Advancing Automation

Sensors & Instruments

Automation.com

November 2019 | Volume XXI

INTRODUCTION

Innovation and technology continue to combine for an intriguing array of new instruments and sensors for today's process and industrial automation industries. Increased connectivity and computing power are helping physical tools cross over into the digital realm. The result is new opportunities for today's manufacturers and engineers to design, monitor and enhance the many assets of their plant. With tools designed for everything from enhancing asset performance, process safety and even worker training, technology is driving an exciting and highly dynamic world of capability and change.

With so many new tools and capabilities, it can be hard to keep up with innovations. That's why Automation.com remains committed to being the top resource for all things automation. Learn the latest about Sensors & Instruments from industry leaders including how smart transmitters enable smart sensors, powering wireless instruments and sensors, and how sensors and systems enable the computer-controlled production of automobiles in this edition of Advancing Automation. Bookmark the Advancing Automation homepage to find archived editions covering control systems, safety, cybersecurity and more.

Automation.com

ADVANTECH

Endress+Hauser
People for Process Automation

65 JAHRE Bürklin
DIE GANZE ELEKTRONIK

TADIRAN BATTERIES

CPI
CHATSWORTH PRODUCTS

TABLE OF CONTENTS

Smart Transmitters Enable Smart Sensors — Page 5
by: Steven J. Smith

I/O, Sensors and Automotive Assembly — Page 12
by: Maxine Cho

Do Your Remote Wireless Devices Need to Run For Decades? — Page 18
by: Sol Jacobs

The Digital Twin – Enabling Realtime Closed Loop Manufacturing Optimization — Page 24
by: Bill Lydon

Servitization for Sensors — Page 28
by: Jonathan Wilkins

Smart Transmitters Enable Smart Sensors

Integrating digital technologies made instrument transmitters smart, with instrument sensors following in their wake.

By: Steven J. Smith, Endress+Hauser

Process instruments consist of two main components: a sensor and a transmitter. The sensor is sometimes part of the instrument assembly, as with some pressure instruments, but is more often separate, as with analytical instruments, such as those used for pH measurement.

Before sensors could become smart, transmitters had to gain intelligence by adapting digital technologies. It would not have been practical, or sometimes even possible, to connect a smart digital sensor to a simple analog transmitter.

Industrial instrumentation has progressed significantly since the 1970s, when the vast majority of instruments simply had a single 4-20 or 0-20 mA (analog) output proportional to the process variable. Some sensors had the inherent ability to measure multiple process variables, but it would require multiple analog outputs to access this additional information.

With an analog transmitter with a single analog output, secondary variables remained stranded, as did data regarding the configuration or health of the instrument. The process variable was relegated to a dedicated analog signal transmitted from the instrument over two wires to an indicator or control system, with a multi-drop configuration.

Working with these instruments required direct access to the device and manual adjustment by maintenance personnel. What was missing from this environment was any information about the instrument itself, or about secondary process variables, for example, the temperature from a pH sensor.

HART Emerges

In the early 1980s, instrument vendors realized the potential benefits of digital technology in instruments. There was a wealth of useful data contained in an instrument including other measured process variables, device configuration, alarm limits, operating time, operating conditions, diagnostic information and a broad range of device health data.

Obtaining this data from an instrument can help optimize the use of the device, and ultimately improve process performance, and HART communications emerged as one of the first ways to access this stranded data to make an instrument smart.

HART digital technology allowed for communications with an analog instrument using a digital communication signal (Bell 202) transmitted over the same two wires as the analog output. This digital signal provided two-way communications between the instrument and a host without disrupting the output, allowing various pieces of data to be accessed. Using HART, users could talk to the instrument, perform configuration or diagnostics—all while it was making one or more real-time process measurements.

At the same time, various companies were making progress in the development of other digital technologies that would be transmitted over dedicated communication highways, each offering specific benefits. Various Fieldbus technologies emerged—including EtherNet/IP, FOUNDATION Fieldbus, Profibus and Modbus—and today these comprise the majority of new applications for fieldbus communications.

In a similarly fashion with respect to wireless digital communications, many technologies have been reduced to two clear leaders: ISA100 and *Wireless*HART.

Digital Technology Expands

The realization that instruments contained a vast amount of valuable data that could be bidirectionally communicated between instruments and control systems dramatically changed the way companies operated a process and managed assets—and it drove the rapid expansion of digital technology in the industrial environment. There are very few instruments today that are not smart, at least to some extent. From the 1980s to 2000, digital communication technologies emerged in industrial markets, and today are providing significant benefits.

Figure 1: This Endress+Hauser Liquiline transmitter offers EtherNet/IP, Modbus RS485 or TCP, PROFIBUS DP, and HART as well as a web server. This transmitter can communicate with up to eight smart sensors.

Around the same time, office computer networks were evolving. In 1989, the first prototype of the internet was developed by Tim Berners-Lee and Robert Cailliau at CERN, eventually leading to the implementation of the World-Wide Web. With networked computers and the internet, there became internet-enabled coordination and integration across the value chain, allowing suppliers to reach customers and business partners regardless of geography.

This internet-enabled integration has also allowed for enhanced access to process data, from the point of measurement all the way to the business system level and beyond. Not only can one see process data critical to the operation of a process, one can also access this key asset information.

As we move well into the second decade of this century, basic information technology has become more deeply embedded in industrial and consumer products, allowing them to become part of the Internet of Things (IoT). In one lifetime, process control migrated from pneumatics to electrical analog, and then to sophisticated digital communications extending out to the internet. And most of today's smart instruments (Figure 1) connect easily to digital communications systems, and in some cases contain web servers and Ethernet ports for direct connection to the internet.

Smart instruments can acquire so much data, they need a high-speed digital interface to send it all. For example, some Coriolis flowmeters can simultaneously detect multiple measured process values including mass flow, volume flow, density, concentration and temperature.

In addition to these measured variables, built-in electronics monitor instrument performance and report status and diagnostic values.

Once smart instruments became widely accepted, mostly by adding the aforementioned features to the transmitter, smart sensors followed.

Smart Sensors Improve Operations

With digital information residing in the sensor and communicated to the transmitter, health diagnostics can be performed, and the state of the sensor and transmitter health can be communicated to the host systems in real time.

Real-time diagnostics and sensor-health data allow for better management of a sensor. The need to clean and calibrate the device can be proactively managed, rather than reactively performed. In fact, some smart sensors can determine if they actually need to be cleaned and calibrated.

For example, calibration cycles for standard temperature sensors in critical service are every six to twelve months. This requires a technician to remove the sensor, take it to a lab for calibration and then re-install it. But an RTD sensor (Figure 2) is able to determine if it needs a calibration when used in sterilize in place (SIP) processes.

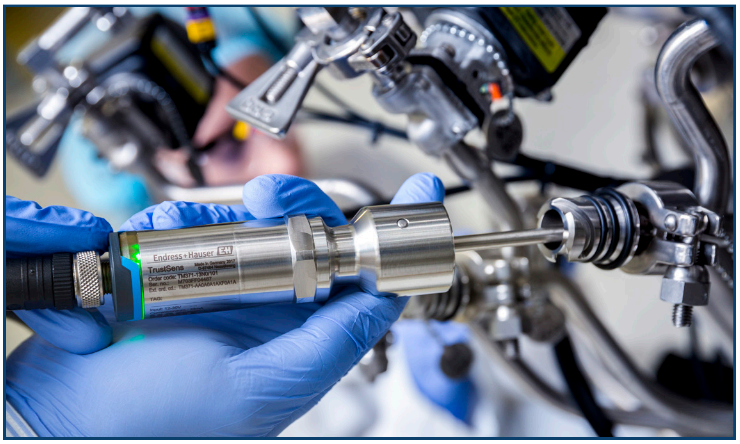


Figure 2: The Endress+Hauser TrustSens RTD checks its calibration every SIP operation.

In SIP processes, steam at 121°C (250°F) is used to sterilize equipment. The sensor uses a reference material with a Curie Point of 118°C (244°F). When the SIP process reaches 118°C, the reference sensor sends a signal. Simultaneously, the RTD measures the temperature. Comparison between these two values is used to determine if the temperature sensor needs calibration. If both sensors read a value close enough to 118°C, the RTD sensor is still in calibration.

Another example of real-time diagnostics and sensor-health data is a four-pole conductivity sensor (Figure 3). This sensor uses four conductors to measure conductivity, and its four-pole design allows the sensor to operate over a broader range of measurement than two-pole conductive sensors. It uses digital sensor technology in the head of the sensor to digitize the measurement signal, and providing a host of performance and diagnostic information.

