Automation NOTEBOOK

Your guide to practical products, technologies and applications

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WHAT YOU NEED TO KNOW ABOUT MACHINE LEARNING

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HOW TO SPECIFY FIBER OPTIC SENSORS

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BEAM TESTING AT PORTLAND STATE

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Your guide to practical products, technologies and applications

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For those who prefer to speak with us in person, please call 1-800-633-0405 x1845. Thanks for your interest, and we look forward to hearing from you.

Editor's Note

"You can't do things like that anymore." That is what someone told me on my 30th birthday. They were referring to the various thrill-filled activities I enjoy. Based on my age, that person felt I was putting my body and health at risk. While the concern was appreciated, I quickly refuted that advice by saying, "If I stop doing the things I love, I will definitely become old." It's been 20 years since that birthday, and I still do whatever physical activity I want. Not just because I enjoy it; I do it because I was once told that I was too old.

When AutomationDirect began, we were told our business plan wouldn't work. Instead of creating just another industrial control supplier, we proudly said, "We WON'T do things like that anymore." And, with thousands of products, and award-winning technical support, we have no intention of stopping anytime soon.

We have filled this issue of NOTEBOOK with great articles such as, our Cover Story explaining how machine learning can help you improve the performance of your machines. Our Tech Brief details how to specify fiber optic sensors and our User Solution takes us down to the farm to show how updating automation control improved the way crops are watered. Plus, our Student Spotlight points to engineering students at Portland State University and their beam testing machine retrofit. We've included information on some of our newest products and lots more.

Of course, Chip McDaniel provides more fun puzzles in the Break Room. Be sure to compare your answers at **www.automationnotebook.com**

editor@automationdirect.com

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CONTRAST SENSORS FOR PRINT MARK DETECTION

Datalogic print mark contrast sensors, with 6-12mm sensing distances, are designed to detect the difference in the wavelength of the reflected light between a target mark and background. Contrast sensors use RGB light emission with automatic selection, and feature teach-in sensitivity adjustment, and selectable light on/dark on outputs.

The S8 Series compact contrast sensors feature horizontal spot orientation, a 25 kHz switching frequency, NPN or PNP logic output, 12-30 VDC operating voltage, and are available with IP67-rated plastic or IP69K-rated 316L stainless steel housings. The S8-series sensors, starting at $68.00, are fitted with a 4-pin M8 quick-disconnect or have an attached 150mm cable with M12 quick-disconnect.

New TL Series contrast sensors feature vertical or horizontal spot orientation, 10-30 VDC operating voltages, aluminum housings, and NPN/PNP or PNP logic outputs. TL-series sensors are fitted with a 5-pin M12 quick-disconnect with adjustable exit angle; models are available with 0-5VDC analog outputs and 15, 20, or 50 kHz switching frequencies. These IP67-rated contrast sensors start at $130.00.

Datalogic print mark contrast sensors are CE, RoHs and Reach compliant, and are cULus approved.

www.automationdirect.com/contrast-sensors

CONTRINEX 3MM TO 30MM TUBULAR AND RECTANGULAR INDUCTIVE PROXIMITY SENSORS

Proximity sensors allow non-contact detection of objects. They are used in many industries, including manufacturing, robotics, semiconductor, etc. Inductive sensors detect metallic objects while capacitive sensors detect all other materials.

Contrinex DW series inductive proximity sensors are available in barrel sizes from 3mm to 30m, and in a rectangular 20mm x 32mm configuration. Extended and triple sensing distance versions are available for both standard industrial and harsh duty applications. With 10 to 30 VDC operating voltage and sensing distances ranging from 1mm to 40mm, cylindrical sensors are available in shielded and unshielded models with nickel silver, nickel silver/chrome, chrome plated brass, or stainless steel housings. DW-series 3mm sensors are fitted with an axial cable; other sizes offer two-meter axial cable, M8 or M12 quick-disconnects. DW-series proximity sensors have an LED indicator and are available with NPN and PNP, and N.O. or N.C. outputs. Starting at $52.00, DW series industrial proximity sensors have an IP67 rating; harsh duty versions have IP68/IP69K ratings.

