere with remote sensing technologies such as ultrasonic sensors. Inclement weather, dust and debris, and complex sensing environments are some issues that can impact standard sensors.

Radar sensors can address these challenges, detecting moving and stationary targets in various ambient conditions. This article reviews the scenarios where radar can outperform alternative options. It examines several types of radar sensors from Banner Engineering, their applications, and design considerations to remember when selecting a sensor.

Why use radar sensors?

Radar is robust in the face of rain, dust, and other common airborne substances, works equally well in bright and unlit spaces, and is unaffected by temperature variations and wind. It can detect surfaces with a wide range of finishes, geometries, and colors, and also penetrate non-conductive materials, allowing radar sensors to peer inside containers.

In addition, radar can be used over relatively long distances while also being resistant to crosstalk, giving it advantages for short-range applications where sensors are in close proximity.

How radar works

Radar works by bouncing electromagnetic waves off target objects, determining distance based on the time it takes for a signal to return. Radar sensors use two main technologies: frequency-modulated continuous wave (FMCW) and pulsed coherent radar (PCR).

FMCW radar emits a constant stream of radio waves, allowing for uninterrupted monitoring of moving and stationary objects. PCR sensors send radio waves in pulses, typically using low-power transmitters. This makes PCR sensors better suited to short-range applications.

Range and material sensitivity are also heavily influenced by the operating frequency. Lower frequencies are better for long-range detection and work well with materials that have high dielectric constants, such as metals and water. Higher frequencies offer greater accuracy and are better suited for detecting smaller objects and a wider variety of materials.

Beam patterns and sensing zones

Radar sensors can be optimized to focus on specific areas of interest and track one or multiple objects. Key parameters include the beam pattern, sensing zones, and dead zones.

Radar sensors emit radio waves in a specific pattern, defined by horizontal and vertical angles. Narrow beam patterns offer precise detection and longer range, while wide beam patterns cover larger areas and better detect irregularly shaped objects.

Many radar sensors allow the configuration of multiple sensing zones within their beam pattern. This feature enables more complex detection scenarios, such as setting different parameters for near and far zones in collision avoidance applications.

The dead zone is the area immediately in front of the sensor where detection is unreliable. Higher-frequency sensors generally have shorter dead zones.

Identifying the optimal radar sensor: start with the basics

There are numerous factors to consider when selecting a radar sensor. In addition to the basic operating parameters, radar sensors have various features that impact their cost, durability, and ease of use. Figure 1 provides a flow chart that illustrates some of these decision points using radar sensors from Banner Engineering as examples.

The Q90R series from Banner Engineering is a useful starting point. These FMCW sensors operate at 60 gigahertz (GHz) to balance range, accuracy, and material detection capabilities. They have a sensing range of 0.15 meters (m) to 20 m, a dead zone of 150 millimeters (mm), and two configurable sensing zones.

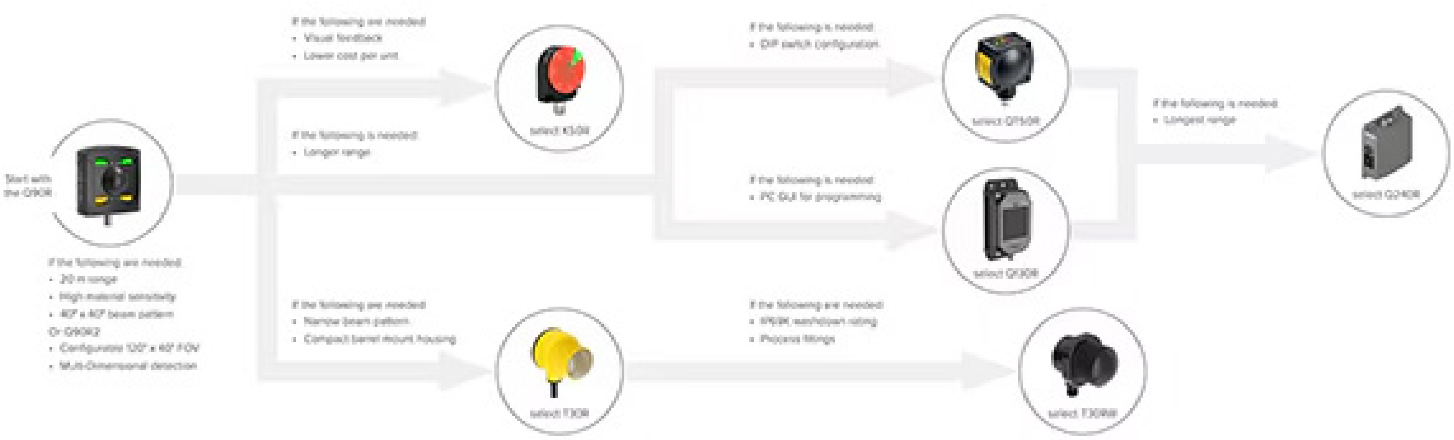


Figure 1: Shown is a flowchart that illustrates the process of choosing a radar sensor. (Image source: Banner Engineering)

Figure 3: The T30R series operates at 122 GHz, has a beam of 15° x 15°, and offers precise detection. (Image source: Banner Engineering)

Figure 2: The Q90R2-12040-6KDQ FMCW radar sensor operates at 60 GHz, can track two targets, and has a wide, configurable field of view. (Image source: Banner Engineering)

An example use case for these sensors is detecting when trucks arrive at a loading dock. Here, the relatively wide 40° x 40° beam pattern makes it easier to find a mounting location that keeps the dock in view.

The Q90R2-12040-6KDQ (Figure 2) builds on these capabilities with a wide, configurable field of view (120? x 40?) and the ability to track two targets, allowing them to tackle more complex sensing scenarios.

Selecting radar for narrow beam applications

In some applications, radar needs to pick out a small target. Here, a sensor from the T30R series (Figure 3) is a good choice. The sensors have a beam pattern of 15° x 15° or 45° x 45°, an operating frequency of 122 GHz, a sensing range of 25 m, a dead zone of 100 mm, and two configurable sensing zones.

With its narrow beam pattern and high operating frequency, this sensor family offers precise detection in specific areas. For example, they can be used to monitor levels within narrow containers.

The T30RW version comes in an IP69K housing suitable for high-pressure, high-temperature wash-down environments such as car washes. It has a sensing range of 15 m and a beam pattern of 15° x 15°.

Selecting a radar sensor for visual feedback

While radar sensors typically integrate into larger automation systems, having an at-a-glance status indicator can be helpful. At an electric vehicle (EV) charging station, for example, a visual display can help drivers correctly position their vehicles.

For applications like these, the built-in LEDs of the K50R series play a valuable role.

Particularly noteworthy are the Pro models, like the K50RPF-8060-LDQ (Figure 4), which offers a colorful, easy-to-interpret display.

Figure 4: The K50RPF-8060-LDQ incorporates LEDs for visual feedback. (Image source: Banner Engineering)

Key specifications for the K50R series include an operating frequency of 60 GHz, a sensing range of 5 m, a dead zone of 50 mm, two configurable sensing zones, and beam patterns of 80° x 60° or 40° x 30°.

Selecting a long-range radar sensor

For applications that require sensing over longer distances, radar operating at 24 GHz is often the best choice. These lower-frequency devices, such as the QT50R series, have a sensing range of 25 m that is valuable for applications such as collision avoidance for mobile equipment. The series also has one or two configurable sensing zones and a beam pattern of 90° x 76°. Its dead zone measures 400 mm for moving objects and 1000 mm for stationary objects.

A notable feature of the QT50R is its ability to be configured through DIP switches. This enables simple setup in the field. However, some applications call for more sophisticated configurations.

For example, the Q130R sensor (Figure 5) is designed for applications requiring sophisticated detection capabilities and advanced configuration options. It operates at 24 GHz, has a range of 40 m, a beam pattern of 90° x 76° or 24° x 50°, a dead zone of 1000 mm, and provides accurate detection of moving and stationary objects.

Notably, the Q130R employs a PC-based graphical user interface (GUI) for complex setup and fine-tuning. For example, it can be used for positioning feedback in a busy rail yard. In this application, the sensor can be configured to ignore trains parked in the background on one track while recognizing other trains as they pass in front.

Conclusion

Radar sensors are uniquely capable of operating in a wide range of outdoor and harsh environments. To maximize the benefits of radar technology, it is essential to analyze the application requirements and select a sensor with the right operating frequency and beam pattern, among other specifications. With a well-chosen radar, many challenging remote sensing applications can be addressed.

Figure 5: The Q130R radar sensor is designed for applications requiring sophisticated detection capabilities and provides accurate detection of moving and stationary objects. (Image source: Banner Engineering)

Sorting through proximity and distance sensor technology choices

By Jeff Shepard
Contributed By DigiKey's
North American Editors

Using proximity and distance sensors to detect the presence and location of items without physical contact can be an important aspect of controlling industrial processes like material handling, agricultural machinery, fabrication and assembly operations, and food, beverage, and pharmaceuticals packaging.

These sensors are available using a variety of technologies including photoelectric, laser, inductive, capacitive, magnetic, and ultrasonic. When determining the best choice for a given application, factors like range, size, accuracy, sensitivity, resolution, and cost need to be considered.

A key factor in many applications is the material of the object to be detected. Some sensors behave differently with hard versus fibrous surfaces, and other sensors can be affected by the color or reflectivity of the object.

This article reviews commonly available non-contact proximity sensor technologies, looking at how they work, their basic performance characteristics and exemplary sensors from SICK, along with some intended applications.

Photoelectric sensors

Photoelectric sensors, like the W10 photoelectric proximity sensors from SICK, are simple to use and install and are available with a range of features suited for numerous applications. The sturdy design of the W10 sensors makes them suitable for precise object detection in challenging environments. The integrated touchscreen speeds parameter setting and sensor deployment (Figure 1).

Figure 1: The touchscreen on these photoelectric sensors can speed commissioning and deployment. (Image source: SICK)

Available teach-ins enable designers to adapt these sensors to specific application requirements. In addition, integrated functions like speed settings, standard and precision measurement modes, and foreground and background suppression mean a single sensor can be used in an array of applications. The sensor series includes four variants, which differ in their operating distances and mounting options.

Background suppression

Photoelectric proximity sensors with background suppression (BGS) use triangulation between the sending and the receiving elements. Signals from objects behind the set sensing range are suppressed. In addition, SICK's BGS technology ignores highly reflective objects in the background and can handle difficult ambient lighting conditions.

Background suppression is especially useful when the target object and the background (like a conveyor belt) have similar reflectivity or if the background reflectivity is variable and can cause interference with detection.

Foreground suppression

Photoelectric proximity sensors with foreground suppression (FGS) can detect objects at a defined distance. All objects between the sensor and the sensing distance (set to the background) are detected. To ensure reliable sensing, the background needs to be relatively bright and should not vary in height.

When objects are on a reflective surface like a white or light-colored conveyor belt, foreground suppression can improve detection. Rather than detecting light reflecting from the object, the sensor detects the object by the absence of the light reflected by the conveyor belt.

Retro-reflective

In a retro-reflective sensor, the emitted light hits a reflector, and the reflected light is evaluated by the sensor. Errors can be minimized by using polarizing filters. Stretch films and plastic wrappings that are transparent can interfere with these sensors. Reducing sensor sensitivity can help overcome those challenges. In addition, the replacement of standard IR light emitters with lasers can enable longer sensing ranges and higher resolution.

Retro-reflective sensor performance can be improved using a lower-than-normal switching hysteresis. In these designs, even minimal light attenuation between the sensor and reflector, for example, caused by glass bottles, can be reliably detected. SICK also offers a monitoring system called AutoAdapt that continuously regulates and adapts the switching threshold in response to the gradual buildup of contamination that could lead to failure of the sensing system.

Through-beam

In contrast with retro-reflective sensors, through-beam sensors use two active devices: a sender and a receiver. Through-beam sensing enables longer sensing ranges. The replacement of IR emitters with laser diodes can further enhance sensing distance while maintaining high resolution and precise sensing.

Fiber-optic

Fiber-optic sensors are a variation on through-beam designs. In a fiber-optic photoelectric sensor, the sender and receiver are copackaged in a single housing. Separate fiber optic cables are used by the sender and receiver. These sensors are especially suited for use in high-temperature applications and in hazardous and harsh environments.

Photoelectric sensor arrays

The RAY26 Reflex Array family of photoelectric sensors like the model 1221950 enable reliable object detection of flat objects as

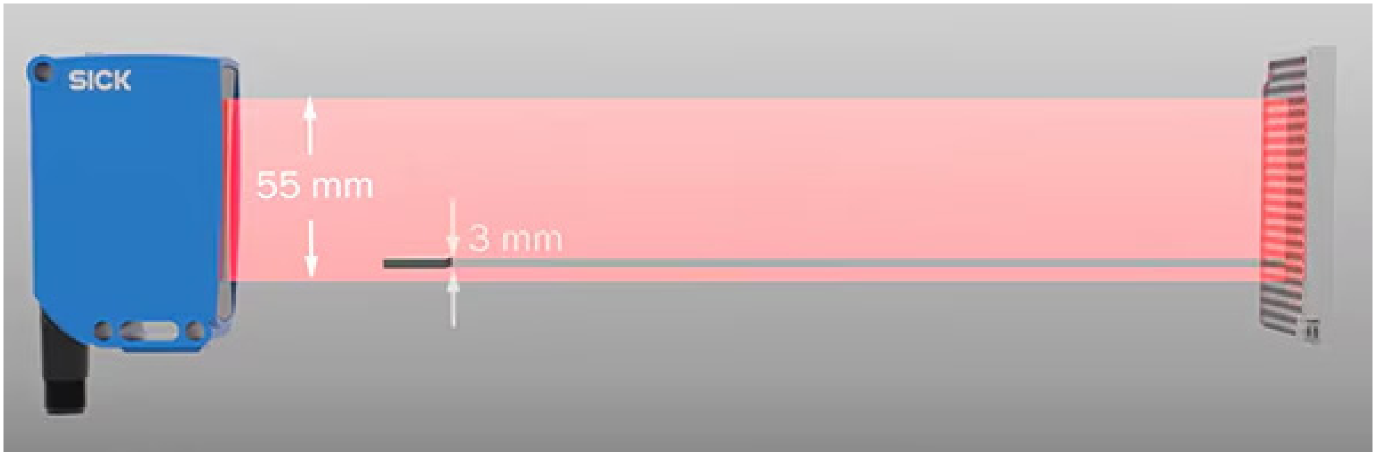


Figure 2: Photoelectric sensor arrays can detect objects as small as 3 mm in a 55 mm high field. (Image source: SICK)

well as fast commissioning. When combined with a reflector, the photoelectric sensors also detect small, flat, transparent, or uneven objects as small as 3 mm. Within a 55 mm-high uniform light array, the sensors detect the leading edge of the object. This means that even perforated objects can be reliably detected without complex switching (Figure 4).