One diagnostic function that makes this sensor particularly smart is Electrode Connection Surveillance, which monitors the connection between the electrodes and the electronics. If there is a connection error, an error message is sent to the transmitter to notify the user of a connection problem within the sensor.

Figure 3: The Endress+Hauser CLS82D four-pole conductivity sensor with Electrode Connection Surveillance smart diagnostics.

Accessing Smart Sensors

Maintenance personnel are stretched thin at many process plants and facilities, resulting in the need to enhance the use of digital technologies, such as remote access to an instrument beyond the control system. With the use of digital communications, especially over an industrial Ethernet network, an instrument can become a “thing” in the industrial internet of things (IIoT).

Some more sophisticated digital transmitters have an embedded web server, permitting properly authorized access from any device connected to the internet and capable of hosting a web browser, such as a smartphone (Figure 4).

Two of the leading networks for local access to smart instruments from host systems are Modbus and EtherNet/IP. Common hosts are control systems and asset management systems.

Modbus is an open protocol, allowing any manufacturer to integrate the protocol into an instrument. Modbus is a serial, master-slave, protocol. The master requests information and the slaves respond, with one master communicating with up to 247 slaves. Each slave in the network is assigned a unique ID. When a Modbus master requests information from a slave, the first data communicated is the slave ID.

Figure 4: A technician can connect a smartphone to an instrument, such as this Endress+Hauser flowmeter, and access the meter via its integrated web server. The same procedure can also be used for access done from a remote PC or tablet.

Modbus can be difficult because one can use 16-bit or 32-bit signed integers and unsigned integers; ASCII strings; discrete on/off values; and 32-bit floating point numbers. To program a system for a device using Modbus communications, a significant amount of information is required about the slave device and its registers. A programmer has to obtain a Modbus map from an instrument manufacturer and carefully program the master to communicate properly with each slave device.

An improved version called Modbus TCP/IP is now available, whereby Modbus data can be framed in a TCP/IP packet, allowing the information to be more easily communicated over an Ethernet network.

EtherNet/IP is becoming one of the most widely used industrial protocols due to its ease of integration and operation. Like Modbus TCP/IP, EtherNet/IP data is transferred in a TCP/IP packet. Each device on an EtherNet/IP network presents its data to the network as a series of data values called attributes.

Because EtherNet/IP uses the Common Industrial Protocol (CIP), consistent device access is possible with one configuration tool. Devices become “objects” on the network that are easy to integrate. Once on the network an object has a profile that allows sensor data to be assigned within the profile, without the need for detailed programming information.

With digital sensors, digital transmitters and control systems communicating, data can be easily and clearly communicated from the process to the host control system, and on up to the enterprise level. Data is no longer just the primary process variable, but also includes secondary process variables, sensor health, sensor performance characteristics, calibration information and real-time diagnostics. All this information can be used to improve the process, optimize the performance of the instrument while extending its life, and maximize productivity of maintenance personnel.

With the advent of the internet, these digital-based devices and systems are being further transformed and becoming part of the Internet of Things (IoT). This transformation will take us to places and capabilities we never imagined. Let’s look at the journey of one industrial process measurement over the past 50 years to see how it has been completely transformed by digital technology: pH measurement.

The Digital Journey of One Measurement

pH is a fundamental measurement that has been used across a range of industrial processes for many years. pH is a measurement of the hydrogen ion activity in a sample and represents the acidic or basic nature of a fluid. The pH range is defined from 0 to 14.

Determining a solution’s pH began as a lab-based measurement. A sample would be brought to a lab and a benchtop pH system would be used to measure the sample. The measuring system didn’t actually measure pH, but calculated pH based on a measured mV potential signal produced by the pH sensor. To do this, a benchtop pH sensor has two electrodes (a measurement electrode and a reference electrode, enclosed in separate glass cells) and, due the effects of temperature on the measurement, a temperature sensor is required.

Figure 5: The Endress+Hauser CPS171D pH sensor stores measuring and operating data in the sensor including serial number, calibration date, number of calibrations, offsets, pH application range, number of calibrations, hours of operation under extreme conditions and other information.

Historically, with lab-based systems, the measuring electrode, reference electrode and temperature sensor were three separate electrodes that were immersed in the sample while connected to electronics that would measure the low-level mV signal and convert this value to pH.

This was truly an analog system and an off-line measurement that involved a significant amount of operator effort, with considerable time lag between the time a sample was collected and results were reported.

One of the first significant changes to occur in the measurement of pH was to integrate the three separate electrodes into one device, which resulted in a “combination” electrode.

The sensor was still an analog device with hardwired connections to the transmitter, and all the inherent problems associated with a hardwired, low-level analog signal. The next significant improvement in pH measurement was the introduction of digital technology to the sensor, enabled by continuing advancements in miniaturization (Figure 5). And, as with all smart sensors, it allows new pH sensors to provide more data, and to operate more reliably.

At the transmitter end of a pH instrument, the data communicated by a digital smart sensor can be read and sent out to a control and/or an asset management host system, also using digital communications protocols. With the abundance of data residing in the sensor, and the ability to digitally communicate this data to a digital transmitter and beyond, users now have the information needed to better operate the process and manage the asset.

Although this example pertains to pH measurements, much of the discussion also applies to other process variables.

Summary

In half a century, technology advances have allowed for the evolution; from the transmission from an instrument of just the primary process variable, to a wealth of information that can be accessed up to the enterprise level. As we move into the future, digital technology will continue to provide more information from instruments, with access from anywhere in the world.

A pH measurement is no longer just the pH value, it also includes the temperature, quality of the calibration, number of calibrations, overall operating time, operating time over critical process conditions and much more. Tools are available to turn this data into actionable information, with virtually no limitations when it comes to improving operations and efficiency.

About the author:

Steven J. Smith is the Senior Product Marketing Manager – Analytical for Endress+Hauser USA, responsible for technology application, business development and product management over a wide range of analytical products. He has a BS Degree from the University of Wisconsin and a MBA from the University of Colorado. Steven has spent the past 30 years working in process instrumentation and control, with industry leading Fortune 500 companies.

ADVANTECH

Intelligent Embedded Computers

IoT-Based Platforms for Automation

intel IoT Solutions Alliance Premier

Product Offerings

Lite version
with essential I/O

ARK-3530L

- Intel® Xeon® E3/7th Gen.Core i7 Desktop fanless system
- Lite functionality version with no expansion slot
- 2 x external accessible 2.5” drive bay and 2 x mSATA
- 12VDC in

Multi-slot
expansion

ARK-3530F

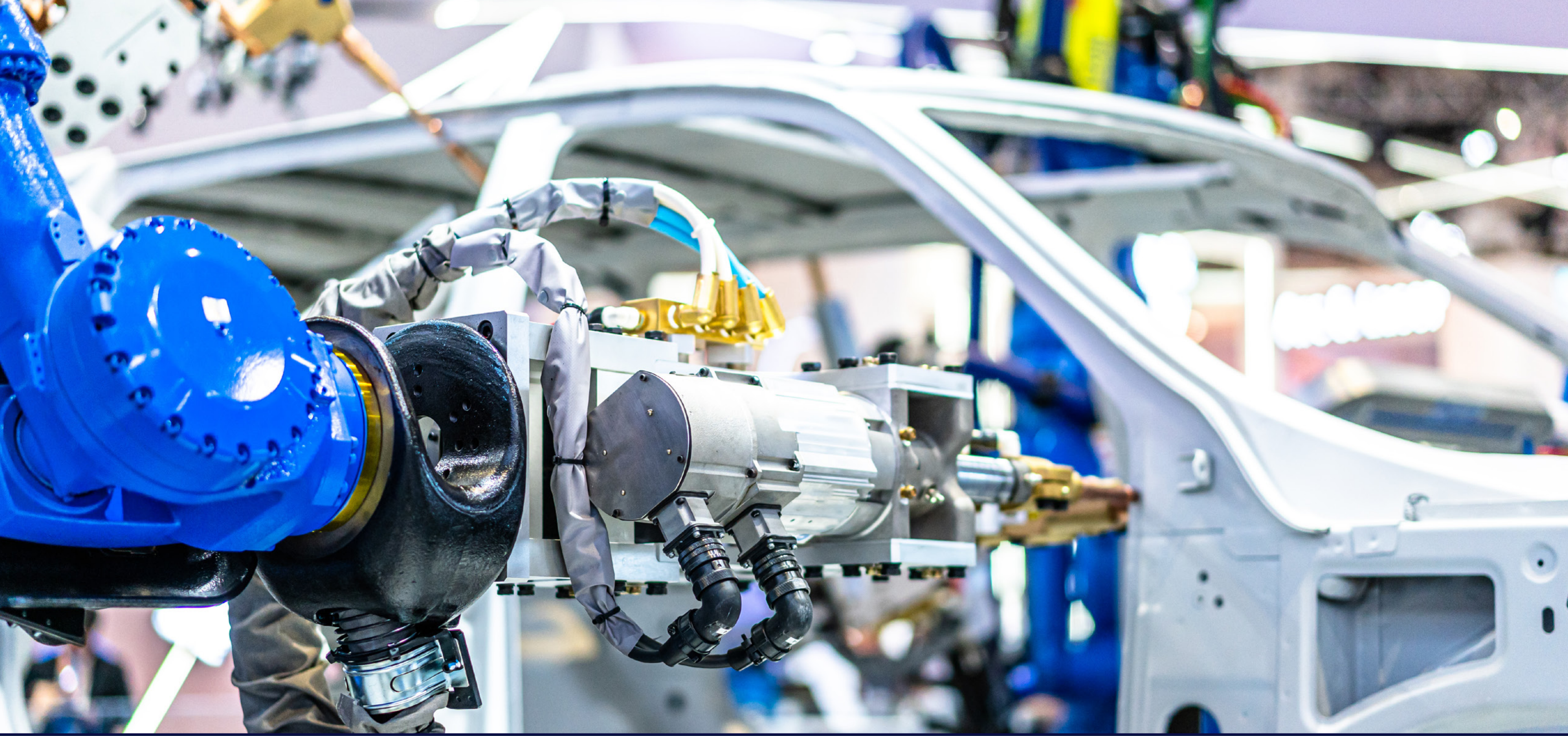
- Intel® Xeon® E3/7th Gen.Core i7 Desktop fanless system
- Standard SKU with 2 x PCI slots
- Support two PCIe x 8 by optional riser card
- Wide power range: 9-36VDC