AutomationDirect offers several resources on presence sensing. Our library. automationdirect.com site has several blog posts that discuss the various technologies and applications, as well as the latest new product press releases, frequently asked questions, and more.

We continue to add to our wide assortment of informative tech tips and how-to videos in our Automation Video Cookbook (**https://www.automationdirect.com/videos/cookbook**). Here you will find chapters devoted specifically to Object Detection and Distance Measuring.

To learn more, or for assistance choosing the right proximity sensor for your application, we also provide a proximity sensor selection guide at:

http://go2adc.com/proxselection

Quality SENSORS at SENSIBLE prices.

Photoelectric Sensors

We've got the high-quality, industrial photoelectric sensors you need at the low cost you're looking for. Our vast selection of photo eyes and photoelectric switches is constantly growing and includes many sensing options and ranges, sizes, body styles, etc. All at prices you won't find anywhere else.

- Diffuse
- Diffuse with background suppression
- Retroreflective
- Through-beam

30mm Mounting Base

Starting at $55 (FWP-DP-1E)

- 8 models available
- 30mm mounted with zinc alloy nickel-plated housing
- Sensing ranges up to 15m
- IP67 rated

DC Rectangular

Starting at $35 (QMRB-0N-0A)

- Over 100 models available
- Available with plastic or 316L stainless steel housing
- IP65/IP67 or IP69K (Harsh Duty/Food & Beverage) rated
- Sensing ranges up to 30m

18mm Cube

Starting at $39 (GXP-AN-1E)

- 12 models available
- NPN or PNP, Light-on, Dark-on output models
- Sensing ranges up to 20m
- IP67 rated

AC/DC Round

Starting at $21.50 (FB6-LN-0E)

- Over 200 models available in 5mm, 8mm, 12mm, 18mm sizes
- Axial cable or M12 quick-disconnect models
- Sensing ranges up to 50m (laser photoelectric version)
- IP67/IP69K rated
- 18mm metal laser sensors available with Class 1 or Class 2 laser, axial or right angle optical head and NPN or PNP logic

Contrast Print Mark Sensors

Starting at $68 (S8-PR-5-W13-NN)

Contrast print mark sensors determine contrast by sensing the difference in the wavelength of reflected (RGB) light between a target mark and the background.

- Teach-in sensitivity adjustment
- 6-12mm sensing distance
- Switching frequencies from 15-50kHz
- Offered with IP67 or IP67/IP69K ratings

Fork Sensors

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Fork sensors (also called slot sensors or "U" sensors) offered with visible red light and laser (Class 1) light to detect very small objects. Select models available for clear object detection.

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RECENTLY ADDED PRODUCTS

CABLE GLAND FITTINGS FOR STRAIN RELIEF AND IP68 INGRESS PROTECTION

IP68-rated for dust and water ingress protection, Bimed cable glands are used in conjunction with cable and wiring throughout electrical instrumentation and automation system industries. They are also used as a sealing and termination device to ensure that the characteristics of the enclosure, which the cable enters, can be maintained adequately. Bimed cable glands are offered in metric (M12-M63), Pg (PG7-PG48), and NPT (3/8"-1") thread sizes and are available with brass or plastic housings. Starting at $2.00 for a five-pack, Bimed cable glands are CE, cULus, and CSA approved.

www.automationdirect.com/wiring-solutions

TYPE SJOOW AND TYPE SOOW THERMOSET RUBBER JACKETED FLEXIBLE PORTABLE CORD

AutomationDirect's line of multi-conductor cables now includes additional 600V and 300V portable hard-usage service cord. Type SOOW and SJOOW portable cord is available in 18 to 10 AWG sizes and in 2, 3, or 4-wire configurations. The multi-conductor cable features bare copper conductors with Class K stranding. The outer jacket is constructed of oil, weather, and water resistant CPE thermoset rubber to provide abrasion and melting resistance; EPDM thermoset rubber insulation provides interior oil resistance.

Available in 20 to 1,000-foot lengths, Type SOOW and SJOOW flexible power cable is rated for severe (600V) and junior severe (300V) service and is approved for outdoor or indoor use with a temperature range of minus 40 to 194 degrees F.