Laser distance sensors

Designers of applications like level monitoring in storage containers, position detection of objects on conveyors, XY position of the axis in automated forklift systems, vertical positioning of cranes in warehouses and overhead conveyors, and diameter monitoring during coil winding can turn to the DT50 Laser Distance Sensors. These sensors support time of flight (ToF) distance measurements up to several meters using reflected laser light to provide immunity to ambient lighting, and precise and reliable operation.

For example, the DT50-2B215252 has a range of 200 to 30,000 mm and several special features, including:

- Rugged housing with an enclosure rating of IP65 and IP67
- Can provide up to 3,000 distance measurements per second
- Minimum response time of 0.83 ms
- Compact housing supports a range of applications from industrial robots to measuring fill heights of storage containers

High-res measurements using statistics

High-definition distance measurement plus (HDDM+) is a high-resolution ToF measurement technology that can be used in laser distance and light detection and ranging (LiDAR) sensors. In contrast with single-pulse or phase correlation sensing technologies, HDDM+ is a statistical measurement process.

The sensor software statistically evaluates the echoes of multiple laser pulses to filter out interference from sources like panes of glass, fog, rain, dust, snow, leaves, fences, and other objects to calculate the distance to the intended target. The resulting distance measurement can have a high level of certainty even under challenging ambient conditions (Figure 5).

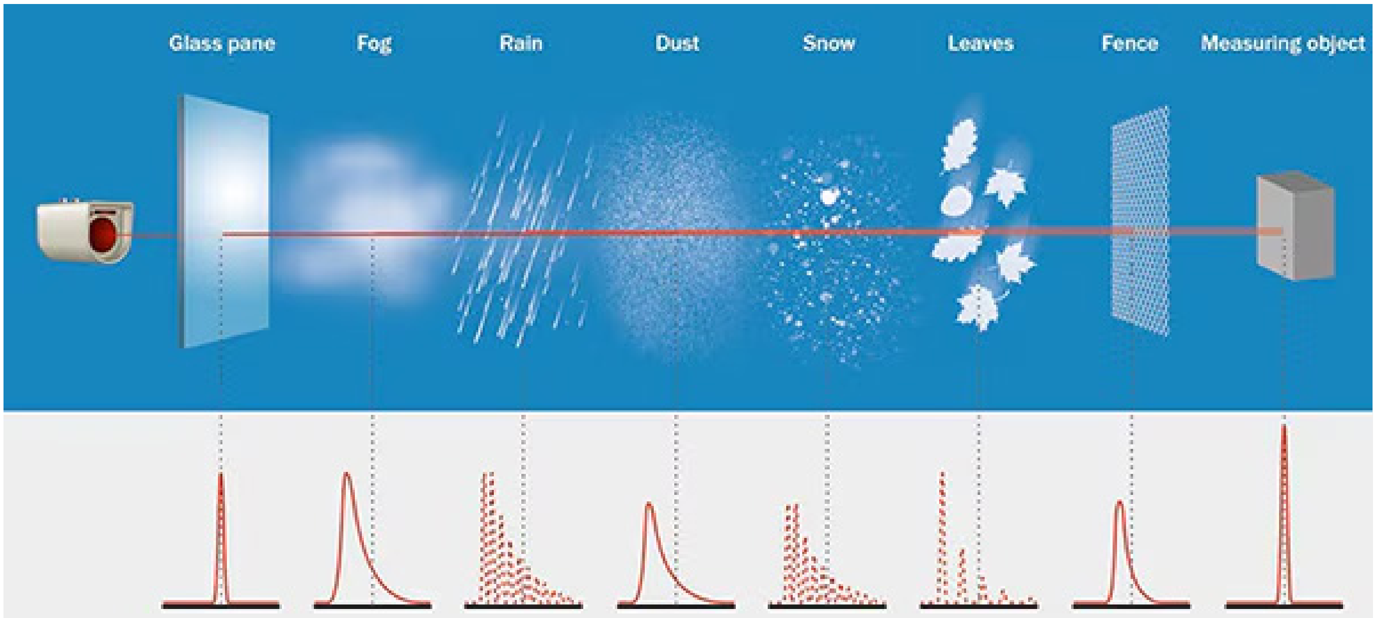


Figure 3: SICK's HDDM+ software uses a statistical evaluation process to eliminate "noise" from items like glass panes, fog, rain, dust, snow, leaves, and fences. (Image source: SICK)

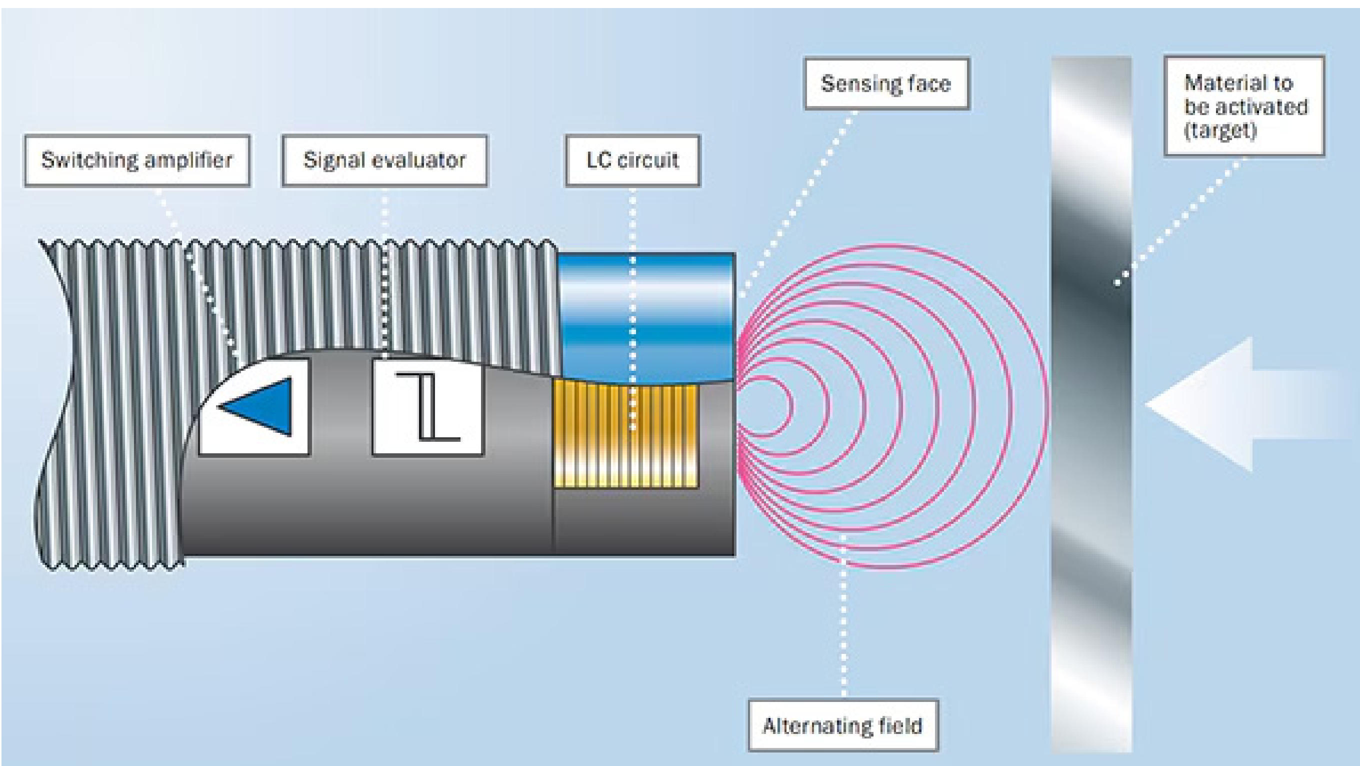


Figure 4: A basic inductive proximity sensor consists of an LC circuit that produces an alternating field, a signal evaluator, and an amplifier. (Image source: SICK)

Typical applications for HDDM+ technology include distance measurement for quality control in electronics production, LiDAR multi-dimensional object detection and position determination in mechanical and plant engineering, and determining the position of industrial cranes or vehicles.

The sensing range of HDDM+ sensors is up to 1.5 km on retro-reflective tape. For example, model DT1000-S11101 has a range up to 460 m with a typical measurement accuracy of ±15 mm for natural objects and an adjustable resolution from 0.001 to 100 mm.

Inductive

Inductive proximity sensors like the IME series from SICK can detect ferrous and non-ferrous metal objects. These sensors consist of an inductor-capacitor (LC) resonant circuit that generates a high-frequency alternating electromagnetic field. The field is dampened when a metallic object enters the detection range. The dampening is detected by the signal evaluation circuit and an amplifier that produces the output signal (Figure 4).

Two important specifications for the sensing distance of several proximity sensor technologies are the nominal sensing distance (Sn) and the secured sensing distance (Sa). Sn does not consider manufacturing tolerances or external influences like operating temperature. Sa takes into consideration both manufacturing tolerances and variations in operating conditions. Sa is typically about 81% of the value of Sn. For example, for the model IME08-02BPSZT0S inductive sensor, Sn is 2 mm and Sa is 1.62 mm.

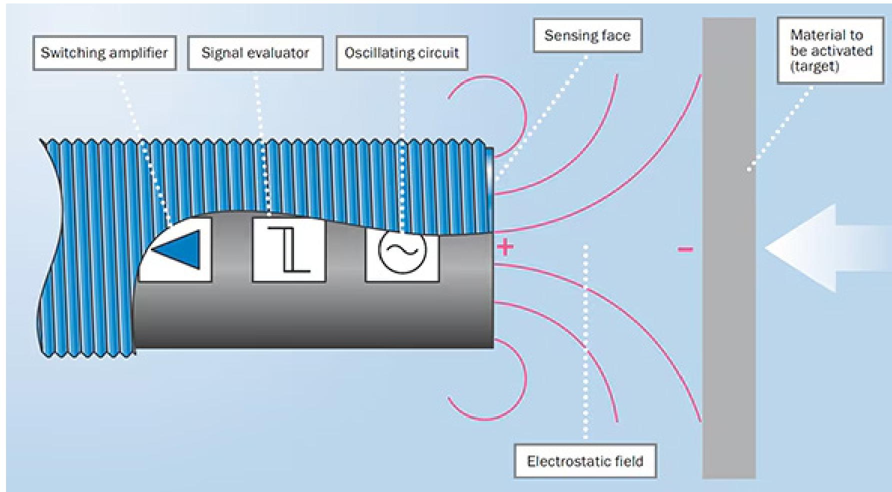


Figure 5: In a capacitive proximity sensor, an oscillating circuit produces an electrostatic field that changes characteristics when the target to be sensed enters the field. (Image source: SICK)

Capacitive sensing

Like inductive sensors, capacitive proximity sensors use an oscillator. In this case, an open capacitor is used where the active electrode in the sensor produces an electrostatic field relative to ground. These sensors can detect the presence of a wide range of materials including metallic and non-metallic objects.

When an object enters the electrostatic field, the amplitude of the oscillations in the resonant circuit change based on the dielectric properties of the material. The signal evaluator detects the change, and an amplifier produces the output signal (Figure 5).

Like inductive proximity sensors, there are several specifications related to the sensing distance of capacitive proximity sensors including Sn, Sa, and a reduction factor. For example, the model CM12-08EBP-KC1 has an Sn of 8 mm and a nominal Sa of 5.76 mm.

The object to be sensed must be at least as large as the sensor face and the sensing distance varies with the reduction factor of the material. Reduction factors are related to the dielectric constant of the material and can vary from 1 for metals and water to 0.4 for polyvinyl chloride (PVC), 0.6 for glass and 0.5 for ceramics.

Magnetic

Magnetic proximity sensors respond to the presence of a magnet. Magnetic proximity sensors from SICK use two detection technologies:

- Giant magneto resistive (GMR) sensors are based on resistors that change their value in the presence of a magnetic field. A Wheatstone bridge is used to detect the change in resistance and produce an output signal. The MZT7 cylinder sensors, like the MZT7-03VPS-KP0 designed for use with T-slot cylinders, use GMR technology to detect piston positioning in pneumatic drives and in similar applications.
- LC technology uses a resonant circuit that resonates with a small amplitude. If an external magnetic field approaches, the resonant amplitude increases. The increase is detected by a signal evaluator and an amplifier produces the output signal (Figure 6). The MM08-60APO-ZUA has an Sn of 60 mm and an Sa of 48.6 mm.

Ultrasonic sensors

For objects up to 8 m away, designers can turn to ultrasonic sensors like the UM30 family from SICK. These sensors have integrated temperature compensation to improve

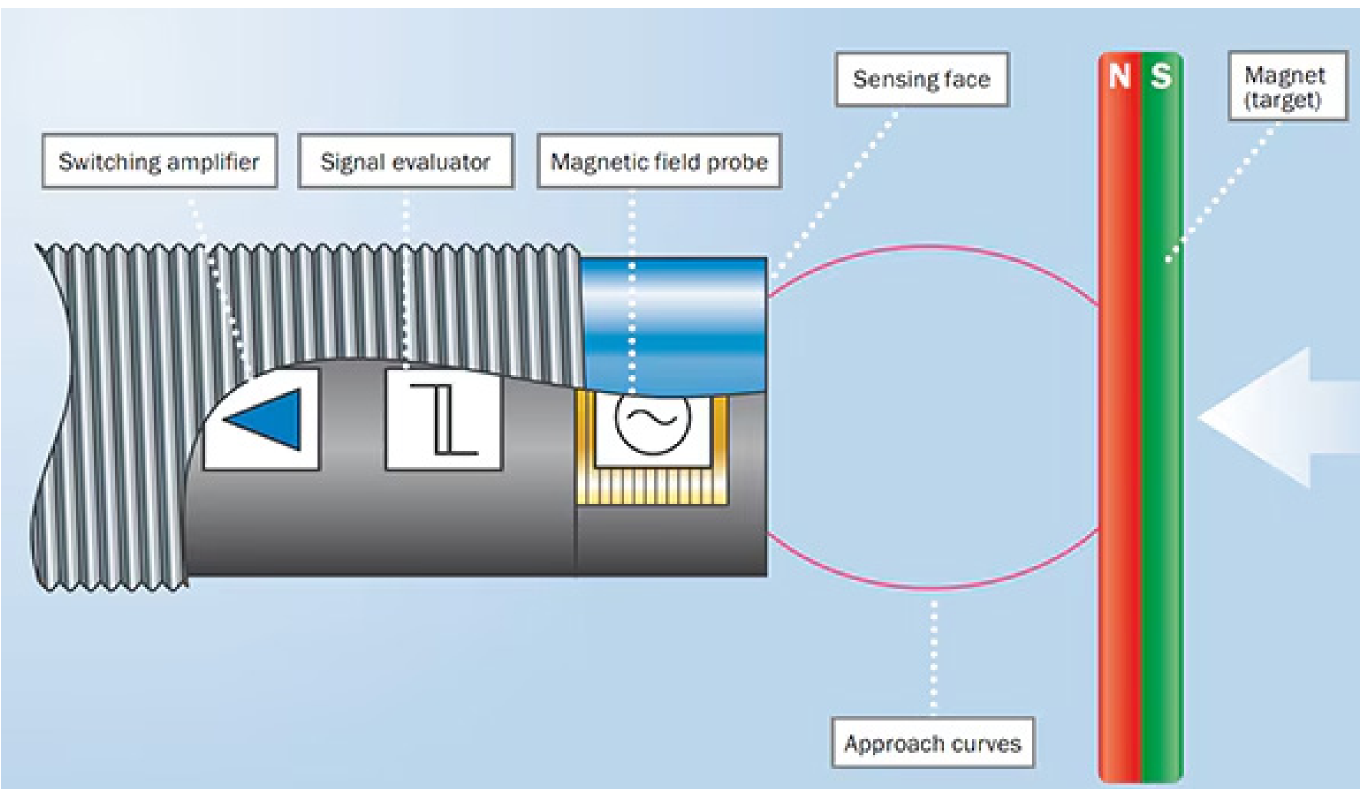


Figure 6: In a magnetic proximity sensor, the field probe can use GMR or LC technology. (Image source: SICK)