Compact DIN-rail
mounting system

ARK-1220

- Intel Atom® E3940 Quad Core SoC
- Dual channel DDR3L support
- Single I/O bezel for in-cabinet installation
- Wide range 12-28VDC input

See more information about our Intelligent Embedded Systems at **Buy.Advantech.com** or call **1-877-825-4146**



I/O, Sensors and Automotive Assembly

How sensors and systems enable the computer-controlled production of automobiles

By: Maxine Cho, Advantech

From vision to vibration, identification to verification, the types and functions of sensors used in the automotive industry is vast and growing. The concept of Industry 4.0 is about connecting machines, work pieces, and systems to a network, and allowing those pieces to influence each other automatically, without a human attendant having to intervene. Sensors are essential to that process, acting as eyes, ears and touch receptors for the robotic systems attached to the production lines.

In an automotive plant, large robotic arms with high payload capabilities and long reach move freely but precisely to spot weld car body panels, install windshields or mount wheels, while smaller robots are used to weld and mount subassemblies like brackets. The sensors on robots help them do their jobs, as well as protect workers from hazardous fumes and hot moldings. The ever-increasing speed and precision available with robotic technology is often due to a combination of better sensors, fast and efficient I/O systems and IoT software at the gateway and server level that processes and converts data from the field.

Here's a look at some of the sensors being used in automotive assembly plants today, and how an embedded computer hardware/software combination is enabling computer-controlled production.

Sensors for automated assembly

A range of highly accurate and very fast noncontact laser sensors are used for various measurement, inspection and defect-detection applications. Noncontact laser sensors are especially good for high-volume applications and for detecting the presence of small parts in an assembly at long distances. The narrow focus of a laser sensor can be a problem in the wrong application, however: If there's excessive vibration in the positioning system, for example, a laser could pass near the target without detecting it. In this case, a standard photoelectric sensor with a wide beam pattern would be more appropriate.

Photoelectric sensors are one of the most common types of laser sensors used in automated assembly. They come in three forms:

- A reflective (or diffuse) photoelectric sensor includes both an emitter and receiver. Light from the emitter hits the target, and the reflected light is diffused from the surface at all angles. If the receiver gets enough reflected light back, the output will switch states. When no light is reflected back, the output returns to its original state.
- Through-beam sensors have separate emitter and receiver units that are aligned so the greatest amount of light from the transmitter reaches the receiver. When the target crosses the path of the light beam, it blocks light to the receiver. This causes the receiver's output to change state. When the target no longer blocks the light, the receiver's output returns to its normal state.
- Retroreflective sensors are like reflective ones in that both contain the emitter and receiver in one unit. With retroreflective sensors, however, light from the emitter is transmitted in a straight line to a reflector and returns to the receiver. When a target blocks the light path, the output of the sensor changes state. When the target no longer blocks the light path, the sensor returns to its normal state.

To measure objects or distances single-point laser sensors can employ either optical triangulation or time-of-flight technology. These sensors can deliver high-speed, high-resolution measurements of position, displacement or distance; thickness or width; and runout or vibration. Two- and three-dimensional sensors also can use these technologies to measure height, width, angles, gaps and shapes, as well as to detect defects.

Renault is reportedly using 2D laser displacement sensors on its G9 engine production line in Cléon, France. Workers slide oil, sealing and compression rings onto each piston and then place many fitted pistons onto a pallet that is moved to an automated inspection platform. Four pistons are simultaneously checked by four sensors, and a profile is generated for each piston and compared against a ringless profile to ensure that all rings are in place. An ultra-thin oil ring can be the hardest to detect, while a 3-millimeter compression ring can be the easiest.

Other manufacturers use the sensors to track surface irregularities, or to provide outputs from reflective tape to verify part placement. Some sensors can accurately scan glass, polished metals and other mirror-like surfaces so manufacturers can inspect and measure gaps and flush on translucent, shiny or opaque surfaces while the car is move down the assembly line.

Another application is the use of image sensors to check the quality of manually applied adhesives. Manufacturers such as Renault Alpine, Renault Nissan and Volvo Trucks use an automated image acquisition, analysis and storage system called Cameo, for example. During production, high-resolution machine vision cameras photograph the parts to be joined, measure and inspect the adhesive beads, and store the images for future reference. Image processing software measures the size and position of the beads to verify that they meet legal, safety and quality requirements.

Enabling Automated Optical Inspection

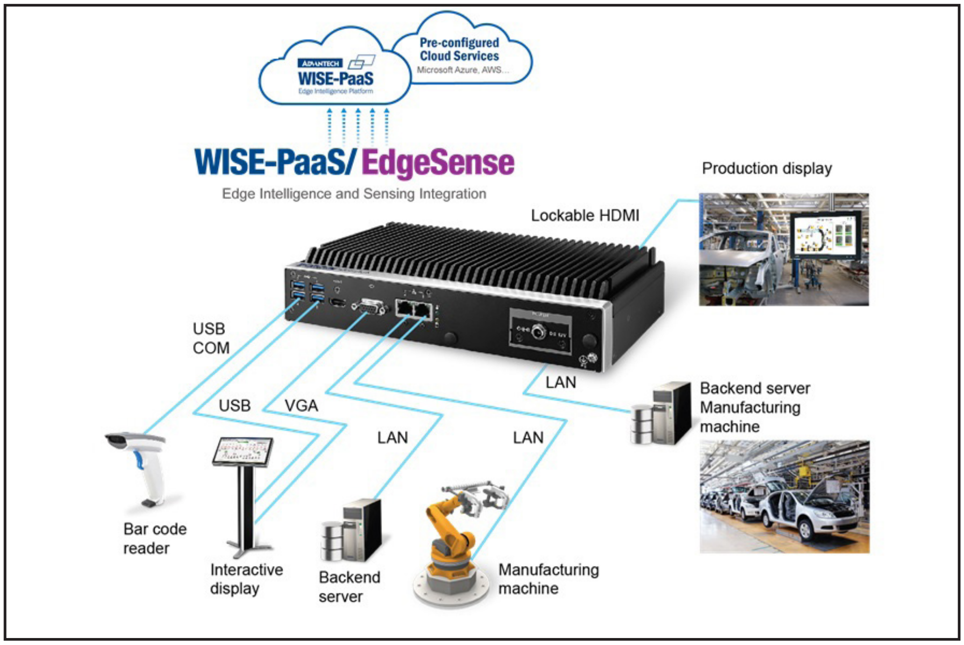
Automated Optical Inspection (AOI) systems use imaging sensors for quality control at production speeds, replacing manual checks of static parts on the production line.
One automotive system integrator combined the strengths of multi-axis robots, machine vision sensors and an Advantech ARK-3520L embedded computer to create an AOI that helps automobile manufacturers improve inspection speed and quality, thus enhancing overall productivity. The inspection solution needed to not only enable industrial cameras to move easily and capture the object from many angles, but also provide a precise and reliable system platform that could be set up and reconfigured easily.