Starting at $8.50 for a 20-foot reel, Type SOOW and SJOOW portable service cord is UL and CSA approved.

www.automationdirect.com/flexible-portable-cord

ACME 3-PHASE ENCAPSULATED TRANSFORMERS (UL / NEMA RATED)

Acme Electric's dry-type encapsulated 3-phase NEMA 3R rated transformers are excellent for dust or lint-laden atmospheres and are suitable for indoor and outdoor use. These high-efficiency transformers are completely enclosed and feature a fully encapsulated core and coil, copper lead wire terminations, electrostatic shield and are fitted with grounding studs for use with non-metallic conduit. With prices starting at $424.00, transformers are available in 480VAC and 600VAC models and in 3 to 15 kVA sizes. Acme encapsulated 3-phase transformers are UL and CSA approved and are RoHS compliant.

www.automationdirect.com/3-phase-transformers

SELF-ADJUSTING CRIMPING TOOLS

These high-quality industrial wire crimping tools are perfect for a wide variety of electrical, electronic, and data connectors. The lightweight, compact, comfortable and self-adjusting tools are designed for crimping ferrules and wire end sleeves. Available in square and hexagonal crimp styles, these crimp tools feature ergonomically shaped handles with hardness and surface textures for comfortable frequent use, a non-slip grip pad for applying pressure against a surface, and ratchet action to ensure crimps are completed according to specification. Priced at $215.00, the self-adjusting crimping tools are designed for insulated and non-insulated ferrules, and automatically adjust to wires sizes from 26 AWG to 8 AWG.

www.automationdirect.com/wire-crimper

SMALLER SIZE TIMING BELTS AND PULLEYS FOR SUREMOTION SYNCHRONOUS DRIVES

New SureMotion® MXL (Mini Xtra Light) series timing belts and pulleys allow speed and torque change while connecting mechanically rotating components for small motor applications. SureMotion MXL series timing belts are 1/4-inch wide, have

a 0.080-inch pitch, and are available in neoprene with fiberglass reinforcement and urethane with polyester reinforcement styles. Neoprene belts have excellent resilience and flame resistance, are available in lengths from 36 to 500 teeth, and start at $5.75 for a 3-pack; urethane belts have excellent wear resistance as well as oil and ozone resistance, are available in lengths from 36 to 400 teeth, and start at $10.50 for a 3-pack.

MXL-series aluminum timing pulleys (sprockets) have a 1/4-inch width and feature a smooth bore with setscrews, a 0.080-inch pitch and range in size from 10 to 120 teeth. MXL-series pulleys start at $7.00.

www.automationdirect.com/synchronous-drives

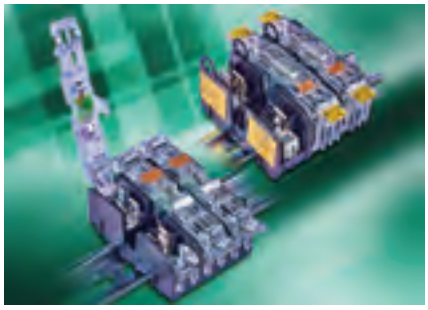
IP69K RATED PUSHBUTTONS, SELECTOR SWITCHES AND INDICATOR LIGHTS

Schmersal IP69K-rated pushbuttons, selector switches and indicator lights have special design features that make the devices suitable for food processing, pharmaceutical, and medical applications. With an ingress protection rating of IP69K, this Schmersal 22mm series is also suitable for marine applications, traffic systems, commercial vehicles, and for use in dusty and dirty environments. When utilized in food processing machines, these devices comply with the special cleaning requirements of the industry to prevent cross-contamination, particularly when used in machines that process raw goods.