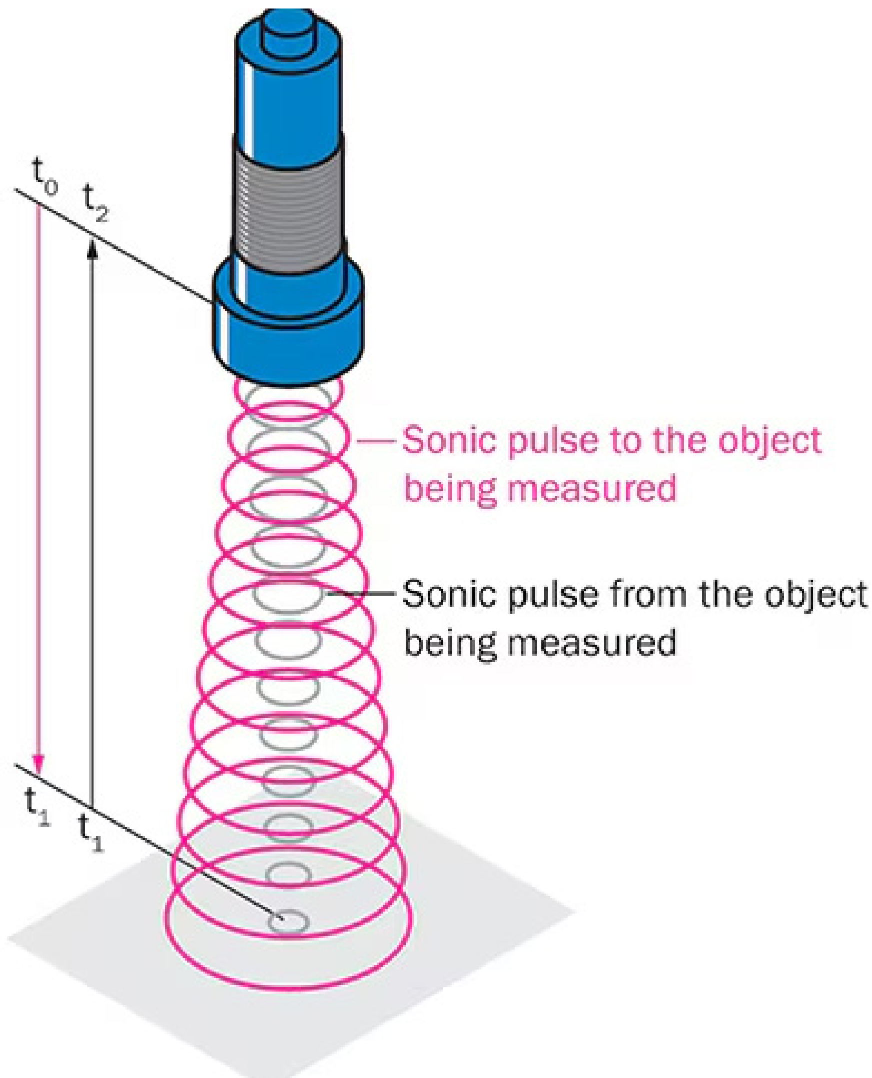
measurement accuracy and provide color-independent object detection, immunity to dust, and operation up to +70°C. They measure distances based on time-of-flight technology where the distance is equal to the speed of sound multiplied by the total acoustic time of flight (t_2) with the total divided by 2 (Figure 6).

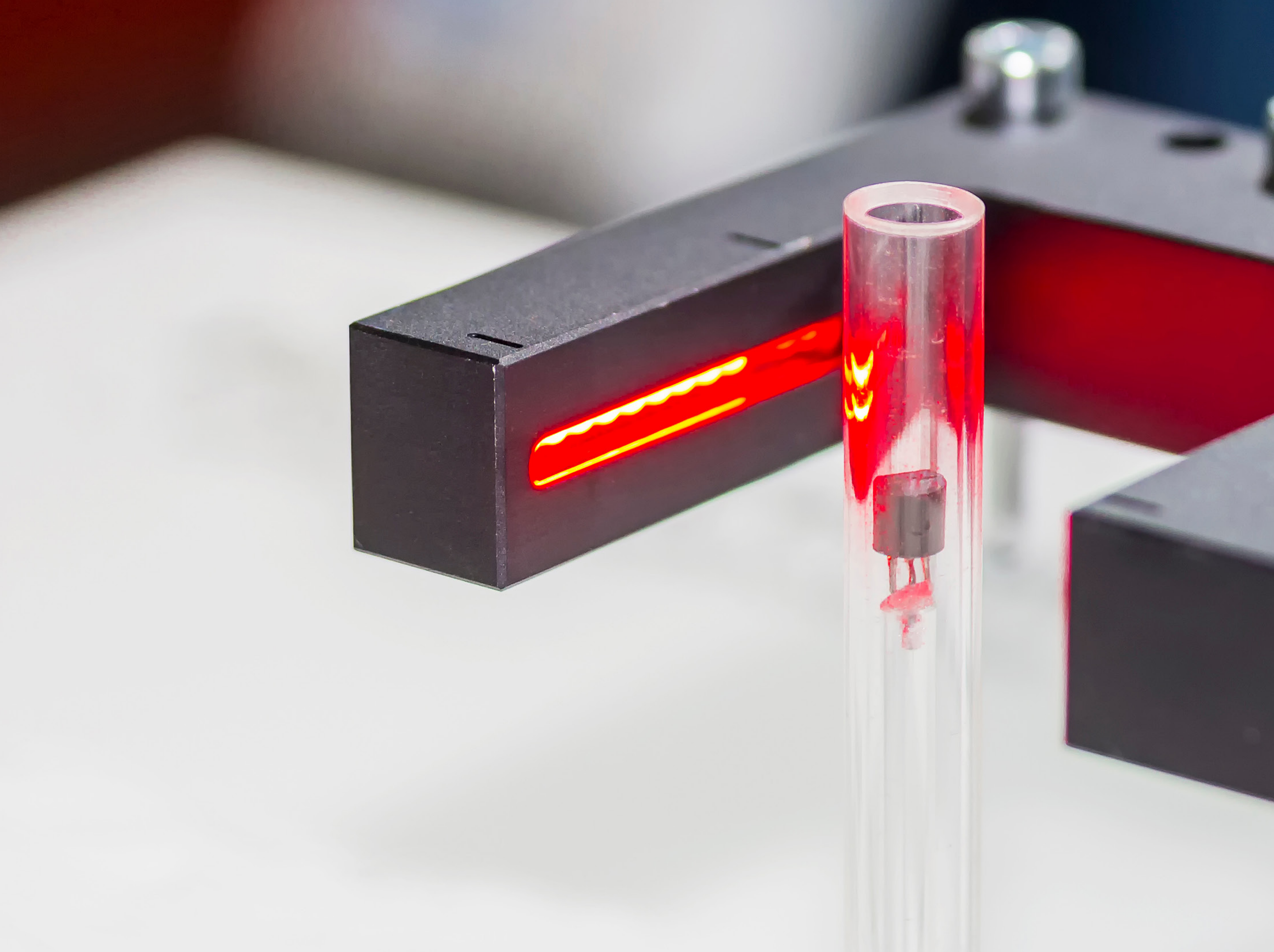
Ultrasonic sensors like model UM30-212111 are suited for applications like empty tote monitoring. An internal temperature monitor produces a measurement accuracy of ±1%. These color-independent sensors can detect hard to distinguish objects even in the presence of dirt and dust.

Conclusion

The good news is that there's a wide range of proximity and distance sensor technology choices. That means there's a solution for every application requirement. The challenge is sorting through the many choices and finding the optimal solution for detection of specific materials under actual application and operating conditions.

Figure 7: Ultrasonic sensors can measure distance based on the total time of flight (t_2) of the sound waves. (Image source: SICK)





Things to consider when selecting an industrial photoelectric sensor

By Eric Halvorson

Simply put, sensors are the eyes and ears of industrial automation. Regardless of the application, without sensors automation is simply not possible in today's manufacturing process. There are many different ways in which we measure our environment through sensors. Whether that is vibration, object detection, temperature or humidity, speed, strain, or a hundred other different sensing technologies, sensors enable the world of industrial automation. One of the many different sensor technologies that we will be talking about here is photoelectric sensors.

Photoelectric sensors are utilized in industrial applications to detect object presence. There are three types, Through-Beam, Retroreflective, and Diffused. They can be used to detect materials such as wood, plastic, metal, and glass depending on the sensor type. Through-Beam sensors utilize a transmitter node and a receiver node. The transmitter will be on one side of the beam, the receiver on the other. These two must be in alignment without any obstruction to the beam to work. With Retroreflective, the sensor contains both the transmitter and receiver in the same unit. The sensor emitter projects the beam to a reflector. The reflector is aligned to reflect the beam back into the receiver.

In a diffused reflective sensor, the sensor again contains both transmitter and receiver in one unit, but instead of needing a reflector to return the beam to the receiver, the sensor is directed at an object and the light returns to the receiver.

There are advantages and disadvantages to each sensor type. With Through Beam, longer range, reliability, and higher accuracy can be achieved. Areas such as wide door openings like a garage door or wide conveyors. This is due to light only needing to travel in one direction. There are some disadvantages as well. For example, cost is higher due to the need for multiple components, being able to detect through thin clear objects due to light refraction. With the need for two modules, set up can be more difficult as well. Things like mounting space requirements, cable management, and alignment prove to be a challenge depending on application. With retroreflective, cost is lower, and setup is easier having only one module and a reflector. There is no need for additional cabling and power, alignment is easier, but distance becomes shorter. Applications for retroreflective include baggage conveyors at airports, vehicle detection at toll gates, as well some material handling applications. Disadvantages of the retroreflective photoelectric sensor are at the reflector. In situations where the object being detected is highly reflective, the sensor may fail to read the object. This can be avoided by adjusting the angles, but it is something to be aware of. With the beam being bi-directional, detection distance is also shorter. When looking at the diffuse photoelectric, cost is again lower, and there is only one point of installation. However, detection distance is much shorter. Rather than relying on a reflector to bounce back the beam, the sensor relies on objects passing in front of the beam. The other downside is depending on the material and color of the object being detected, the sensor may struggle in detection.

Considerations

When selecting your photoelectric sensor there are a number of things to consider before deciding on one type of photoelectric over another. Here are a few points you will need to look at.

1. Location. The location of the sensor plays a significant role in the type of sensor technology you can use. What is the detecting range for your application or to put it simply, how far with the object to be detected be from the sensor? Is there sufficient mounting space for the sensor module, bracket, and required cabling for power and connectivity? What are the environmental conditions in the area where the sensor(s) will be mounted? What level of ingress protection will the sensors need?
2. Beam Size. Select a sensor with a beam size that is appropriate for the size of the target you are looking to detect. The target must be big enough that it will break the beam and trigger detection.
3. Sensor Output. There are two-wire sensors and three-wire sensors. Each provide different outputs. In a two-wire sensor configuration, the sensor acts as a switch and will toggle the output on or off. With three-wire configurations, logic is required. In this case, the sensor triggers an event with a connected PLC using sourcing or sinking currents (PNP vs. NPN).
4. Output configuration. You will need to determine whether your sensor application would require a Light-on, Dark-on, Light-off, or Dark-off configuration is the next step. Depending on the needed configuration will help to select the proper sensor. Circuit function will help to identify the type of

sensor you need. Through-beam, retroreflective, and polarized retroreflective sensors are all capable of Light-Off and Dark-Off output configurations whereas Diffuse Reflective sensors are capable of Light-On and Dark-On configurations.

5. Excess Gain. Excess Gain is the measure of the minimum light energy needed to ensure proper triggering of the sensor. When selecting your sensor, you need to ensure there is sufficient excess gain to allow for proper detection. This will be especially important in dirty industrial environments. When researching your sensor options, most manufacturers will provide an excess gain curve chart for both non-polarized and polarized sensors. These charts will provide maximum distance vs. maximum receiver gain based on a clean environment. There are levels to consider based on the cleanliness of air in which the sensor will be operating. Here are some examples to help explain the level of air contamination and how they impact sensor operation and object detection.

a. Clean Air – Ideal Conditions, perfectly clean air.

b. Slightly Dirty Air – Non-industrial areas

c. Low Contamination – Warehouse, light manufacturing

d. Moderate Contamination – Milling Operations

e. High Contamination – Heavy particulate, extreme washdown environments

f. Extreme Contamination – Coal bins

Photoelectric sensors are indispensable tools in modern industrial automation, offering reliable and versatile object detection capabilities. Understanding the nuances of Through-Beam, Retroreflective, and Diffused sensors is crucial for selecting the optimal solution for specific applications. By carefully considering factors such as location, beam size, sensor output, output configuration, and excess gain, engineers can ensure the successful integration of photoelectric sensors into their automation systems. The judicious choice of these sensors contributes significantly to enhanced efficiency, productivity, and quality control in various industrial settings.

How multi-sensor asset monitoring can improve performance in industry 4.0 factories and logistics and in datacenters

By Jeff Shepard
Contributed By DigiKey's North American Editors

Monitoring machines for parameters like vibration and temperature can provide real-time data on machine performance and health and give manufacturers the data needed to schedule proactive maintenance, reduce downtime, and improve productivity.

Humidity and temperature monitoring in logistics facilities or during transport can improve operational performance and preserve goods like vaccines or fresh produce. Environmental monitoring systems with wired and wireless connectivity are available to suit various applications, including enterprise and Cloud data centers.