The modular design of Advantech ARK computers supports different function requests with multiple I/O slots and I/O expansion available through iDoor and ARK-Plus, a second layer of the system. For the AOI, the integrator used Advantech PCIE-1674E and PCIE-1672E communication cards to connect industrial cameras quickly. By using the Power over Ethernet (PoE) feature, the cards can supply power to the cameras mounted on robots and eliminate the need for power wiring.

Support for flexible production: A case study

Automotive system integrators and OEMs need a powerful but flexible platform to integrate all the sensors and systems needed for automated assembly. Particularly when retrofitting production lines to produce new models, users need computers that can be flexibly adjusted or upgraded for reconfiguration with minimal extra investment.

For one automotive OEM, a compact, high-performance embedded computer coupled with software to enable data acquisition, data display and remote monitoring and control proved to be the right solution. The need was for a high-quality, high-throughput, flexible production system connected to the automaker's networked process control manufacturing system.



Advantech WISE-PaaS/DeviceOn software running on an ARK-2250 computer is the hub through which one automaker acquires sensor data from robotic cells and elsewhere, processes it and displays it.

The goal was to provide detailed information about the parts needing to be installed and to record production details for product quality control. The embedded computer used in this case had to be equipped with suitable computing and data storage capabilities, as well as software for integrating Industrial Internet of Things (IoT) functions.

The OEM chose Advantech ARK-2250 fanless embedded computers and backend servers running Advantech WISE-PaaS/RMM software. The compact sized of the ARK-2250 (260 x 54 x 140.2 mm, or 10.24" x 2.13" x 5.52") enabled it to be mounted onto robotic monitor arms at each workstation of the assembly facility. Sensors and actuators were attached with lockable wires, and power, network and other cables were secured to ensure operational reliability and stability.

The 6th Gen Intel® Core™ U-series (i3/i5/i7) processor ensures the ARK-2250 delivers high computing performance. The computers include HDMI, VGA and optional 3rd party display interfaces, for providing information to operators, as well as industrial-grade ruggedness, in terms of wide voltage and temperature range support, that let them withstand the harsh plant environment.

Using the ARK-plus expansion module and iDoor I/O modules, an ARK system can be expanded easily to increase storage capacity or add industrial interfaces. The iDoor technology lets system integrators choose the functions they need without paying for functions they will never use. It also provides opto-isolation that blocks high voltages and voltage transients, so that a surge in one part of the system will not disrupt or destroy sensitive electronics elsewhere.

WISE-PaaS/DeviceOn, Advantech's IoT software solution, aggregates and integrates the software resources needed for customers to develop their own industrial control, IoT, or cloud applications. It focuses on remote device management and monitoring, allowing the ARK-2250 to control devices such as sensors, solenoid valves and indicators, and to collect and export sensor data to a NoSQL Server database for IoT data storing. That database archives production records and aggregates data for process improvement and system maintenance.

The WISE-PaaS/DeviceOn software is deployed at the gateway and server levels. The WISE-agent on the gateway side converts data sent from the field level in different data formats into the IoT-standard MQTT protocol, and then passes the unified data to the backend WISE-PaaS/DeviceOn server and cloud database. It also integrates the IBM Node-REDrule engine that can be used to establish data logic flow of the IoT system with simple drag-and-drop operations.

The hardware/software combination meets the OEM's need for data acquisition, edge intelligence, and remote monitoring control functions. With this tool, the user can establish logical operating rules to allow different systems in the factory to work in together. When the controller detects a potential problem in the data it collects from sensors and actuators, for example, it can automatically close the process, issue alerts and alarms, and/or send messages to assigned remote computers or mobile devices.

The Advantech WISE-PaaS/DeviceOn software suite also provides a complete SDK (Software Development Kit) including WISE-Agent plugin, a dashboard builder, RESTful API and UI Framework plugin that system integrators can easily use to collect new data, add functions and even develop their own industrial application. For cloud analytics of sensor data, the WISE-PaaS/DeviceOn provides both a relational database for application related data and a NoSQL database for all kinds of other IoT data. Microsoft Azure cloud service access lets users easily establish cloud applications in the Azure Marketplace.

With sensors acting as eyes, ears and touch receptors for robotic systems, IoT software connecting machines and systems, and embedded computers aggregating and processing all the data, automotive manufacturing continues to become more flexible and efficient. Production line modifications and upgrades get easier, and Industry 4.0 marches on.

Customizing an ARK computer

Automotive OEMs and system integrators who need an embedded computer for equipment integration may find standard product offerings lacking and customization options confusing. Advantech's modular ARK computers come with customization service that helps users build their applications on best-fit box computers with a series of pre-certified I/O modules. Advantech customization services also include software OS and peripheral selections. The whole process typically saves 50% of the time normally spent on customizing systems. Learn more through this video: https://youtu.be/Ust1RCSLISI

About the Author:

Maxine Cho is a content specialist for Advantech Inc.

Details about the ARK computers are available online, as is information on i-Door I/O modules, WISE-PaaS/DeviceOn software, and more. Visit https://www.advantech.com/resources.

Do your remote wireless devices need to run for decades?

Some primary batteries offer faster discharge rates (sprinters) while others run on micro-amps of energy (marathoners) to last up to 40 years. Self-discharge is largely to blame for runner fatigue.

By: Sol Jacobs, Tadiran Batteries

Remote wireless devices used in industrial automation applications are powered by primary (non-rechargeable) batteries.

Some applications can get by with consumer grade batteries that deliver higher discharge rates of energy, resulting in very short operating life (alkaline). Also available are consumer grade lithium batteries that deliver medium to high discharge rates of energy with short to medium operating life, including iron disulfate ($LiFeS_2$), and lithium manganese dioxide ($LiMNO_2$) chemistries (see Table 1).

Table 1: Comparison of Primary Lithium Cells

Primary Cell	$LiSOCL_2$ Bobbin-type with Hybrid Layer Capacitor	$LiSOCL_2$ Bobbin-type	Li Metal Oxide Modified for high capacity	Li Metal Oxide Modified for high power	Alkaline	$LiFeS_2$ Lithium Iron Disulfate	$LiMnO_2$ CR123A
Energy Density (Wh/1)	1,420	1,420	370	185	600	650	650
Power	Very High	Low	Very High	Very High	Low	High	Moderate
Voltage	3.6 to 3.9 V	3.6 V	4.1 V	4.1 V	1.5 V	1.5 V	3.0 V
Pulse Amplitude	Excellent	Small	High	Very High	Low	Moderate	Moderate
Passivation	None	High	Very Low	None	N/A	Fair	Moderate
Performance at Elevated Temp.	Excellent	Fair	Excellent	Excellent	Low	Moderate	Fair
Performance at Low Temp.	Excellent	Fair	Moderate	Excellent	Low	Moderate	Poor
Operating life	Excellent	Excellent	Excellent	Excellent	Moderate	Moderate	Fair
Self-Discharge Rate	Very Low	Very Low	Very Low	Very Low	Very High	Moderate	High
Operating Temp.	-55°C to 85°C, can be extended to 105°C for a short time	-80°C to 125°C	-45°C to 85°C	-45°C to 85°C	-0°C to 60°C	-20°C to 60°C	0°C to 60°C

On the opposite side of the spectrum are a growing number of low-power remote wireless devices that use very small amounts of energy, measurable in micro-amps of average current. Many of these devices are connected to the Industrial Internet of Things (IIoT) and require decades of maintenance-free operation without battery replacement.

Not all batteries can handle extreme temperatures

Lithium-based batteries have high intrinsic negative potential, exceeding that of all other metals, with an operating current voltage (OCV) ranging from 2.7 V to 3.6 V. Lithium batteries are also non-aqueous, with the absence of water enabling them to endure extreme temperatures without freezing.

Among all commercially available chemistries, bobbin-type lithium thionyl chloride ($LiSOCl_2$) cells are preferred for use in remote locations and extreme environments, where the application draws average current measurable in micro-amps.

Bobbin-type $LiSOCl_2$ batteries feature the highest capacity and highest energy density of any lithium chemistry, along with an extremely low annual self-discharge rate (less than 1% per year), enabling certain devices to operate for up to 40 years. Bobbin-type $LiSOCl_2$ chemistry also features the widest possible temperature range (-80°C to 125°C), along with a glass-to-metal hermetic seal that resists battery leakage. Common applications include AMR/AMI metering, M2M, SCADA, tank-level monitoring, asset tracking, and environmental sensors, to name a few.