Schmersal 22mm (IP69K, N Series) control and signaling devices include illuminated and non-illuminated pushbuttons, emergency stop / mushroom pushbuttons, selector switches, and indicator lights. The smooth, modular design of the contact and light terminal blocks makes the devices easy to install and easy to clean. Schmersal 22mm control devices start at $12.00.

www.automationdirect.com/pushbuttons

MODULAR FUSE BLOCKS FOR CLASS CC AND MIDGET FUSES



New modular fuse blocks include Class CC and Midget fuse blocks, and a combination modular fuse block (for use with transformers). These fuse blocks have a fully modular snap together design and offer the flexibility of DIN rail or panel mounting for easier installation. There is a complete array of wire termination options with 10-18 AWG Cu 75/90°C capability suitable for a broader range of applications. An optional clear IP20 "finger-safe" cover with and without blown-fuse indication enhances safety and reduces maintenance time. Universal marker label provisions provide ease of circuit identification and a patented Lock-Out/Tag-Out system also enhances safety. These modular fuse blocks have an electrical rating of 600V AC/DC with up to 30A and a SCCR rating of 200kA. These UL, CSA and CE approved Modular Class CC and Midget fuse blocks start at $4.75

www.automationdirect.com/fuse-holders

KONNECT-IT® DIN-RAIL TERMINAL BLOCKS NOW AVAILABLE IN CONVENIENT 25-PACKS

Konnect-It KN Series screw-type terminal blocks meet the demands of the industrial environment and are available in a variety of single-level, double-level, triple-level, sensor, mini, grounding, fuse holder and disconnect block types. Konnect-It terminal blocks and related components are economical, modular in design and fit on a 35mm DIN rail (standard), or 15mm DIN rail (mini version). The terminal blocks are available in multiple colors, accept a wide range of wiring sizes and most have a 100kA SCCR rating. Konnect-It single-level terminal blocks start at $6.00 for a 25-pack. Double-level terminal blocks start at $23.00 for 25, and Mini 15mm DIN rail terminal blocks start at $9.00 for a package of 25. Available Konnect-It accessories include end brackets and covers, separators, jumpers, marking tags, top covers and label holders.

www.automationdirect.com/Konnect-it

MORE DISCRETE AND ANALOG I/O MODULES FOR PRODUCTIVITY2000® PLCS

The modular, rack-based Productivity 2000 PLC system now has 47 discrete and analog I/O modules providing over 400 local I/O points. With remote expansion, over 4,000 total I/O points are available. New AC and DC discrete I/O modules include 8-point, 100-120 AC input and output modules, 8 and 15-point, 3.3-24 VDC input and output modules and 32-point,12-24 VDC high-density DC input modules.

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Starting as low as $47.00, these I/O modules easily connect to photo eyes, proximity sensors, limit switches, push buttons, light curtains, or any other discrete control device. Starting at $101.00, new 12-bit, 4-channel, current and voltage analog I/O modules are available with or without OLED message displays to measure and control process variables such as level, flow, and pressure. The new 16-point standalone ZIPLink fuse module provides convenient fuse protection for PLC outputs.

www.automationdirect.com/productivity2000

THERMISTOR INPUT MODULE FOR TERMINATOR FIELD I/O AND DO-MORE T1H SERIES PLCS

The T1F-16TMST ($399.00) is a 16-channel Thermistor input module with a temperature input range of -40° to 150° C (-40° to 300° F) and a resolution of +/- 0.1°C or °F. Thermistors have a very high sensitivity making them extremely responsive to changes in temperature. The T1F-16TMST supports the most commonly used NTC (negative temperature coefficient) thermistors. Available to use as part of the Terminator Field I/O system or with the economical Do-more T1H series PLC. The Do-more T1H PLC supports stackable base units, discrete and analog I/O modules, along with Ethernet connectivity and custom communication protocols as built-in functions. A Do-more T1H CPU supports up to 256 I/O points in three stackable rows. For larger applications, Ethernet-based remote I/O can be connected for hundreds of additional digital and analog I/O points.

www.automationdirect.com/fieldIO

NEW NEMA 182TC OR 184TC FRAME MARATHON MOTORS

There are 10 New NEMA 182TC or 184TC frame Marathon motors with YxxxA catalog numbers that match frame size, horsepower and are equivalent in dimension, weight and performance to non "A" suffix models they replace. Refer to the motor drawings for any minor differences from the previous models. The wide variety of available Marathon AC motors includes induction motor models ranging from 1/4 HP to 100 HP and feature dual 230/460 VAC and 575 VAC voltages with a base speed of 1200 RPM or 1800 RPM. Marathon inverter-duty industrial motors are rated for continuous operation in a 40°C ambient environment and for altitudes up to 3,300 feet. Marathon motors are performance-matched to DURAPULSE and GS series AC drives and have a 3-year warranty. Marathon AC motor prices start at $152.50.