Monitoring vibration can be beneficial for identifying potential machine problems before they occur. International Organization for Standardization (ISO) 10816 can be an important reference. It provides guidance for evaluating vibration severity in motors used for pumps, fans, compressors, gearboxes, blowers, dryers, presses, and similar machines that operate in the 10 to 1000 Hz frequency range.

This article presents some key considerations for selecting between wired and wireless connectivity for monitor systems and how using wired and wireless networks is not an either/or choice. It then examines the four classes of vibration severity as defined in ISO 10816. It concludes by discussing various options for implementing both wired and wireless condition monitoring systems, including using multiple sensors for monitoring vibration, temperature, humidity, and representative applications.

Banner Engineering offers a choice of equipment health monitoring (EHM) gateways that provide easy access to the EHM network data. Industrial EHM designers can choose between the company's SNAP ID wired gateway solutions with a local display for sensor readings or an optional Cloud dashboard and the CLOUD ID wireless gateways designed to connect with a Cloud dashboard (Figure 1) directly. Common features of these two choices include:

- A range of sensors to select from to optimize EHM operation
- Rapid deployment supported by automatic recognition of connected sensors without additional programming
- Sensor data readily available for adjusting equipment or for scheduling needed maintenance to minimize downtime and maximize productivity
- Cloud connectivity support by both systems
- Preconfigured dashboards available and customizable for optimal data visualization

Wired or wireless EHM gateway?

While they have some common features, there are essential differences between the wired and wireless EHM gateways. The AMG-SNAP-ID asset monitoring gateway (AMG) supports commissioning, monitoring, and alarms for up to 20 sensors and converters. It supports Modbus and Banner's SNAP SIGNAL connectivity and scans for individual

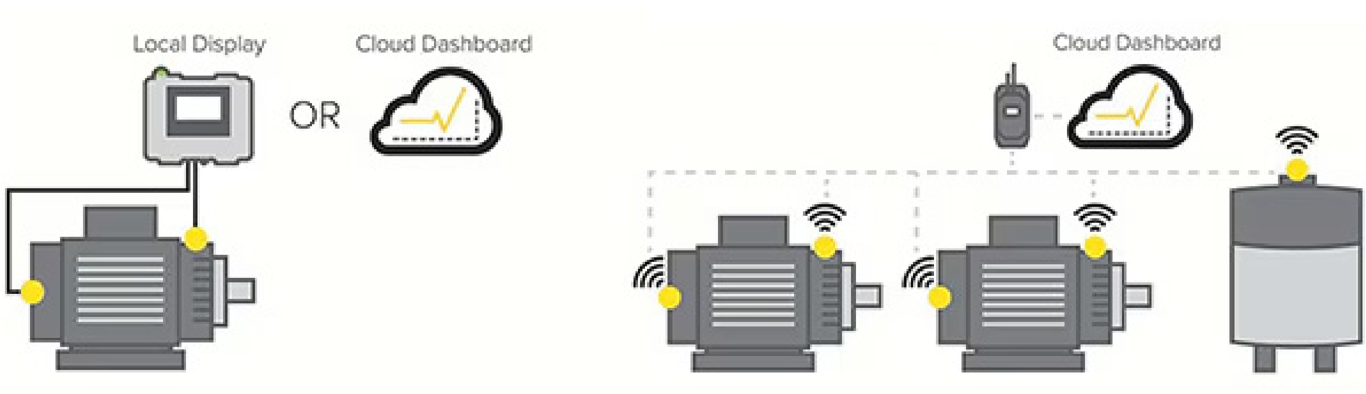


Figure 1: Banner's SNAP ID wired (left) and CLOUD ID wireless (right) EHM gateways have several common features. (Image source: DigiKey)

sensors or converters, auto-detecting model information. Users can change and assign Modbus server ID numbers to build and commission custom EHM solutions. Connected devices can be grouped, and alarms can be assigned thresholds individually. The alarm status is visible on the touchscreen and by the color of the light on the top of the enclosure.

When reaching directly up to the Cloud is required, EHM system designers can turn to the DXM1200-X2 IIoT gateway to connect up to 200 devices from both Banner and third parties to deliver performance and machine health data. It can automatically detect and connect with sensor nodes and deliver data to the Banner Cloud software. Developers can choose between simple or complex programming tools. The IIoT gateway can process information on the edge and then send it via both Ethernet and cellular networks to be monitored anywhere in the world with an intuitive Cloud dashboard (Figure 2).

Figure 2: The wireless (left) and wired (right) IIoT sensor network gateways include several common features. (Image source: Banner Engineering)

Wired and wireless EHM architectures

Wired and wireless EHM architectures are not mutually exclusive. Wired systems can have wireless elements, and wireless architectures often include wired connectivity.

For example, a basic wired EHM architecture can include several junction boxes connected to multiple sensors like the 4-port R50-4M125-M125Q-P and the 8-port R95-8M125-M125Q-P. Banner's Sure Cross R70SR serial data radios, like the 900-MHz R70SR9MQ and the 2.4-GHz R70SR2MQ, can extend network range without additional cabling. Features of these radios include (Figure 3):

- RS-485 serial interface
- Support for star and tree network topologies
- Support for self-healing, auto-routing radio frequency network with multiple hops to further extend network range
- Frequency hopping spread spectrum (FHSS) technology for reliable data transmissions

In a large facility, numerous systems can be spread out over a wide area, including:

- Air compressors
- Pumping systems
- Conveyor systems
- Numerous electric motors and machines
- Gearboxes
- Air filtration systems
- Level measurement and monitoring in storage tanks

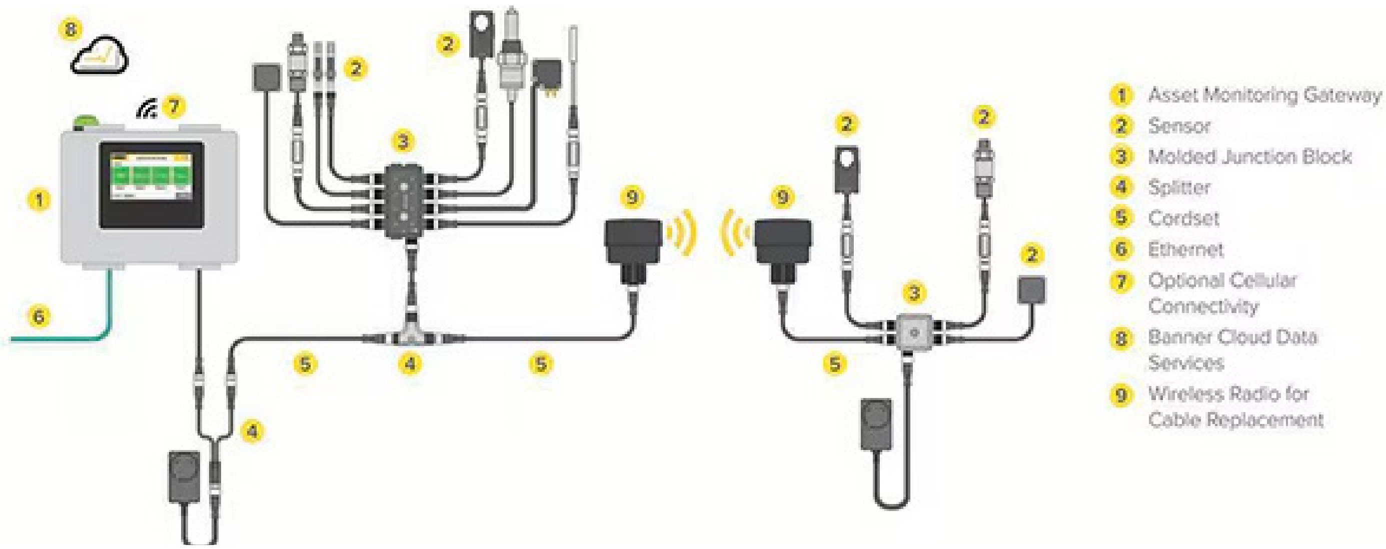


Figure 3: Basic wired asset monitoring topology (left) with example of a wirelessly connected remote sensor cluster (right). (Image source: DigiKey)

In these cases, EHM system performance can be improved by combining wired and wireless technologies. The DXM1200-X2 wireless IIoT gateway mentioned above includes Modbus wired connectivity. If Ethernet is needed, designers can turn to the DXMR90-X1. The DXMR90-4K can implement IO-Link master/controller functions. In addition to the choice of Modbus, Ethernet, and IO-Link, designers can use the R709 serial data radios to provide wireless connectivity to physically dispersed assets (Figure 4).

ISO 10816 vibration severity

ISO 10816 is an important standard for EHM systems. It quantifies vibration severity for machines like electric motors, pumps, and generators. The standard uses the root mean square (rms) value of acceleration, displacement, or vibration velocity. ISO 10816 also includes considerations for peak-to-peak values. The vibration severity has the highest rms value when measuring two or more parameters. The standard classifies vibration severity into four levels:

- Good usually indicates newly commissioned machinery.
- Satisfactory vibrations indicate the unrestricted operation region.
- Unsatisfactory vibrations indicate a need for restricted operation and scheduling preventative maintenance.
- Unacceptable vibrations indicate that machine damage is likely.

Vibration and machine learning

Even "identical" machines are not exact replicas. That's where machine learning (ML) comes in. Banner Engineering offers VIBE-IQ, a vibration monitoring software package that uses machine learning (ML) to establish a unique baseline operating value for each machine's vibrations. The ML software then automatically sets warning and alarm thresholds. It can automate complex EHM calculations and analysis. Some features of VIBE-IQ include:

- Continual monitoring of rms velocity from 10 to 1,000 Hz, rms high-frequency acceleration from 1,000 to 4,000 Hz, and temperature
- Only monitors motors that are running

Figure 4: IIoT wireless gateways (lower left) are available with Modbus, Ethernet, and IO-Link connectivity. (Image source: Banner Engineering)

Machine			Class I Small Machines	Class II Medium Machines	Class III Large Rigid Foundation	Class IV Large Soft Foundation
Vibration Velocity Vrms	in/s	mm/s				
	0.01	0.28				
	0.02	0.45				
	0.03	0.71		good		
	0.04	1.12				
	0.07	1.80				
	0.11	2.80		satisfactory		
	0.18	4.50				
	0.28	7.10		unsatisfactory		
	0.44	11.2				
	0.70	18.0				
	1.10	28.0		unacceptable		
	1.77	45.9				

Figure 5: IEC 10816 includes four categories of vibration severity. (Image source: Banner Engineering)

- Uses data for trend analysis as well as real-time monitoring to identify conditions like:
  - Misaligned or imbalanced systems
  - Worn or loose components
  - Excessive bearing wear
  - Improperly mounted or driven motors
  - Over temperature conditions
- Proactively sends alerts to the host controller or the Cloud

Vibration and temperature

Vibration is not the only clue that a machine might need preventative maintenance. A rising temperature trend can also alert the EHM system of potential problems, especially if the rising temperature is correlated with increasing vibrations.

Combining the two parameters gives a more complete picture of the equipment's condition. They can alert operators to different sets of conditions and provide multiple benefits:

- Vibration can identify mechanical issues like misalignments, imbalances, bearing wear, etc.
- Temperature increases can identify electrical problems like overheating windings or lubrication problems.
- When detecting anomalous operation, correlating out-of-band vibration and temperature can help identify possible causes. For example, vibration patterns can help identify the root cause.
- Planning preventive maintenance can be aided by monitoring both temperature and vibration. A gradual temperature rise is not necessarily as much of a problem as increasing vibrations that can demand more immediate correction.
- Learn how to improve longer-term asset selection and utilization using sensor data to identify potential operating limitations before they become problems.

When temperature and vibration need to be monitored, EHM system designers can turn to the QM30VT2 sensor in an aluminum housing or the QM30VT2-SS-QP in a stainless steel housing, both from Banner Engineering. Both sensors can connect to a Modbus radio or any Modbus network as a slave device via RS-485. Their small form factor enables them to fit into tight locations (Figure 6). Other features include:

- High-accuracy temperature and vibration measurements
- Temperature measuring range of -40°C to +105°C, with a resolution of 1°C and an accuracy of ±3°C
- Detects dual-axis vibration up to 4 kHz bandwidth with an accuracy of ±10% at 25°C and a default sampling frequency of 20 kHz
- Outputs for rms velocity, rms high-frequency acceleration, peak velocity, and other parameters pre-processed from the vibrational waveforms

Vibration spectral banding is an advanced capability. It allows users to split the wide band fast Fourier transformation (FFT) to get rms velocity or acceleration data for narrower frequency bands in addition to the 10 to 1,000 Hz and 1,000 to 4,000 Hz scalar data. Depending on users' needs, the band frequencies can be input manually or automatically generated based on a dynamic or static speed input. Spectral band analysis can aid in diagnosing problems with rotating machines more specifically.