The passivation effect reduces battery self-discharge

All batteries experience self-discharge, where cell capacity gets exhausted even when the battery is not connected to an external load. The ability to control passivation is unique to bobbin-type $LiSOCl_2$ batteries.

Passivation occurs when a thin film of lithium chloride (LiCl) forms on the surface of the lithium anode, thus impeding the chemical reactions that result in battery self-discharge. When a load is placed on the cell, the passivation layer causes high initial resistance, resulting in a temporary drop in cell voltage until the discharge reaction slowly removes the passivation layer: a process that repeats itself every time the load is removed.

Several factors can influence passivation, including: the current capacity of the cell, length of storage, storage temperature, discharge temperature, and prior discharge conditions, as partially discharging a cell and then removing the load increases the amount of passivation relative to when the cell was new.

Passivation serves to reduce a battery's self-discharge rate, but too much of it can block energy flow. Different bobbin-type $LiSOCl_2$ batteries have varying amounts of passivation and self-discharge, including cells with medium energy flow rates and higher self-discharge (lifespan of 10 years) and cells with lower flow rates and lower self-discharge (lifespan of up to 40 years).

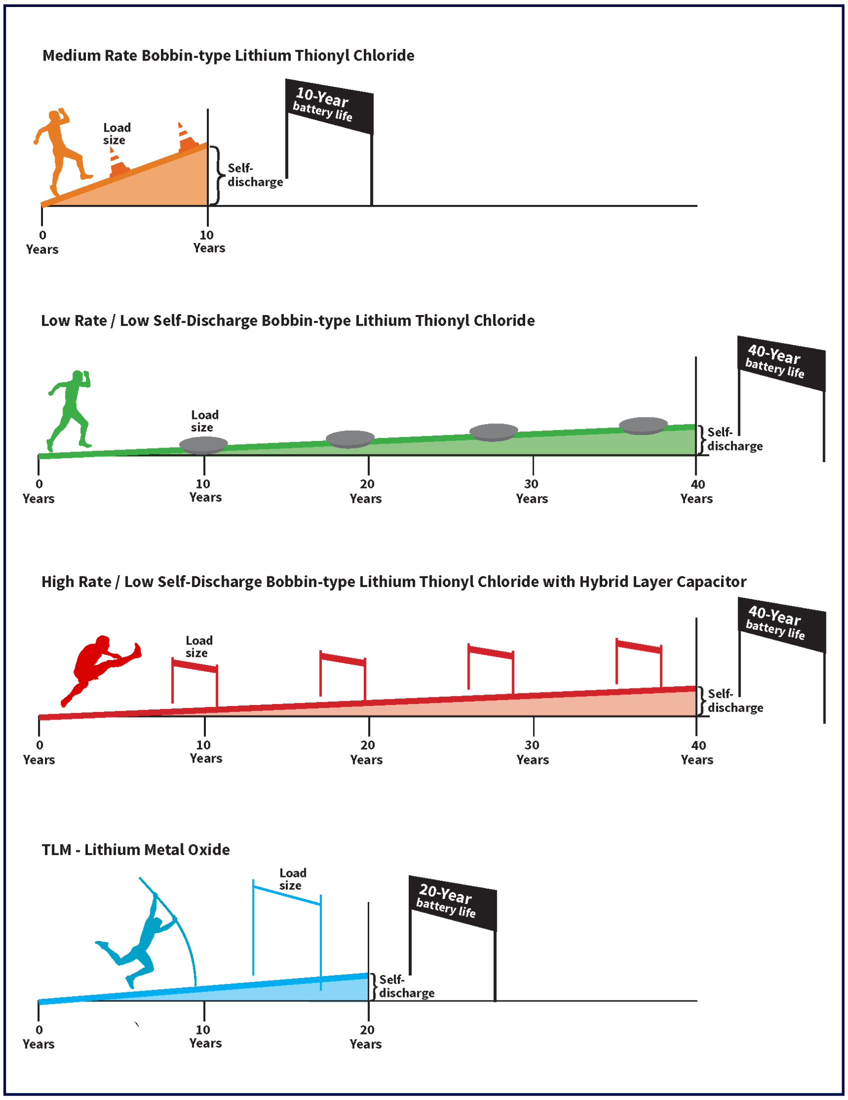
Battery self-discharge is also affected by the quality of the raw materials and the way the battery is manufactured. For example, a lower quality bobbin-type $LiSOCl_2$ battery designed for ultra-long-life can lose 3% of its normal capacity each year to self-discharge, thus exhausting 30% of its initial capacity every 10 years, making 40-year battery life impossible to achieve. By contrast, a superior quality bobbin-type $LiSOCl_2$ battery can feature a self-discharge rate of 0.7% per year, retaining 93% of its original capacity after 10 years, enabling up to 40-year operating life.

The Race Analogy: running a marathon

The Distance – is equivalent to the battery/ device operating life. The farther a runner can travel, the more years a device will be able to operate.

The Incline – is equivalent to the battery self-discharge. The higher the self-discharge rate, the larger the incline. Just as a higher incline draws more power and shortens the duration of the run, higher battery self-discharge reduces the availability of useful power for device operation and lowers the operating life.

Hurdles – are equivalent to pulses. The higher the hurdle, or obstacle, the higher the pulse ability of the battery.



Certain applications require very high energy drain rates and high pulses, such as medical power tools and actuators, where average current measurable in amps, may be well suited for lithium metal oxide batteries. Applications requiring moderate rates of discharge, measurable in milli-amps to amps, such as powering a flashlight or consumer toy for limited operating times, may be best suited for alkaline, $LiFeS_2$ and $LiMNO_2$ batteries that are able to deliver medium pulses. Ultra-long-life, low-drain applications, with average current measurable in micro-amps, including many remote wireless sensors, require the use of standard bobbin-type $LiSOCl_2$ batteries that can run marathons due to their very low self-discharge rates, but are not designed to deliver high pulses due to their low rate design.

Wireless connectivity and the IIoT has expanded demand for ultra-long-life applications require periodic high pulses of energy to power two-way wireless communications. To serve these applications, standard bobbin-type $LiSOCl_2$ batteries must be modified using a patented hybrid layer capacitor (HLC). The standard bobbin-type $LiSOCl_2$ cell delivers low daily background current (to continue running marathons) while the HLC delivers periodic high pulses (for steeple jumping). The patented HLC also features a special end-of-life voltage plateau that can be interpreted to deliver low-battery status alerts.

Consumer applications often use supercapacitors to deliver high pulses electrostatically rather than chemically. Supercapacitors are especially suitable where environmental conditions are moderate, but rarely used in industrial applications due to inherent drawbacks such as short-duration power, linear discharge qualities that prevent use of all the available energy, low capacity, low energy density, and high annual self-discharge rates (up to 60% per year). Supercapacitors linked in series also require the use of cell-balancing circuits, which adds to their cost and bulkiness and consumes additional energy, which further increases their self-discharge rate.

Long-life applications cannot be easily simulated with short-term tests

Long-term battery performance is difficult to predict using short-term tests, so appropriate methods must be used to deliver verifiable results that predict long-term performance. Here are some proven techniques:

Long-Term Laboratory Testing. The ideal way to monitor battery self-discharge is to continually test batteries over time under various conditions, covering almost every possible scenario. The accumulated data points can be used to measure cell size, temperature, load size, etc. This process can result in an ever expanding database that delivers highly accurate predictive models.

Accelerated Testing. The Arrhenius equation, which is based on a two-fold increase of reaction rate for every 10°C rise in temperature, can be helpful in shortening the time it takes to simulate long-term operation. Arrhenius tests are run at 72°C, equivalent to about 32 times the theoretical lifetime of battery at 22°C. However, short-term tests using the Arrhenius method tend to show inaccurate results.

Calorimeter Testing. An extremely accurate test method is to measure the amount of actual heat energy lost using a state-of-the-art microcalorimeter, which is capable of detecting energy dissipation down to the 0.1W level.

Heat energy is generated three ways: entropy change, often referred to as reversible heat; cell over-protection, often referred to as irreversible heat; and chemical reactions, including self-discharge reactions that affect cell capacity, and side reactions that do not affect cell capacity.

Calorimeter testing can be especially useful for measuring losses in battery capacity that occur during long-term storage or from operation (including self-discharge), measurable using thermodynamic equations and cell voltage considerations. To ensure accurate long-term test results, the batteries need to be be stabilized for one year prior to testing, as self-discharge during the first year tends to be higher than in subsequent years.

Lithium Titration. In special circumstances, such as exposure to extreme temperatures and prolonged high current pulses, lithium titration can be used to measure available cell capacity. The battery is cut open, and then titration is used to dissolve the remaining lithium to determine its volume. The higher the self-discharge rate, the less amount of lithium will be found in in the cell.