www.automationdirect.com/marathon-motors

ADDITIONAL NITRA MODULAR SOLENOID VALVES, MANIFOLDS, CONTROL DISTRIBUTION BLOCKS

NITRA BVS-3 series modular solenoid valves, starting at $28.00, are body ported 3-port (3-way) poppet valves with 12VDC, 24VDC, or 120VAC coils. Low current models for portable applications are now available. NITRA BVS-4 series modular solenoid valves, starting at $46.00, are body ported 4-port (4-way) spool valves with 12VDC, 24VDC, 24VAC or 120VAC solenoid coils. BVM series manifolds with push-to-connect air connections simplify the mounting and wiring of BVS series solenoid valves. BVM-3 series modular manifolds start at $54.00 in 4 and 8-station styles. BVM-4 series modular manifolds, starting at $22.00, are available in 2, 3 and 4-station models. Control distribution blocks are also now available for BVS-4/BVM-4 assemblies; added accessories include replacement solenoid coils, aluminum manifolds and blanking plugs.

www.automationdirect.com/pneumatics

HOW TO SPECIFY FIBER OPTIC SENSORS

By Andrew Waugh,
Sensor and Safety Components Product Manager, AutomationDirect

Fiber optic sensors work well in tight spots and in applications with a high degree of electrical noise, but care must be taken when specifying these critical components.

Sensing part presence in machines, in fixtures and on conveyors is an important part of industrial automation. Error proofing assembly and controlling sequence based on presence or absence of a part is often required. In many cases, one can't just assume the part is where it should be or the nest is empty as expected, so a presence sensor must be used for verification.

There are many types of sensors on the market including inductive, magnetic, capacitive and photoelectric. Each has its own strengths and weaknesses depending on the application. Photoelectric sensors, however, have the broadest offering of types and technologies, and the widest range of applications.

Photoelectric sensors come with a variety of light emission types (infrared, visible red, laser Class 1 and 2), sensing technologies (diffuse, background suppression, reflective, through-beam), and housing configurations (photo eye or fiber optic). This article focuses on specifying and applying fiber optic sensors as they provide advanced capabilities and configuration options, and are great for tight spots where a photo eye sensor won't fit.

Fiber Optic Technology

Fiber optic sensors, sometimes called fiber photoelectric sensors, include two devices which are typically specified separately: the amplifier, often called the electronics or fiber photoelectric amplifier; and the fiber optic cable, which includes the optic sensor head and the fiber cable which transmits light to and from the amplifier.

The basic theory behind all photoelectric sensors is quite simple. Every photo eye has a light emitter producing the source signal and a receiver which looks for the source signal. There are many different technologies for sensing and measuring the light transmitted to the receiver. For example, background suppression sensors look for the angle at which the light is returned, while standard photo eyes look for the amount of light, called excess gain, returned to the sensor. Other sensors monitor the time light takes to return to provide distance measurement.

Photo eyes contain the emitter and receiver in either one optical sensor head such as used in diffuse and reflective units, or two optical sensor heads as used in through-beam units. Fiber optic sensors have all the electronics in a single housing, with the optical heads for the emitter and receiver separated from and connected to the electronics housing via a fiber cable. The emitted and received light travels through these fiber cables, much like high speed data in fiber optic networks.

A benefit to this segregation is that only the sensor head needs to be mounted on the machine. The integrated fiber optic cable is routed and plugged into the amplifier which can be mounted in a safe place, typically a control enclosure, protecting it from the often harsh manufacturing environment.

The variety of options available for both amplifiers and fiber optic cables is vast. Amplifiers range from basic to advanced, and machine builders continue to demand more functions including logic and communication capabilities.