Temperature and humidity

Monitoring temperature and humidity can be important in data centers, warehouses, cleanrooms, refrigerators, or chillers. A temperature and humidity sensor like the DX80N9Q45THA can help to:

Preserve goods like fresh produce or vaccines where knowing the temperature and humidity are essential to long-term viability and preventing spoilage

Protect equipment like servers and storage devices in a data center where excessive temperature or humidity can interfere with normal operation or lead to breakdowns

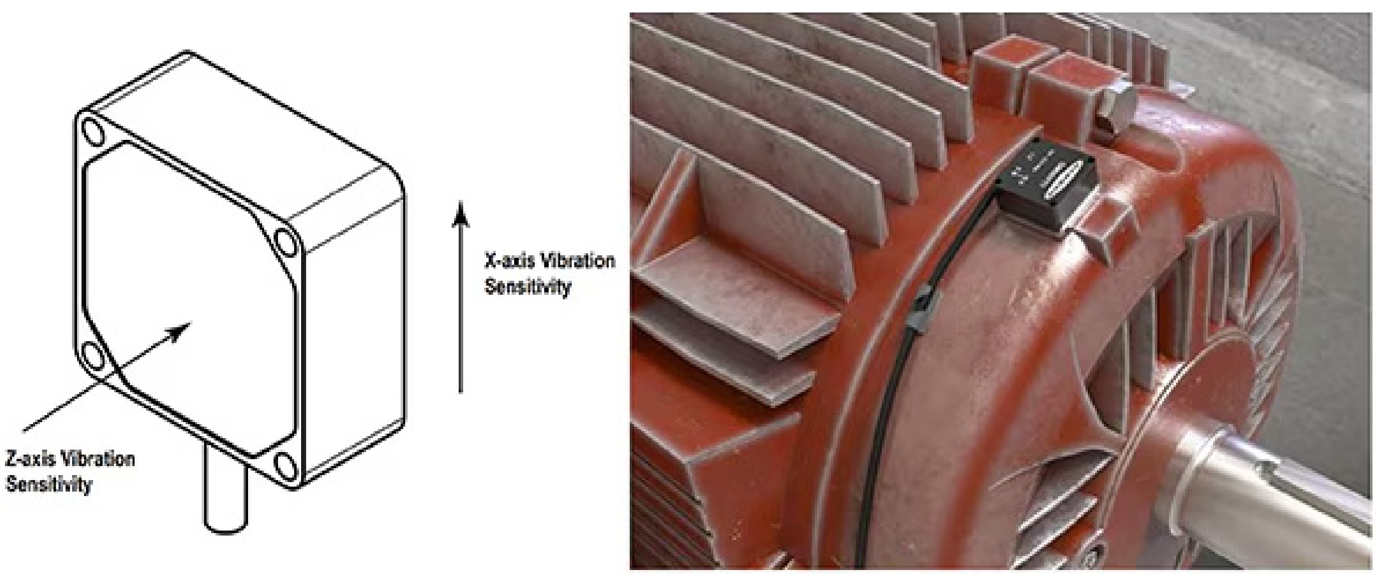


Figure 6: Two-axis vibration plus temperature sensors can be mounted directly on motor housing (right). (Image source: Banner Engineering)

Enhance health and safety of people in warehouses and other facilities where high humidity can make it difficult for workers to keep cool in elevated temperatures, potentially leading to heat exhaustion

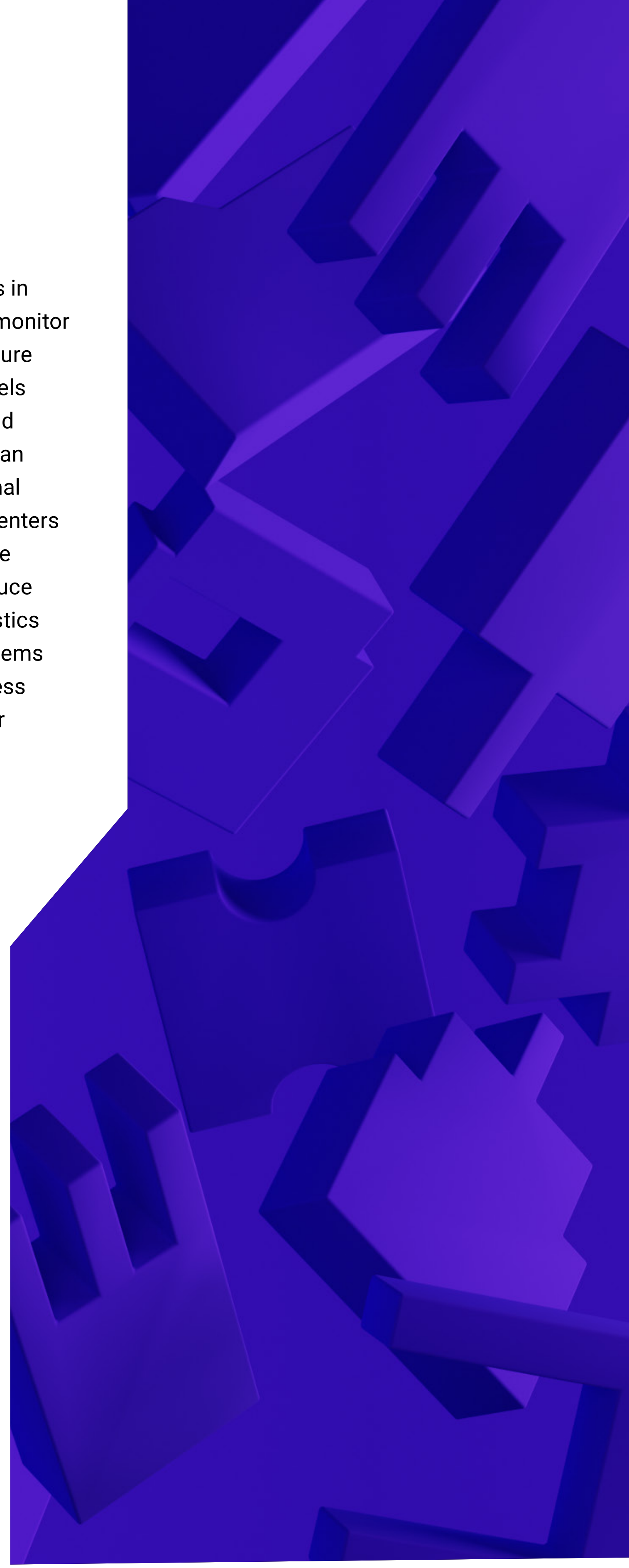
The temperature measuring range of -40°C to +85°C with a resolution of 0.1°C and accuracy of ±0.6°C from -40°C to 0°C, ±0.4°C from 0°C to +60°C, and ±1.2°C from +60°C to +85°C. The humidity sensor can measure from 0% to 100% RH with an accuracy of ±2% at +25°C, ±3% from 0°C to +70°C and 10% to 90% RH, and ±7% from 0°C to +70°C and 0% to 10% or 90% to 100% RH.

When the unit is turned on, it operates in fast sample mode and sends data every two seconds. After five minutes, the node enters the default mode and sends data at five-minute intervals. Sample rates of 15 minutes or 64 seconds are user-selectable.

Models with 900 MHz radios transmit at 1 W (30 dBm) or 250 mW (24 dB user-selectable). The 250 mW mode reduces the range but improves battery life in short-range applications. For 2.4 GHz models, transmit power is fixed at about 65 mW (18 dBm). When operating in storage mode, the radio is shut off to conserve battery life.

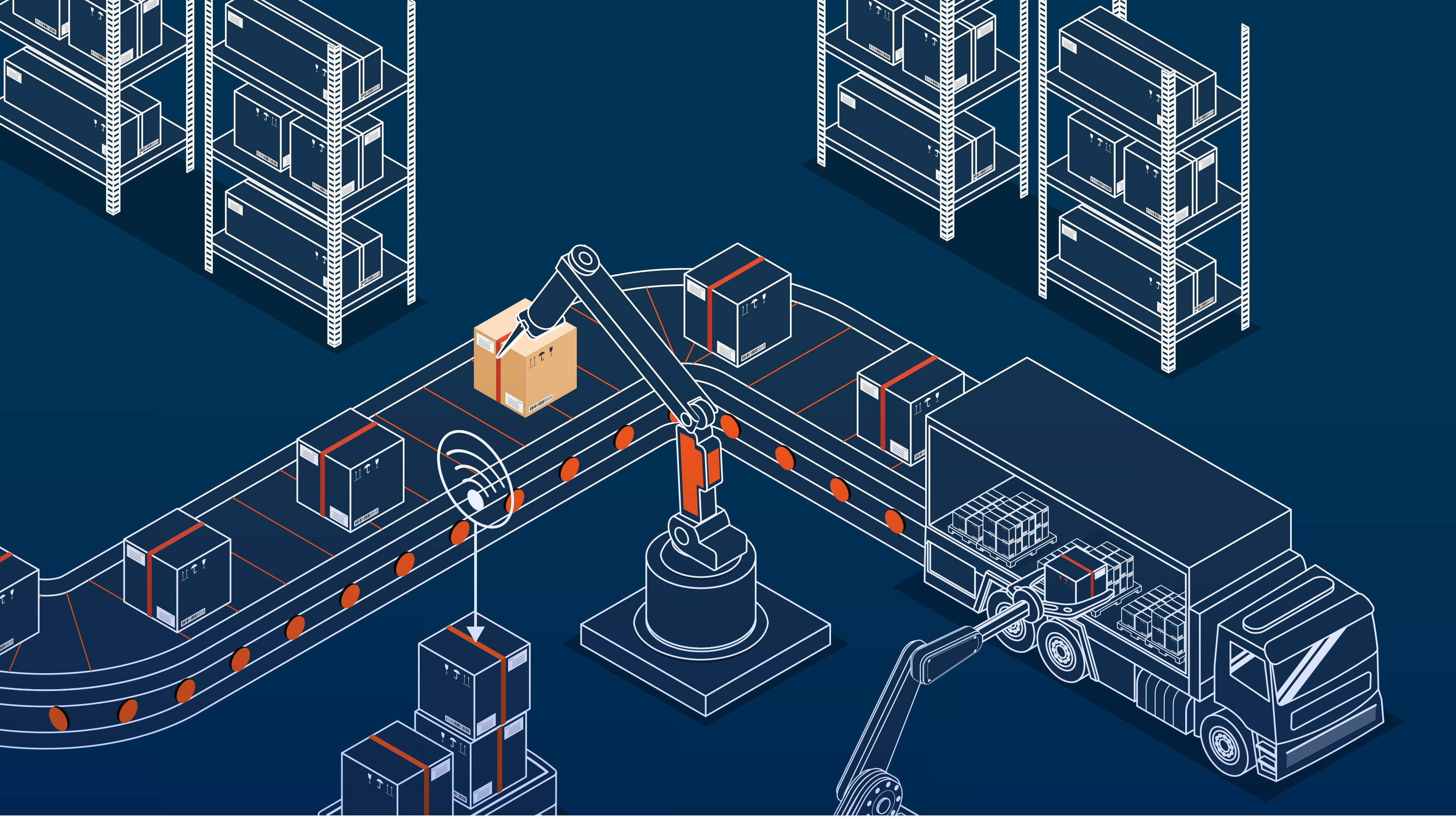
Conclusion

Effective EHM systems in Industry 4.0 factories monitor vibration and temperature to help ensure high levels of uptime. Humidity and temperature sensors can also improve operational performance of data centers and preserve goods like vaccines or fresh produce in warehouse and logistics operations. These systems can use wired or wireless connectivity to monitor multiple parameters.



How sensor fusion enables AMRs to maneuver around factory floors efficiently

By Jeff Shepard
Contributed By DigiKey's North American Editors



With increasing instances of people and autonomous mobile robots (AMRs), also called industrial mobile robots (IMRs), working in the same area, multiple inherent safety risks must be addressed. The safe and efficient operation of AMRs is too important to rely on a single sensor technology.

Multi-sensor fusion, or simply "sensor fusion," combines technologies like laser range finding (LIDAR), cameras, ultrasonic sensors, lasers obstacle sensors, and radio frequency identification (RFID) to support a range of AMR functions, including navigation, path planning, collision avoidance, inventory management, and logistics support. Senor fusion also encompasses alerting nearby people to the presence of the AMR.

To address the need for the safe and efficient operation of AMRs, the American National Standards Institute (ANSI) and the Association for Advancing Automation (A3), formerly the Robotic Industries Association (RIA), are developing the ANSI/ A3 R15.08 series of standards. R15.08-1 and R15.08-2 have been released, focusing on basic safety requirements and integrating AMRs into a site. R15.08-3 is currently under development and will expand the safety requirements for AMRs, including more detailed recommendations for using sensor fusion.

In anticipation of R15.08-3, this article reviews some of today's best practices related to safety and sensor fusion in AMRs, beginning with a brief overview of functional safety requirements currently used with AMRs, including generic industrial safety standards like IEC 61508, ISO 13849 and IEC 62061, and the safety requirements for sensing human presence like IEC 61496 and IEC 62998. It then presents a typical AMR design detailing the numerous sensor technologies, presents representative devices, and looks at how they support functions like navigation, path planning, localization, collision avoidance, and inventory management/ logistics support.

Requirement	Type			
	1	2	3	4
Safety performance in accordance with IEC 62061 and/or ISO 13849-1	N/A	SIL 1 and/ or PL c	SIL 2 and/ or PL d	SIL 3 and/ or PL e
SIL = safety integrity level; PL = performance level				

Table 1: Safety requirements for ESPE by type specified in IEC 61496. (Table source: Analog Devices)

Good, better, best

AMR designers have a range of safety standards to consider, starting with general-purpose functional safety standards like IEC 61508, ISO 13849, and IEC 62061. There are also more specific safety standards related to sensing human presence, such as IEC 61496, IEC 62998, and the ANSI/A3 R15.08 series of standards.

IEC 61496 offers guidance for several sensor types. It refers to IEC 62061, which specifies requirements and makes recommendations for the design, integration, and validation of electrosensitive protective equipment (ESPE) for machines, including safety integrity levels (SILs), and ISO 13849 that covers safety of machinery and safety-related parts of control systems including safety performance levels (PLs) (Table 1).

IEC 62998 is newer and can often be a better choice since it includes guidance on implementing sensor fusion, using artificial intelligence (AI) in safety systems, and using sensors mounted on moving platforms outside the coverage of IEC 61496.

R15.08 Part 3, when it's released, may make the R15.08 series the best since it will add safety requirements for users of AMR systems and AMR applications. Likely topics may include sensor fusion and more extensive AMR stability testing and validation.

Sensor fusion functions

Mapping the facility is an essential aspect of AMR commissioning. But it's not a one-and-done activity. It's also part of an ongoing process called simultaneous localization and mapping (SLAM), sometimes called synchronized localization and mapping. It is the process of continuously updating the map of an area for any changes while keeping track of the robot's location.

Sensor fusion is needed to support SLAM and enable the safe operation of AMRs. Not all sensors work equally well under all operating circumstances, and different sensor technologies produce various data types. AI can be used in sensor fusion systems to combine information about the local operating environment (is it hazy or smoky, humid, how bright is the ambient light, etc.) and enable a more meaningful result by combining the outputs of different sensor technologies.

Sensor elements can be categorized by function as well as technology. Examples of sensor fusion functions in AMRs include (Figure 1):

- Distance sensors like encoders on wheels and inertial

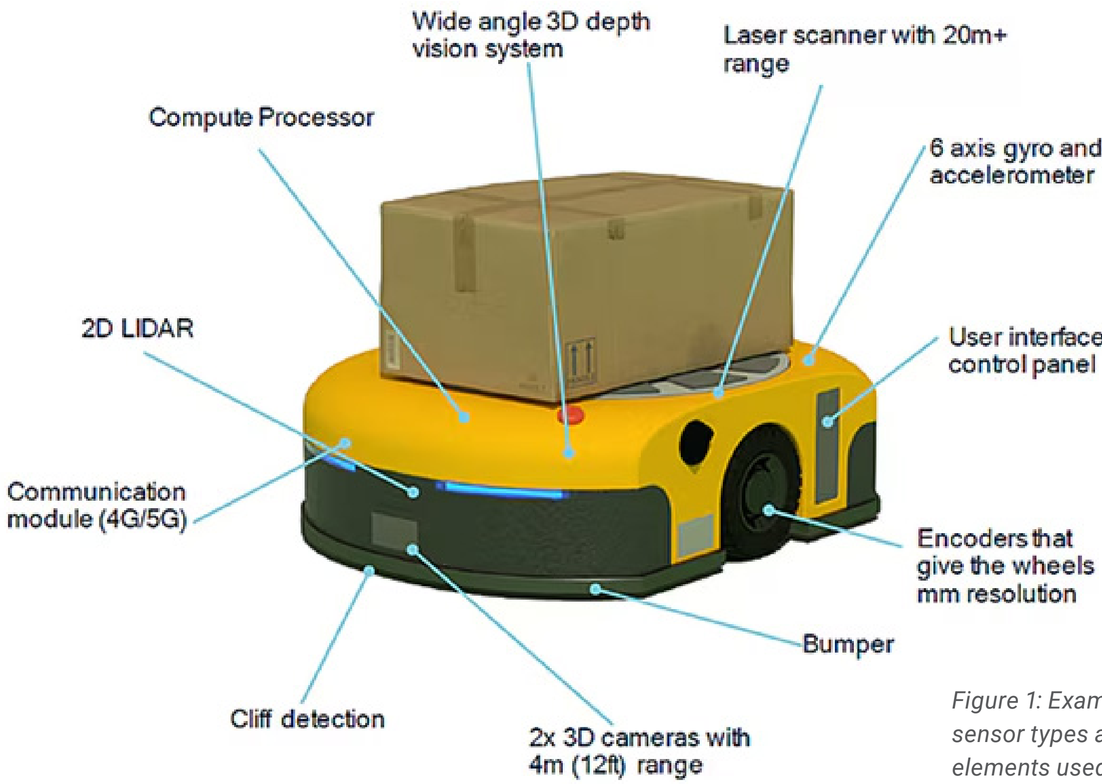


Figure 1: Examples of common sensor types and related system elements used in AMR sensor fusion designs. (Image source: Qualcomm)

measurement units using gyroscopes and accelerometers help measure the movement and determine the range between reference positions.