Field Results. Tadiran works closely with its customers to randomly test batteries taken from long-term deployments to demonstrate in real-life how long-term exposure to extreme temperatures can accelerate battery self-discharge. Batteries have been tested for decades in the field to validate predictive models.

Another useful indicator of long-term battery performance is to calculate the number of Failures In Time (FITs), measurable in billions of device operating hours for devices in the field. Tadiran batteries have achieved FIT rates ranging between 5 and 20 batteries per billion, which is extremely low compared to the industry average.

Due diligence is required when specifying an industrial-grade battery

Short-term tests generally under-represent the true impact of passivation and long-term exposure to extreme temperatures. If extended battery life is an essential requirement, then appropriate due diligence is required to properly evaluate competing batteries. Complete verification requires fully documented long-term test results, in-field performance data from similar applications, and customer references.

Certain applications demand verifiable test data, such as meter transmitter units (MTUs) used in AMR/AMI utility metering, as a large-scale battery failure can disrupt customer billing systems and disable remote service start-up and shut-off capabilities. The possibility of such wide-scale chaos could force a utility to prematurely invest millions of dollars to replace batteries early so as not to jeopardize data integrity.

Other factors need to be considered when specifying an industrial-grade lithium battery, including: the amount of current consumed in active mode (along with the size, duration, and frequency of pulses); energy consumed in stand-by or sleep mode (the base current); storage time (as normal self-discharge during storage diminishes capacity); expected temperatures (including during storage and in-field operation); equipment cut-off voltage (as battery capacity is exhausted, or in extreme temperatures, voltage can drop to a point too low for the sensor to operate).

If a remote wireless application draws milli-amps of average current, this added power demand could be enough to prematurely exhaust a primary battery. These applications could be better suited for some form of energy harvesting device in conjunction with a rechargeable lithium-ion (Li-ion) battery to store the harvested energy.

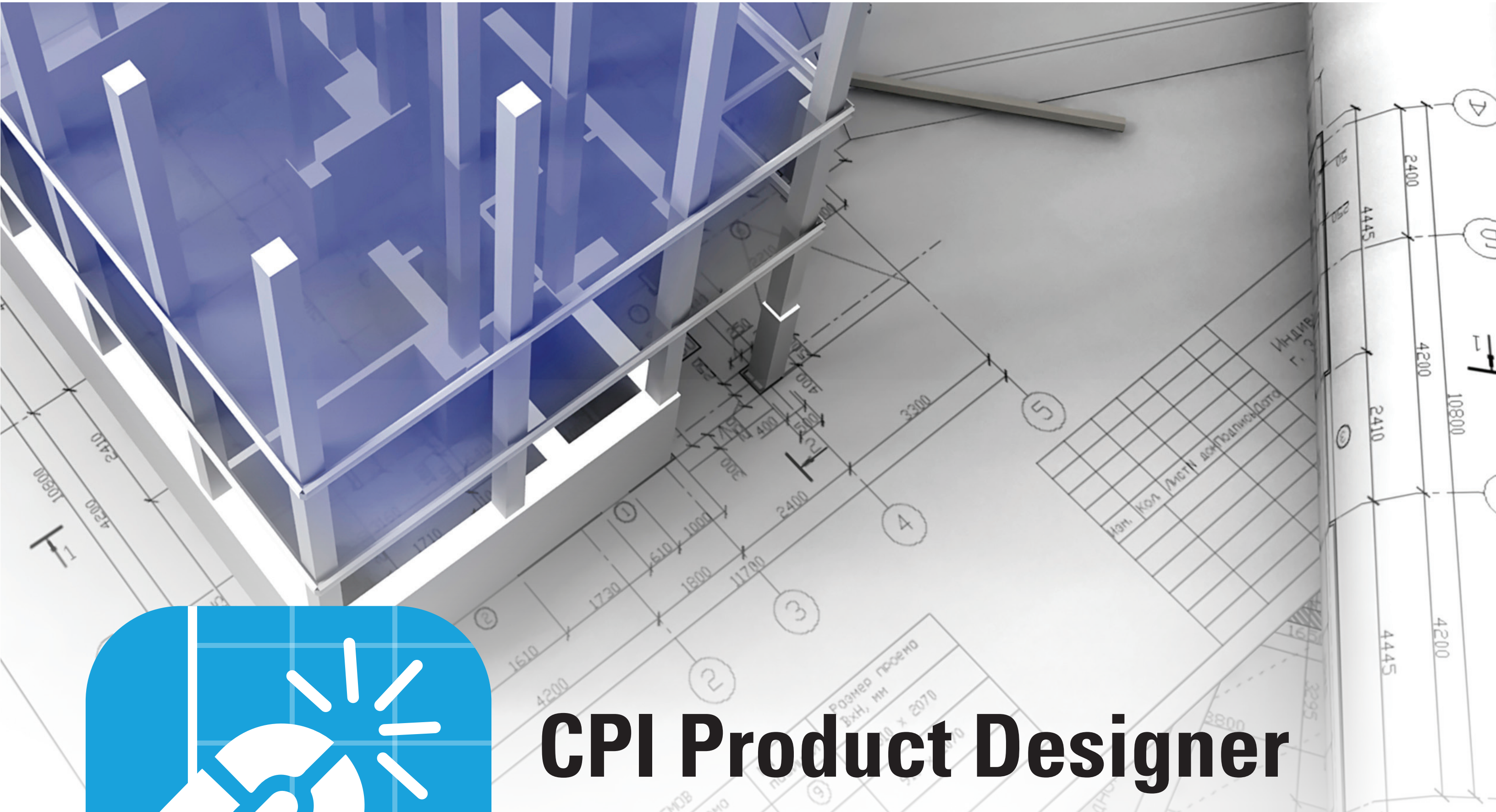
Consumer grade rechargeable Li-ion batteries can operate for up to 5 years and 500 recharge cycles, within a moderate temperature range, and no ability to deliver high pulses. According to our runner analogy, this would be a 10K jog at moderate temperatures with no big hills. By contrast, industrial grade rechargeable Li-ion batteries can operate for up 20 years and 5,000 full recharge cycles (think of this as a half-marathon). Industrial grade Li-ion batteries can also be charged and discharged at extreme temperatures, and can deliver up to 15A pulses to power two-way wireless communications (see Table 2).

		TLI-1550 (AA)	**Li-Ion**
		Industrial Grade	**18650**
Diameter (max)	[cm]	1.51	1.86
Length (max)	[cm]	5.30	6.52
Volume	[cc]	9.49	17.71
Nominal Voltage	[V]	3.7	3.7
Max Discharge Rate	[C]	15C	1.6C
Max Continuos Discharge Current	[A]	5	5
Capacity	[mAh]	330	3000
Energy Density	[Wh/l]	129	627
Power [RT]	[W/liter]	1950	1045
Power [-20C]	[W/liter]	> 630	< 170
Operating Temp	deg. C	-40 to +90	-20 to +60
Charging Temp	deg. C	-40 to +85	0 to +45
Self Discharge rate	[%/Year]	<5	<20
Cycle Life	[100% DOD]	~5000	~300
Cycle Life	[75% DOD]	~6250	~400
Cycle Life	[50% DOD]	~10000	~650
Operating Life	[Years]	>20	<5

Every application is unique, so it is important to specify (and then verify) the ideal battery: whether you need a sprinter (high discharge potential); a medium distance runner (moderate to high discharge rate with fairly low self-discharge); or a marathoner, including elite cells that can run for up to 40 years while periodically jumping high pulse hurdles.

About the author:

Sol Jacobs, VP and General Manager, Tadiran Batteries
Sol Jacobs has over 30 years of experience in powering remote devices. His educational background includes a BS in Engineering and an MBA.