Fiber Optic Sensor Amps

Fiber optic amplifiers range from those with basic electronics and plug-and-play functionality, to models with fully configurable electronics (*Figure 1*). Some even have electronic units that can handle up to 15 fiber inputs in a manifold-like configuration. Output indication is highly desirable on fiber optic electronics as it shows whether the sensor is working properly, but other basic functions, shown in *Table 1*, must be specified. The output format and connection to the amplifier are important because they define the interface to the controller, and teaching the on and off setpoints is an integral part of amplifier configuration.

Output types can be set normally open or normally closed; switching options include sinking, sourcing or push-pull, which allows the device to either sink or source the signal automatically depending how the circuit is wired. Electrical connection options are generally prewired with at least a 2m cable, or a quick-disconnect with a standard M8 or M12 multi-pin connector. Switch settings are programmed by dialing in a potentiometer or digitally via pushbuttons.

Figure 1: A variety of fiber optic amplifiers are available, with simple to advanced configuration options.

Specification of Fiber Optic Electronics
• Output NO/NC
• Output type - NPN or PNP
• Output configuration NPN/PNP/push pull
• Connection – cable or quick disconnect
• OLED display
• Signal strength
• Filtering
• Pulse output
• On/off delay
• Adjustable measurement speed
• Sensitivity adjustment
• Teach – automatic or potentiometer

Table 1: Specification of Fiber Optic Electronics

Beyond the basics, advanced amplifier capabilities provide significant flexibility with features such as pulse outputs, on/off delays, and the ability to eliminate intermittent signals. These advanced electronics give machine builders the ability to drill down and tweak amplifier parameters as required by the application.

On/off delays are often desired to slow the reaction of the control system to changes in sensed parameters. In the case of intermittent signals, some applications present the sensor with spurious, short-term signals which aren't consistent with overall operating conditions. The ability to eliminate these signals at the sensor frees up the controller from this task.

Most all models will provide output status LEDs, while some offer graduated displays to provide a coarse view of signal strength and output status. More advanced units have multiline OLED displays with customized diagnostics and programming.

Filtering is an option often needed with increased sampling rates as it provides a more resilient measurement less susceptible to ambient conditions. This stronger signal, however, requires the unit to operate at slower switching frequencies. Pulse outputs allow stretching the input signal which may help when the operating frequency is too fast for a PLC input. On/off delays give machine builders the ability to add timers when the output signal starts and stops.

Advanced units provide more programming options such as sensitivity adjustments. Using these options, machine builders can teach the machine to sense part absence, part presence or both for difficult materials like glass. This teaching function reduces or eliminates the need for programming the controller to perform these functions.

They can also set the output to switch off/on at two switch points; for example, switching on at one and off at another, such as supplying a fill level signal for a pump.

Fiber Cable Choices
• Optic cable selection – diffused or through-beam
• Plastic or glass fiber
• Optical head options
• Sensing range
• Fiber environmental ratings

Table 2: Fiber Cable Choices

Seeing the Light with Fiber Cable

Fiber optic cables don't conduct electricity, but instead transmit light. They come in a variety of configurations with different material types and optic head styles (*Figure 2, pg. 12*). *Table 2* lists some of the decisions needed when specifying fiber optic cable.

Diffused fiber optic cables have two leads to insert in the amplifier for the emitter and receiver light, with the two leads joined together near the single optical head. Through-beam fiber optic cables are two separate, identical cables which are connected to the amplifier, each with their own optical head. One cable transmits the emitting light, and the other transmits the receiving light. A common mistake is only ordering one through-beam cable as some suppliers may provide one piece per part number, while others package the required two cables.

Fibers materials are generally either plastic or glass. Plastic units are thinner, less expensive and provide a tighter bending radius. Glass units are more rugged and

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Figure 2: There are many choices for fiber optic cables and heads, with proper selection heavily dependent on application requirements.

can handle higher operating temperatures. Plastic fibers can be cut to length with a special one-time cutter, while glass fibers cannot be cut once received from the supplier. The fiber jacket material can also vary from a basic extruded plastic to stainless steel braiding to operate reliably in the toughest environments.