- Image sensors like three-dimensional (3D) cameras and 3D LiDAR are used to identify and track nearby objects.
- Communications links, compute processors, and logistics sensors like barcode scanners and radio frequency identification (RFID) devices link the AMR to facility-wide management systems and integrate information from external sensors into the AMR's sensor fusion system for improved performance.
- Proximity sensors like laser scanners and two-dimensional (2D) LiDAR detect and track objects near the AMR, including people's movement.

2D LiDAR, 3D LiDAR, and ultrasonics

2D and 3D LiDAR and ultrasonics are common sensor technologies that support SLAM and safety in AMRs. The differences between those technologies enable one sensor to compensate for the weaknesses of the others to improve performance and reliability.

2D LiDAR uses a single plane of laser illumination to identify objects based on X and Y coordinates. 3D LiDAR uses multiple laser beams to create a highly detailed 3D representation of the surroundings called a point cloud. Both types of LiDAR are relatively immune to ambient light conditions but require that objects to be detected have a minimum

threshold of reflectivity of the wavelength emitted by the laser. In general, 3D LiDAR can detect low-reflectivity objects with more reliability than 2D LiDAR.

The HPS-3D160 3D LiDAR sensor from Seeed Technology integrates high-power 850 nm infrared vertical-cavity surface-emitting laser (VCSEL) emitters and high-photosensitive CMOS. The embedded high-performance processor includes filtering and compensation algorithms and can support multiple simultaneous LiDAR operations. The unit has a range of up to 12 meters with centimeter accuracy.

When a 2D LiDAR solution is needed, designers can turn to the TIM781S-2174104 from SICK. It features an aperture angle of 270 degrees with an angular resolution of 0.33 degrees and a scanning frequency of 15 Hz. It has a safety-related working range of 5 meters (Figure 2).

Figure 2: This 2D LiDAR sensor has an aperture angle of 270 degrees. (Image source: SICK)

Ultrasonic sensors can accurately detect transmissive objects like glass and light-absorbing materials that LiDAR can't always see. Ultrasonic sensors are also less susceptible to interference from high dust, smoke, humidity, and other conditions that can disrupt LiDAR. However, ultrasonic sensors are sensitive to interference from environmental noise, and their detection ranges can be more limited than LiDAR.

Ultrasonic sensors like the TSPC-30S1-232 from Senix can complement LiDAR and other sensors for AMR SLAM and safety. It has an optimum range of 3 meters, compared to 5 meters for the 2D LiDAR and 12 meters for the 3D LiDAR detailed above. This temperature-compensated ultrasonic sensor is IP68-rated in an environmentally sealed stainless-steel enclosure (Figure 3).

Figure 3: Environmentally sealed ultrasonic sensor with an optimum range of 3 meters. (Image source: DigiKey)

Sensor fusion usually refers to using several discrete sensors. But in some cases, multiple sensors are co-packaged as a single unit.

Three sensors in one

Visual perception using a pair of cameras to produce stereoscopic images plus image processing based on AI and ML can enable the AMR to see the background as well as identify nearby objects. Sensors are available that include stereo depth cameras, a separate color camera, and an IMU in one unit.

Figure 4: This module includes stereo depth cameras separated by 95 mm, a separate color camera, and an IMU. (Image source: DigiKey)

Stereo depth cameras like the Intel RealSense D455 RealSense Depth Cameras use two cameras separated by a known baseline to sense depth and calculate the distance to an object. One key to precision is using a sturdy steel framework that ensures an exact separation distance between the cameras, even in demanding industrial environments. The accuracy of the depth perception algorithm is dependent on knowing the exact spacing between the two cameras.

For example, the model 82635DSD455MP depth camera has been optimized for AMRs and similar platforms and has extended the distance between the cameras to 95 mm (Figure 4). That enables the depth calculation algorithm to reduce the estimation error to less than 2% at 4 meters.

D455 depth cameras also include a separate color (RGB) camera. A global shutter for up to 90 frames per second on the RGB camera, matched to the depth imager field of view (FOV), improves the correspondence between the color and depth images, enhancing the ability to understand the surroundings. D455 depth cameras integrate an IMU with six degrees of freedom that enables the depth calculation algorithm to include the rate of motion of the AMR and produce dynamic depth awareness estimates.

Lighting and sounding the way

Flashing lights and audible alerts for people near an AMR are important to AMR safety. The lights are usually in the form of a light tower or light strip on the sides of the AMR. They help the robot communicate its intended action(s) to people. They can also indicate status like battery charging, loading or unloading activities, intention to turn in a new direction (like the turn signals on a car), emergency conditions, and so on.

There are no standards for light colors, flashing speeds, or audible alarms. They can vary between AMR makers and are often developed to reflect the specific activities in the facility where the AMR operates. Light strips are available with and without built-in audible alert mechanisms. For example, the model TLF100PDLBGYRAQP from Banner Engineering includes a sealed audible element with 14 selectable tones and volume control (Figure 5).

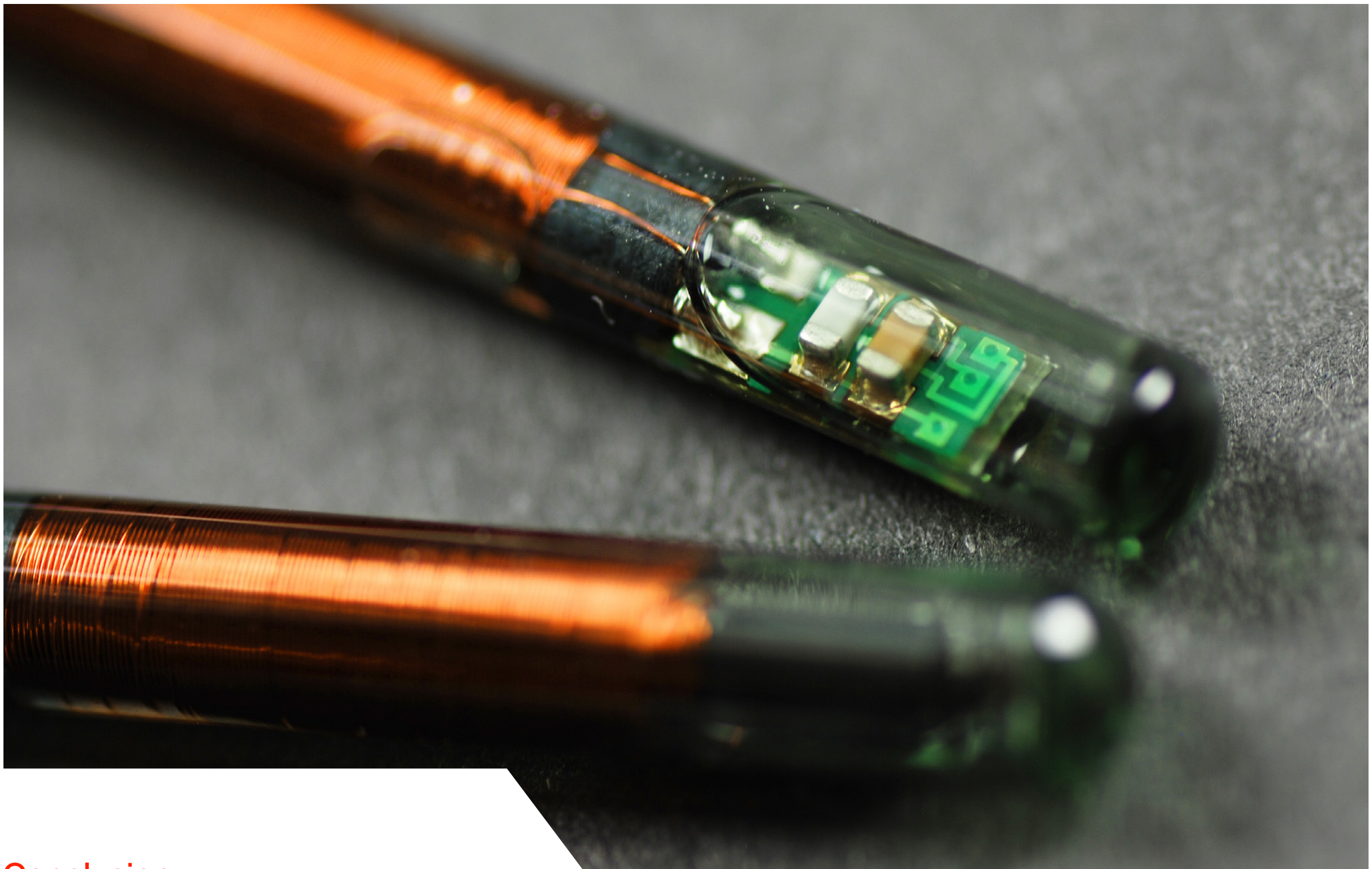
Figure 5: This light bar annunciator includes a sealed audible element (top black circle). (Image source: DigiKey)

Logistics support

AMRs operate as part of larger operations and are often required to integrate with enterprise resource planning (ERP), manufacturing execution system (MES), or warehouse management system (WMS) software. The communications module on the AMR coupled with sensors like barcode and RFID readers enable AMRs to be tightly fused into enterprise systems.

When a barcode reader is needed, designers can turn to the V430-F000W12M-SRP from Omron, which can decode 1D and 2D barcodes on labels or Direct Part Mark (DPM) barcodes. It includes variable distance autofocus, a wide field of view lens, a 1.2-megapixel sensor, a built-in light, and high-speed processing.

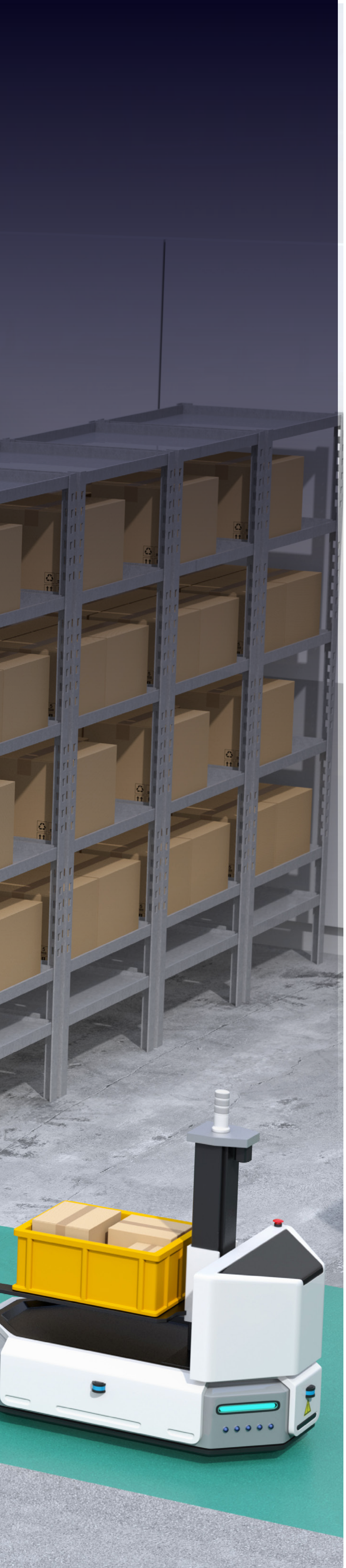
The DLP-RFID2 from DLP Design is a low-cost, compact module for reading from and writing to high-frequency (HF) RFID transponder tags. It can also read the unique identifiers (UDI) of up to 15 tags at once and can be configured to use an internal or external antenna. It has an operating temperature range of 0°C to +70°C, making it suitable for use in Industry 4.0 manufacturing and logistics facilities.



Conclusion

Sensor fusion is an important tool for supporting SLAM and safety in AMRs. In anticipation of R15.08-3, which may include references to sensor fusion and more extensive AMR stability testing and validation, this article reviewed some current standards and best practices for implementing sensor fusion in AMRs. This is the second article in a two-part series. Part one reviewed the safe and efficient integration of AMRs into industry 4.0 operations for maximum benefit.

How safety laser scanners can protect people and machines



By Jeff Shepard
Contributed By DigiKey's North American Editors

Safety laser scanners can contribute to safety in industrial and logistics facilities. They can protect people from unsafe interactions with machines, and they can protect machines from unintended interference by people.

Several factors are needed to maximize the effectiveness of safety laser scanners. The first is to determine if a laser scanner is the best solution or if another technology, like a light curtain, may be better suited for the application.

Once it's been determined that a scanner is the best choice, there are important decisions to make, including the:

- Selection of the optimal safety protection fields and field sets
- Use of a standard like the International Organization for Standardization (ISO) 13855 for positioning safeguards with respect to the approach of a person
- Selection of the correct multiple sampling value
- Selection of a scanner with the optimal feature set

This article starts by reviewing the factors that affect when to choose a scanner and when to choose a light curtain. It then presents the important selection criteria for using scanners and looks at representative safety laser scanners from IDEC, Omron, SICK, and Banner Engineering.

Scanner or curtain?

One of the first considerations is: what physical space is being protected? Both scanners and light curtains can protect people from harm and protect machines from interference. While there is some overlap in the protective capabilities of scanners and light curtains, they are generally suited to different applications, such as:

Point-of-operation protection, which refers to the active area of a machine where work is performed. Light curtains are suited for this application since they can be positioned in an optimal location, and their resolution can be set up to detect fingers, hands, or feet/legs and provide the required level of protection. Scanners usually need a longer minimum distance from hazards because of their longer response times and are not generally used for point-of-operation protection.