CPI Product Designer

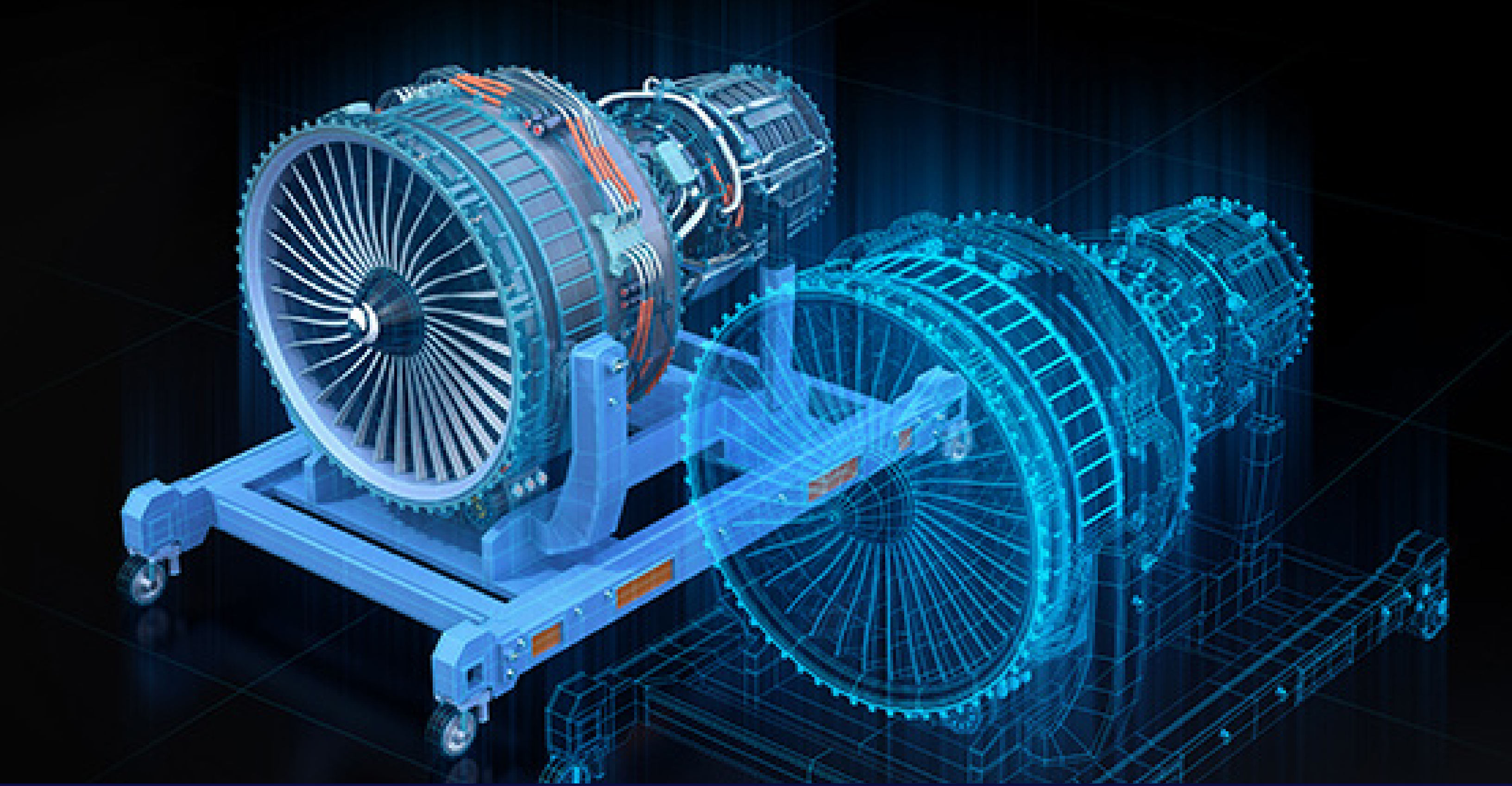
You design it. We build it.

In just a few clicks, the CPI Product Designer from Chatsworth Products (CPI) helps you select, size and accessorize the exact enclosure you need for your next NEMA-rated industrial enclosure application. And with an intuitive point-and-click design, compatibility verification every step of the way, and the ability to generate a bill of material (BOM), drawings, and sales documents that arrive within minutes, the CPI Product Designer saves time, ensures accuracy and delivers a high-quality solution—every time. **Design your next enclosure at chatsworth.com today.**

CHATSWORTH PRODUCTS

Protecting your technology investment.

chatsworth.com | 800-834-4969



The Digital Twin – Enabling Realtime Closed Loop Manufacturing Optimization

By: Bill Lydon, Automation.com

The Digital Twin has become one of the most powerful concepts of Industry 4. 0. The implementation of model-based, real-time, closed-loop monitoring, control, and optimization of the entire manufacturing and production process, the Digital Twin concept is helping organizations achieve real-time integrated manufacturing. The fundamental idea of the Digital Twin is to have a virtual model of the ideal manufacturing operations and processes, that will benchmark the actual production metrics in real time. The broadest implementation models include all of the factors that affect efficiency and profitability of production, including machines, processes, labor, incoming material quality, order flow, and economic factors. This provides a wealth of information which organizations can use to identify and predict problems before they disrupt efficient production. The Digital Twin is a prominent example of a practical macro level closed-loop control that is now feasible with the advanced hardware, software, sensors, and systems technology now available.

A critical part of the creation of a digital twin is the need to have a complete information set, including the capture of real-time information with a wide range of sensors based on these requirements. To facilitate this information collection, some common sensor strategies include the following:

Leveraging Existing Connected Sensors

This is typically the popular first step since it does not require physical installation of new sensors. What it does require is application engineering and a software project to link information to the IT network. It may also require new software to be added to SCADA, PLC, HMI, DCS systems, in order to accomplish communication with enterprise and other systems.

Adding New Sensors to Existing PLC's & Controllers

If there are unused sensor interfaces on the controller or available slots to add new interface cards, which can accommodate more sensors, then adding new sensors to existing controllers can be an option. This also requires application engineering in order to add these sensors to the program in the controller. It may also require the addition of new software to to HMI, DCS systems in order to facilitate communication with enterprise and other systems. In this strategy, there is a risk that making changes in these controllers and systems will create performance and operating issues, so it may require significant amount of systems and application engineering to ensure reliable operation.

Installing Edge Devices

In addition to practical concepts, like the Digital Twin, the Industrial Internet of Things (IoT) has led to companies bringing a wide range of edge devices to market. These edge devices are designed to capture information and communicate directly to enterprise systems and cloud applications, particularly Amazon Web Services and Microsoft Azure. Many new sensors are not required to be part of the control & automation strategies in the plant, but are required to monitor operating parameters for a complete digital twin, and close the information loop. Edge devices typically connect directly to the IT network. The advantage to this is that they are non-intrusive having no or very minimal impact on existing control software architecture. This can be an efficient way to communicate directly with production, maintenance and business systems.

Embracing Smart Sensors

There are new classes of smart sensors emerging that can communicate directly with production, maintenance and business systems. Wireless sensors can be an efficient way to acquire data with standard technology, including WirelessHART and ISA100, primarily used in process applications. For discrete points, the IO-Link wireless version is an option. There are also a number of sensors that communicate over standard wireless ethernet Wi-Fi with various software interfaces.

OPC UA Can Help

OPC UA is emerging as a fundamental technology for implementing the Digital Twin. Digital FactoryOPC UA technology provides an efficient and secure infrastructure for the communications of contextual information, from sensor to business enterprise computing, for all automation systems in manufacturing and process control. OPC UA is leveraging the accepted international computing standards and putting automation systems on a level playing field with the general computing industry. OPC UA uses common computing industry standard Web Services, which are the preferred method for system communications and interaction for all networked devices. The World Wide Web Consortium (W3C) defines a Web Service as "a software system designed to support interoperable machine-to-machine interaction over a network." This is precisely the task of automation systems. OPC UA is being built into a number of sensors and other devices, in order to simplify the communication process.

A Path to Holistic Integration

With the implementation of the Digital Twin, manufacturers may be able achieve greater profits and competitiveness through Realtime Closed Loop Manufacturing Optimization. This is an example of holistic integration of all the factors of production, and though the Digital Twin is virtual, it represents one of the most tangible examples of the Industrial Industry of Things bringing value to today's manufacturers.

Related Articles

Is IT/OT Convergence Becoming Misguided Thinking?

Bill's Top 10 Automation & Control Trends for 2019 – Accelerating Change & Reaching the Tipping Point

Digitalization – What is an automation professional's role?

Democratizing Digitalization to Achieve Manufacturing Competitiveness – PTC LiveWorx 2019

Can Manufacturers Compete When Trapped in Existing Automation Architectures?