Perimeter protection, which guards multiple sides of a machine. Like point-of-operation protection, light curtains are well suited to provide compact solutions for perimeter protection. If a person crosses the perimeter, a stop signal can be sent, and the machine is stopped. While both light curtains and scanners can be used in perimeter protection, safety light curtains are used more often in perimeter protection, and scanners are used more often in area protection.

Access control and area protection, which can be implemented with a light curtain or scanner depending on the specific application needs. Light curtains are suitable when there's a single point of entry. For example, individually monitoring and evaluating each beam of light enables a light curtain to differentiate between a "tall" person and a "short" material carrier, like a pallet crossing a threshold, and modify its response accordingly.

Scanners can be set up to monitor a 275° area to create a user-defined two-dimensional protected zone (Figure 1). They can also establish multiple protection zones based on the distance between a person and the protected machine and slow or stop it as appropriate.

Mobile systems like autonomous mobile robots (AMRs) and automatic guided vehicles (AGVs) can benefit from using multiple scanners. Those scanners can be battery-powered and installed to work cooperatively, simultaneously monitoring dozens of safety zones around the vehicle. Different zones can be activated based on vehicle speed, position, and anticipated changes in direction. The data from the scanners can be supplemented with encoders on the wheels and other sensor inputs to support AMR navigation.

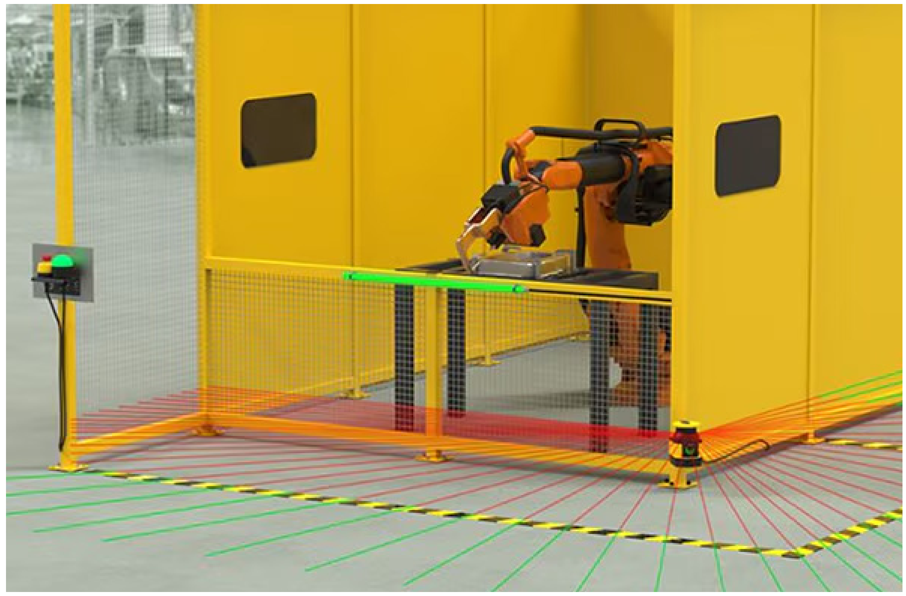


Figure 1: A safety laser scanner like this can monitor a 275° area to create a two-dimensional protected zone and send an alarm if any unexpected person or object enters that area (red lines). (Image source: Banner Engineering)

What level of safety?

Once the physical space being protected has been defined, the next consideration is the needed level of safety. In addition to having different application benefits, light curtains and safety laser scanners support different levels of safety as defined by various international standards.

For example, ISO 13849-1 defines the reliability of safe control functions using performance levels (PLs) from "a" to "e", with PLe representing the highest level.

Safety laser scanners meet the criteria of PLd and are suitable for use in applications where safety is a major priority. A PLd rating is granted to systems with the probability of a dangerous failure every 1 to 10 million hours (141 to 1,141 years based on continuous operation). Light curtains are available with a wider range of options from PLc to PLe.

IEC 62061, Safety of machinery: Functional safety of electrical, electronic, and programmable electronic control systems is another important standard. It's based on a risk assessment and reduction strategy for safety control functions like light curtains and safety laser scanners. It includes functional requirements specifications and safety integrity level (SIL) requirements.

Examples of functional requirements include frequency of operation, response time, operating modes, duty cycles, operating environment, fault reaction functions, and so on. The resulting SILs are measured on a scale from 1 to 4 (Figure 2).

ISO 13855 defines how to place scanners with respect to a person's approach. For example, if a scanner is mounted at a height of 300 mm, a resolution of 70 mm is sufficient to detect a human leg. At lower mounting heights, the recommended minimum resolution is 50 mm.

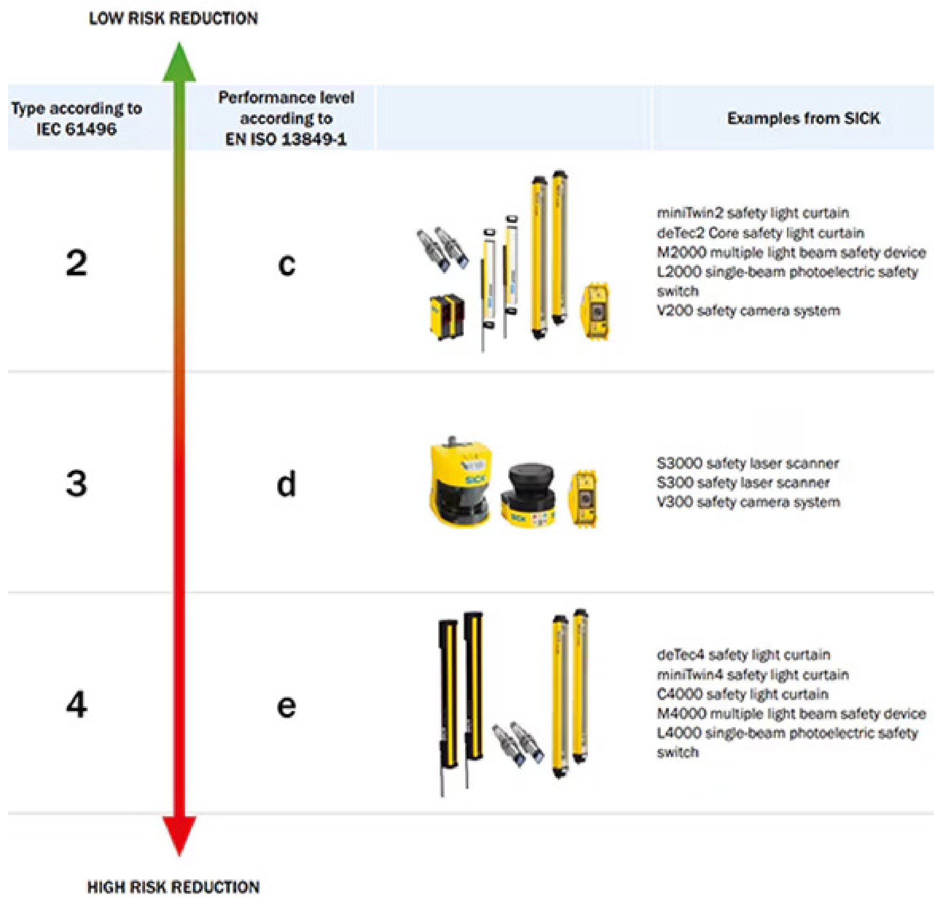


Figure 2: Safety laser scanners meet the criteria of PLd and SIL3 and are suitable for use in applications where safety is important. (Image source: SICK)

Scanner specifications

Once it's been determined that a safety laser scanner satisfies the application requirements and can support the needed level of safety, it's time to consider specifications. Examples of important scanner specifications include:

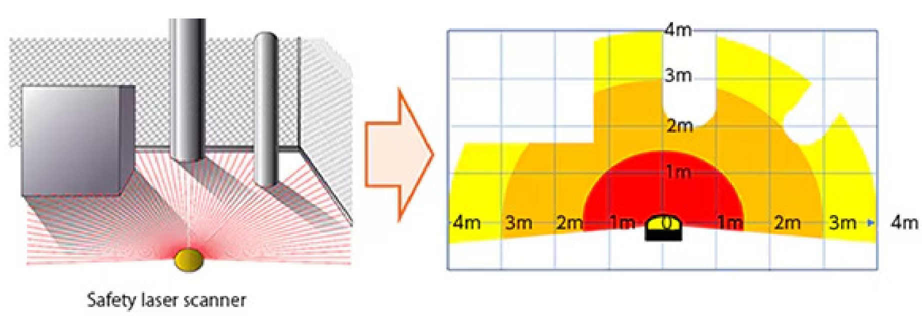


Figure 3: Commissioning can be sped up by using a scanner that uses scanned data for automatic configuration to identify stationary objects in the warning zones. (Image source: IDEC)

Scan angle. Several scan angles are available, such as 190°, 270°, and 275°. The scan angle and its structure determine how the scanner gets mounted into the system to monitor the needed area(s).

Protection zones. Safety laser scanners have multiple protection zones, including the primary protection zone and one or more warning zones. Some can use scanned data for automatic configuration to ignore stationary objects in the warning zones (Figure 3). In some cases, a safety laser scanner can scan multiple zones sequentially or simultaneously. For example, one scanner can support up to 70 unique safety zone sets. On an AMR, this feature enables the scanner to adjust the scanned areas based on the surroundings and speed of movement.

Protective field range. It is the maximum distance that the protected area can extend from the scanner. Typical values range from 3 to 10 m. The required protective field range depends on local regulations and the scanner's response time and resolution.

Resolution. It is measured in mm and determines the minimum size object the scanner can accurately detect. Typical values range from 30 mm to 200 mm.

Response time. Also called detection time, it measures how quickly a scanner can recognize the approach of an object. Typical values range from 60 to 500 ms.

Sampling. Indicates how many times an object must be scanned in succession to be recognized by the scanner. By default, it usually takes at least two sampling scans. However, for some scanners and under some circumstances it can require ten or more successive sampling scans to recognize an object.

Dual protection zones

Safety laser scanners have various features and functions that suit different application needs. For example, IDEC's SE2L safety laser scanners include master/slave functionality and dual protection zones. The master/slave function enables one scanner to communicate with up to three other scanners. That can significantly simplify system design and allow the use of a lower-cost controller since the safety controller only needs to communicate with the master, which relays the instructions to the slave scanners. The model SE2L-H05LP can be installed using 2 to 20 m long cables, further enhancing flexibility.

These scanners have a scan cycle time of 30 ms and can include 32 patterns in the scan area. Using the dual-zone function, a single SE2L unit can independently scan two adjacent zones simultaneously, eliminating the need for a second scanner and simplifying system design.

Low power for battery-operated safety

Extending the run times of AGVs and AMRs can be an important consideration. Those applications can benefit from using Omron's compact (104.5 mm) OS32C-SP1-4M safety laser scanner. It consumes a maximum of 5 W (3.75 W in standby mode) and has 70 sets of safety zone and warning zone combinations available, making it suitable for use in complex environments (Figure 4).

Figure 4: This low-power safety laser scanner supports 70 sets of safety zone and warning zone combinations, making it suitable for AMRs operating in complex or dynamic environments. (Image source: Omron)

Other features include:

- Minimum resolution can be set to 30, 40, 50, or 70 mm.
- Safety zone varies with resolution:
  - 1.75 m (30 mm resolution)
  - 2.5 m (40 mm resolution)
  - 3.0 m (50 mm resolution)
  - 4.0 m (70 mm resolution)
- Warning zone radius up to 15 m
- Configurable response time from 80 ms up to 680 ms.
- Zone switching time can be set from 20 ms to 320 ms

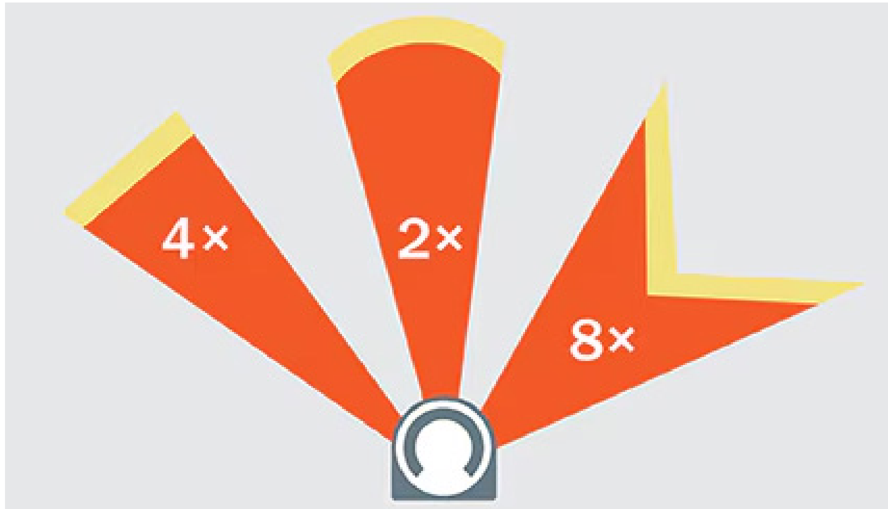


Figure 5: The S300 Mini Standard safety laser scanners can implement multiple sampling levels and different resolutions for each scan field. (Image source: SICK)

Triple fields with selectable sampling and resolution

SICK's S300 Mini Standard safety laser scanners feature selectable detection resolutions and sampling levels. For example, model S32B-2011BA supports 30, 40, 50, and 70 mm resolution diameters. Multiple sampling and resolutions can be individually defined for each field, including simultaneous protective fields (Figure 5). These scanners support up to 48 freely configurable fields and 16 switchable field sets. The triple field function enables a protective field and two warning fields to be used simultaneously.

Eliminating the need for a safety PLC

The SX5 safety laser scanners from Banner Engineering feature an integral muting function that can monitor and respond to signals and automatically suspend the safeguarding function to allow an object to pass through the safety zone without generating a stop command. The muting function allows the suspension of the entire safety zone (total muting) or just a section of the safety zone (partial dynamic muting).

An SX5 master unit, like the SX5-ME70, can control up to three remote units like the SX5-R; the scanner can also read incremental encoder inputs to modify the safety zone based on the vehicle's speed. These functions can eliminate the need for additional control hardware like a safety PLC.

Conclusion

If properly specified, configured, and integrated, safety laser scanners are well suited to protect people and machines in applications like access control, area protection, and on mobile systems, including AGVs and AMRs. They meet the requirements of PLd and SIL3 and are suitable for use in applications where safety is an important consideration. These scanners are available with various combinations of features and functions to suit a range of application needs.

Remote I/O devices optimize automation control systems

By Art Pini

DigiKey

Factory and industrial automation systems must reliably connect human operators, machinery, computers, and sensors over communications links. This process typically starts with raw materials that are moved through a series of workstations where a product is formed, measured, calibrated, inspected, packed, and shipped, all under the control of a factory automation system.

These systems start with supervisory control and data acquisition (SCADA) architectures, where computers and networked communications systems provide high-level supervision and control of the production processes. The SCADA systems are often located remotely from the actual production facilities, and remote operation is usually accomplished using cloud data services (CDSs), which provide data links and group interoperability.

SCADA systems manage and monitor factory performance by controlling machines through local programmable logic controllers (PLCs) and receiving feedback through networked sensors that guide their work. The PLCs interface with the process plant or machinery. Remote input/output (I/O) components are the communications backbone of the automated factory, as shown in Figure 1.

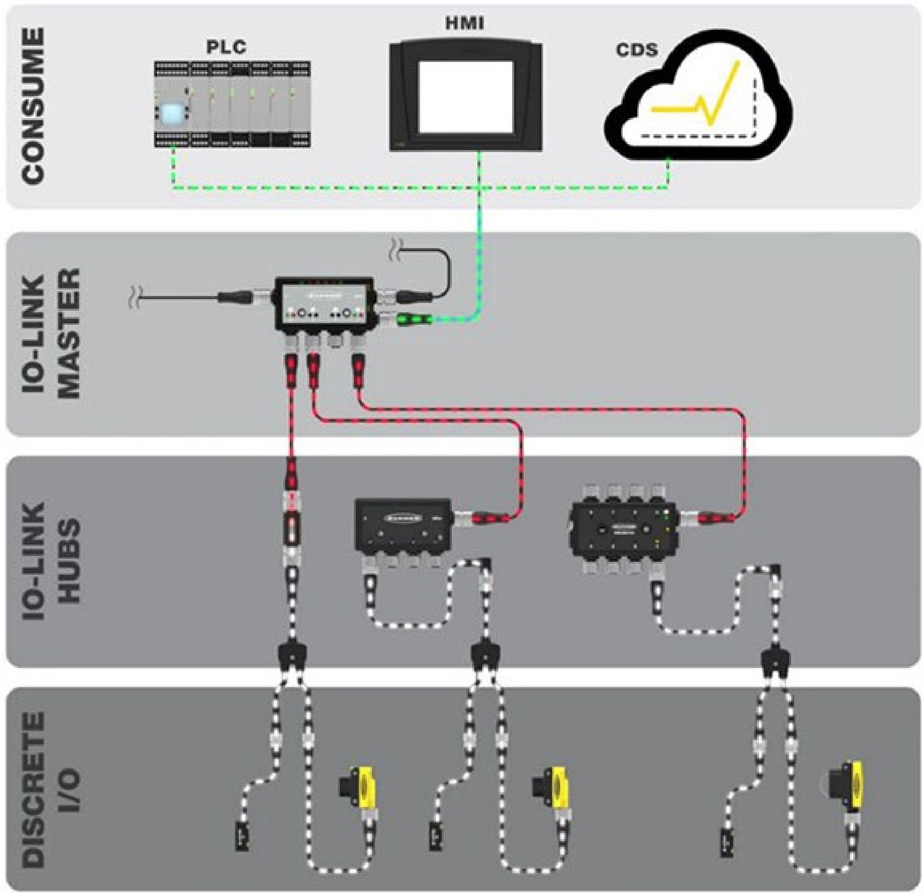


Figure 1 : Remote I/O components form the nerve system of a modern automated factory. (Image source: Banner Engineering)

Discrete sensors and actuators monitor and control local operations. Their signals are linked using appropriate hubs and are sent to the master for local processing before being sent to the SCADA system.

Industrial data buses

Automated machines can use many sensors or actuators, but their direct connection to the control room would result in large and expensive cables. To avoid this situation, designers have developed several sensor buses to consolidate these connections. Modbus and IO-Link are two widely used networks (Figure 2).

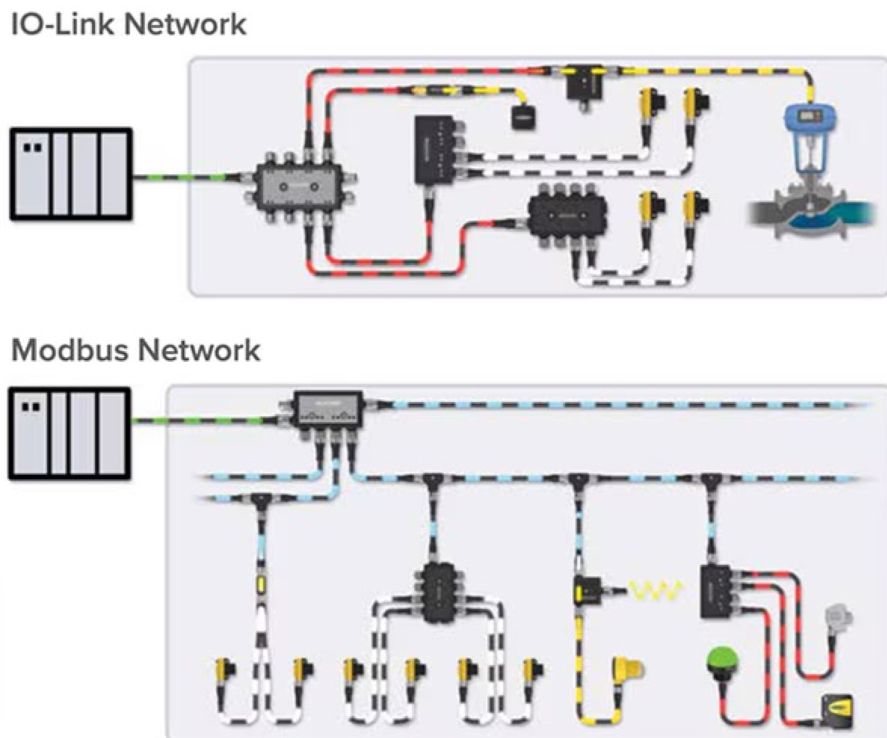


Figure 2: IO-Link and Modbus networks reduce the number of wires used in an automated machine, and allow using standardized cable assemblies. (Image source: Banner Engineering)

The networks reduce the number of wires routed to the control room through hubs and controllers. They also permit using standardized cable assemblies, which reduce wiring and maintenance costs.

Banner Engineering designs remote I/O blocks that help automated machine designers enhance their control system architecture. They offer products that decrease wiring complexity by combining multiple signals into an integrated data stream, resulting in lower installation, integration, and diagnostic costs.

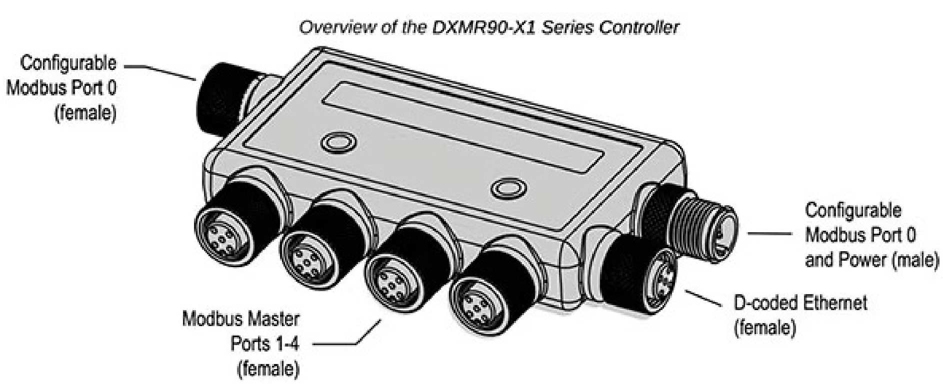
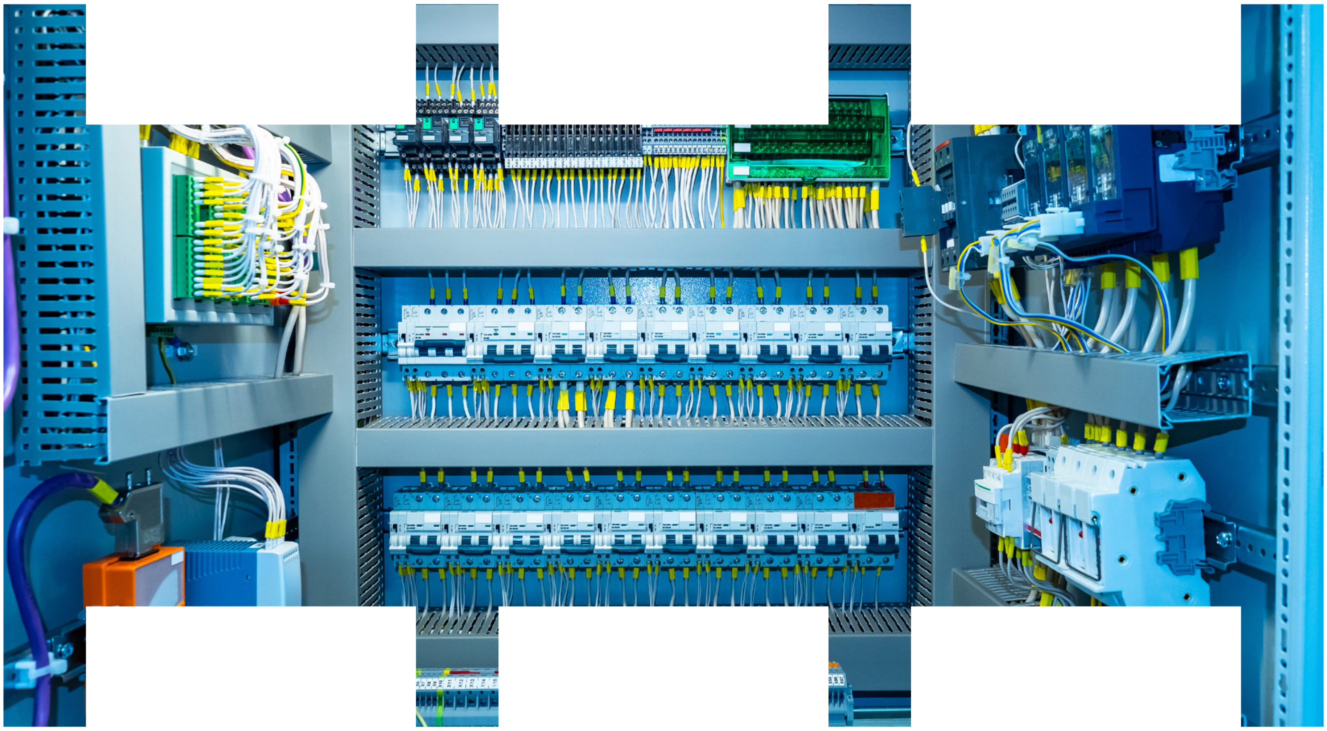


Figure 3: The DXMR90-X1 controller has seven I/O ports. (Image source: Banner Engineering)

Examples of remote I/O blocks

Banner Engineering's DXMR90-X1 programmable controller (Figure 3) has seven I/O ports and combines data from multiple sources, providing local processing before sending the data to the SCADA system. This controller can collect data from various sensors and convert it to standard Ethernet protocols. The seven ports include four individual Modbus masters, supporting up to four independent networks. It can deploy Modbus slave device data to EtherNet/IP, Modbus TCP, or PROFINET networks. The controller is powered by a 12 to 30 volt DC



source with a power consumption of 120 milliamperes (mA) at 12 volts and utilizes LED indicators to report its status.

Housed in a compact enclosure, the controller is ingress protection (IP) rated at IP67, meaning it is dust-tight and protected against short-term immersion in water. It is rated to operate over a temperature range of -40 to +70°C.

The DXMR90-X1 uses standard M12 connectors, with a single male M12 port (Port 0) for power and Modbus RS-485 connections, and a single female M12 port for daisy-chaining the Port 0 connections. There are also four female M12 ports for the Modbus master connections and a female M12 D-Code Ethernet connector.

The controller is coupled to remote sensors via a hub. The Banner Engineering R95C-8B21-KQ is an eight-port IO-Link hub (Figure 4) that offers an easy way to connect non-IO-Link devices to an IO-Link system. It connects two discrete channels to the eight four-pin M12 connector ports, which can be configured as 16 inputs or as 8 inputs and 8 outputs. Data from the channels is connected to an IO-Link master.

Two configurable I/O pins per port support PNP (sourcing) or NPN (sinking) outputs. LEDs that indicate port activity are placed on each side for mounting flexibility. The hub also supports host mirroring, where a selected port input or output discrete signal can be routed to the PLC or the host connection.

The hub is rated to operate off 18 to 30 volts DC with a maximum current draw of 400 mA. It can supply a pass-through current of up to 500 mA per port and is protected against reverse polarity and power transients.

Figure 4: The R95C-8B21-KQ eight-port hub supports both NPN and PNP outputs. Indicator LEDs report port activity and IO-Link status. (Image source: Banner Engineering)

Figure 5 : An IO-Link-to-analog output converter produces a current or voltage output controlled by the IO-Link master. (Image source: Banner Engineering)

Packaged in a rugged nickel-plated brass and PVC body, the hub has IP65, IP67, and IP68 ratings for indoor use only.

Analog signals predate automation, but since many sensors still have them as outputs, they need to be converted to Modbus or IO-Link protocols. The Banner Engineering R45C-2K-MQ 2-port converter reads two analog signals as a voltage or a current and outputs them in a Modbus protocol. Analog inputs are made via two M12 female connectors, while the output is via a five-pin M12 male connector. LEDs indicate the input and output status. The R45C-2K-MQ is powered from an 18 to 30 volt DC source with a maximum current draw of 4 amperes (A) at 24 volts. The converter operates over a temperature range of -40 to +70°C and is environmentally rated at IP65, IP67, and IP68 for indoor use only.

Data converters can also take digital commands from the master controller and output an analog voltage for devices such as pneumatic actuators, solenoids, or motor starters. The converter can be located near the controlled device, minimizing analog signal losses and electromagnetic interference. The Banner Engineering R45C-K-UQ converter (Figure 5) allows automation designers to output an

analog value of voltage or current by sending the numerical analog value from the IO-Link master. The converter has an output voltage range of 0 to 11 volts and an output current range of 0 to 24 mA.

Like the other Banner Engineering remote I/O devices, it has environmental ratings of IP65, IP67, and IP68, with an operating temperature range of -40 to +70°C. It can be powered from an 18 to 30 volt DC source, drawing only 50 mA, and can pass power up to a maximum current of 4 A. Connectivity to the IO-Link master is via a conventional four-pin M12 male connector. The analog output uses a four-pin female M12 connector.

Conclusion

Banner Engineering Remote I/O Blocks help automation designers optimize the deployment of control systems. Multi-protocol support reduces wire count and installation costs, while onboard programmability provides design flexibility and eases system integration.