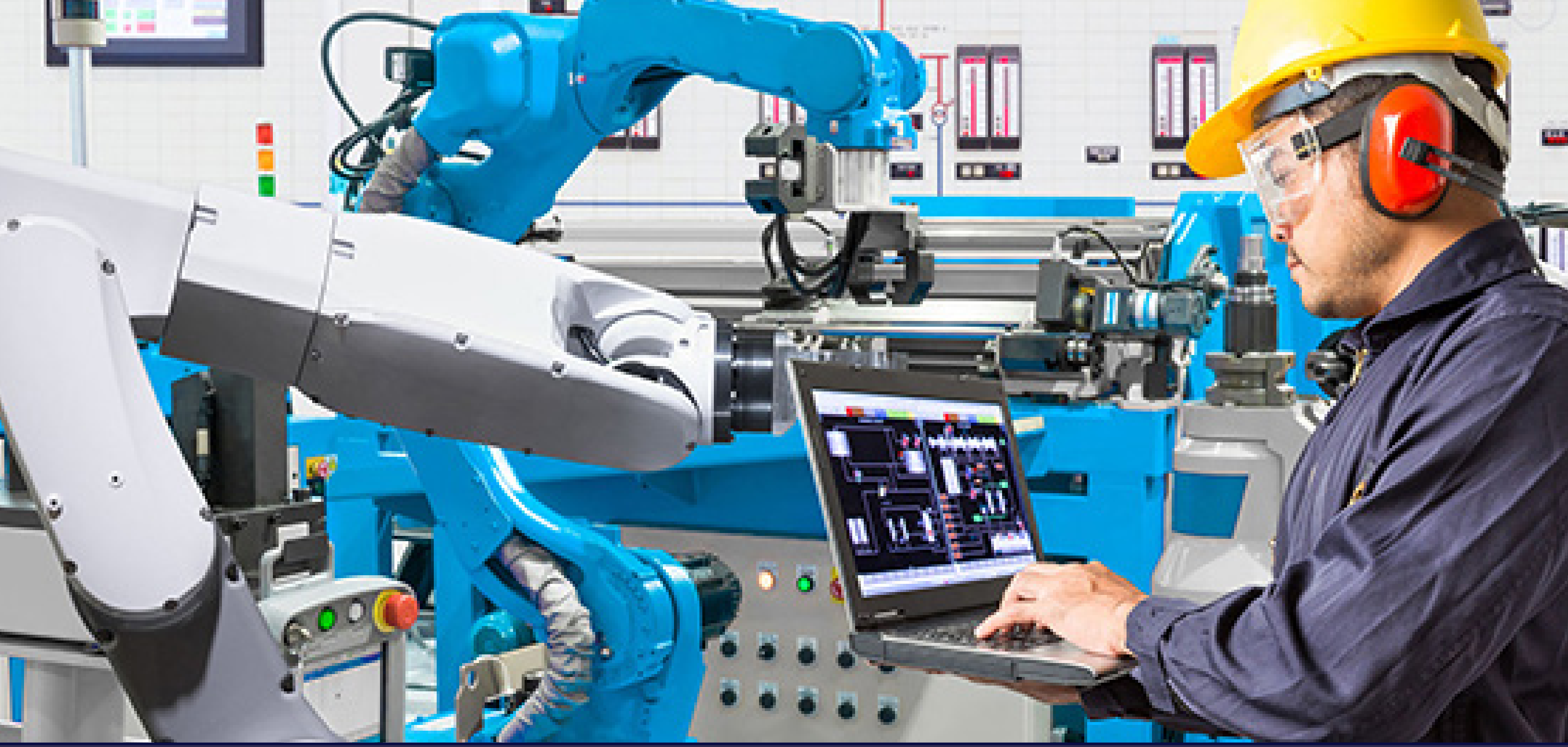
Insights from 2019 3DEXPERINCE Forum: Inside Boeing's Digital Transformation Journey using ISA-95

Tension in Industrial Automation: Open Systems and the User's Dilemma

---

About the authors:

Bill Lydon is contributing editor for Automation.com and InTech magazine. Lydon brings more than 10 years of writing and editing expertise to Automation.com, plus more than 25 years of experience designing and applying technology in the automation and controls industry. Lydon started his career as a designer of computer-based machine tool controls; in other positions, he applied programmable logic controllers (PLCs) and process control technology. In addition to working at various large companies (e.g., Sundstrand, Johnson Controls, and Wago), Lydon served a two-year stint as part of a five-person task group, where he designed controls, automation systems, and software for chiller and boiler plant optimization. He was also a product manager for a multimillion-dollar controls and automation product line and president of an industrial control software company.



Servitization for Sensors

Is S_2aaS a viable business model?

By: Jonathan Wilkins, EU Automation

Servitization is not a new phenomenon. Manufacturers of industrial equipment have long provided extended warranties, future inspections and extensive service contracts as part of their sales pitch. Today however, the rapid pace of change in North American manufacturing is causing a dramatic increase in the servitization of products. The reason for this spike? Sensors.

Many servitization business models rely on the use of sensors in their products. Using data and information gathered by these sensors embedded into equipment, the service provider can continuously monitor the state of their product. Then, they can provide the necessary upgrades, repairs or maintenance to the product when it is required, thus adding extra value for the customer.

Consider an industrial heating ventilation and air conditioning (HVAC) system as an example. If an internal sensor identifies an air conditioning unit is not ventilating air to the correct temperature, the HVAC supplier can be alerted immediately. This allows the fault to be dealt with quickly and of course, takes the responsibility of noticing, fixing and paying for repairs away from the end-user.

But, what is the case for the servitization of sensors themselves?

Servitization is happening in all industries. The manufacturing sector has already begun exploring the potential of Robots as a Service (RaaS) and has widely adopted various Software as a Service (SaaS) models—think Supervisory Control and Data Acquisition (SCADA) and Manufacturing Execution Systems (MES) as an example. In fact, when the idea of Sensors as a Service first emerged, the abbreviation had to be relegated to S_2aaS, to avoid confusion.

Using a subscription model, S_2aaS would allow manufacturers to pay a monthly or annual charge for the deployment of sensors in their facility. The cost would include maintenance, support and regular upgrades. Sounds ideal, but the servitization of sensors is not without its challenges.

Integration with existing sensors

The most obvious problem is the integration of new sensors with existing technology. Most manufacturers will use an array of equipment in their facility, all from varying manufacturers, models and production years. Some of this older machinery will not be equipped with sensors at all. However, some newer devices may have propriety sensors built in, that can be difficult to replace.

In these instances, it is important to ensure that the S_2aaS provider can either; collect data from your existing sensors to compile a complete report or, is advanced enough to warrant replacing the existing sensing technology. For example, some standard sensors are limited to indicating the presence or absence of an object, whereas smart sensors can provide up to 32 bytes of cyclical data—which could provide much more value.

Ensuring sensors are smart

Conveyor systems are often fitted with sensors to ensure they only operate when they are carrying products, thus saving energy. A standard sensor can only identify if a product is present, whereas a smart sensor uses a combination of motion, proximity, weight and image sensing to detect how many products are on the conveyor and how effectively the conveyor is operating.

Beyond this, smart sensors can also be used to monitor the health of equipment in a facility. Using the conveyor system as an example, accelerometer sensing can be used to monitor the vibration of the equipment, indicating when there may be a mechanical problem or a sign of breakdown. With this in mind, switching existing sensors for advanced versions could be incredibly beneficial.

Before switching however, manufacturers should ensure that the sensors offered by the S_2aaS provider are advanced enough to provide an improvement. Sensors enabled with IO-Link technology, for example, can communicate much more data. IO-Link is an open standard protocol that provides a common communication for a sensor's parameters and features.

Ensuring that sensors are enabled with IO-Link technology means that other IO-Link devices can connect to the sensors. By doing this, manufacturers can collect a much more detailed wealth of data than standard sensors could deliver.

Assessing sensor requirements

Before embarking on a subscription-based model for smart sensors, manufacturers should first decide whether they actually need to collect more detailed data from their facility, and whether the investment will provide benefits to their business.

Another consideration is whether a subscription-based model will provide better value for money than a regular, purchase-based model. For example, some sensors are subject to frequent damage due to the application in which they operate. Food and beverage manufacturing are good examples of this.

Due to regular washdowns of equipment and varying temperatures during the manufacturing process, sensors used in food manufacturing often require repairing or replacing. Extreme temperatures in particular can put enormous strain on sensors, limiting their ability to collect and report data.

In these instances, opting for a S_2aaS can ensure that sensors will be repaired and replaced as soon as necessary—without the unexpected costs associated with buying a brand-new sensor.

Like all servitization business models, S_2aaS could provide numerous benefits to the customer. Using a subscription-based service, manufacturers can rest assured their sensors will be monitored, repaired and replaced whenever required. However, it is important to remember that not all servitization models can guarantee the same level of service.

Before jumping on the S_2aaS bandwagon, it is vital that manufacturers do their own research to ensure their service provider can provide real added-value.

About the author:

Jonathan Wilkins is the marketing director at industrial parts supplier EU Automation. With offices in Europe, Asia and North America and a global network of partner suppliers, EU Automation https://www.euautomation.com/ provides customers in 155 countries with new reconditioned and obsolete automation parts.