Optical head selection is the most crucial part of fiber optic sensor specification because it greatly affects the detection of the small stationary or moving parts found in most applications. Head selection differs in how the emitter and receiver optics are oriented in angle and dispersion to the object to be detected. Heads can have rounded bundles of fiber to project a circular beam, or spread out to form a horizontal, ribbon-like projection.

Round bundles in a diffuse head can be strictly bifurcated with all emitter fibers on one half and all receiver fibers on the other. This is common, but can cause a lag in reading a part moving perpendicular to the bifurcation line. Another option is to have the emitter and receiver fibers dispersed evenly in the head to produce a more homogenous beam. Homogenous fiber mixing gives equal exposure to sending and receiving light, and provides detection independent of part travel direction.

Sensing range for fiber optics is impacted by the amplifier, fiber cable length and type of optical head. Due to these many factors, it is usually difficult to determine an exact working range, but suppliers typically supply an estimate. Generally speaking, through-beam styles have a longer range than diffuse. The longer the fiber cable, the shorter the range; advanced amplifiers usually have stronger emitting signals and longer ranges as well.

Connecting Fiber Optic Sensors

The use of distributed I/O and distributed smart devices has been increasing throughout machine automation, and fiber optic sensors are no exception. Connecting multiple fiber optic sensor cables to a single manifold of electronics has its advantages.

Fiber optic amplifiers are commonly single-channel stand-alone units. With slim housings and common DIN rail mounting, they can easily be sandwiched and stacked in a panel. The drawback can be routing electrical connections for each of the single amplifiers.

Another option is to use a fiber optic manifold which groups multiple fiber channels to one central control and electrical point (*Figure 3*). These manifolds typically utilize an OLED display with menus to allow programming of each fiber channel. Each

Figure 3: Fiber optic manifolds with expansion electronics simplify and reduce the number of wires to the machine controller by converting sensor signals to digital data, and combining signals logically if desired. Pictured is AutomationDirect's new three-channel OPT2042 fiber manifold which is expandable to 15 channels. It accepts various plastic and glass fiber optics, and transmits and receives data via IO-Link to allow full 15 channel diagnostics on a single 4-pin connector. It can also be wired with two 8-pin M12 connectors to hardwire each channel if needed, for example in applications where the controller doesn't support IO-Link.

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fiber channel can be configured separately, such as setting light-on or dark-on, and switching hysteresis. This central control also allows grouping of outputs via basic AND/OR logic, which can reduce and simplify the output signal to the PLC.

Applications and Issues

Fiber optics work well and are commonly used in applications where there is significant electrical noise generated by such sources as automated welding, variable frequency drives and motors. Fiber cabling is immune to electrical noise, and the electronics can be mounted away from the noise in a shielded enclosure.

Another very common application is small part assembly. These operations tend to be fully automated and thus require multiple sensors to confirm part placement (seated), and assembly verification to confirm an operation was completed. Typically, the parts are moving in and out of a stage quickly on carriers or an indexing table. There is minimal travel tolerance, so precise measurement of position is essential.

A fiber optic solution provides various options in head size, orientation and light dispersion to allow the smallest and most accurate light focus for each application regardless of the electrical housing size. With on-board logic, one channel of a two-channel sensor can confirm a part is in place to trigger an assembly action, while the other channel can confirm that assembly was completed.

A common issue in fiber optic installations is excessive flexing of the fibers. Since the fiber cables are bundles of individual fibers, they typically feel quite pliable, allowing an installer to bend the fibers beyond their recommended maximum bend radius very easily. This can cause irrecoverable plastic deformation of the fibers, which will reduce the light transmission, or sever it entirely in the worst case. The maximum bend radius is listed with all fibers and varies depending on fiber material, bundle size and fiber dispersion in the bundle; and it must be adhered to in all cases.

Regardless of the application, machine builders must select the proper sensor technology. If fiber optic sensors are used, amplifiers and fiber optical heads must be carefully selected for the application to provide robust sensing performance.

--This article originally appeared in Machine Design magazine, October 2016.

WAREHOUSE EXPANSIONS IN-CREASE ORDER THROUGHPUT AND INVENTORY CAPACITY

By Joan Welty,
AutomationDirect

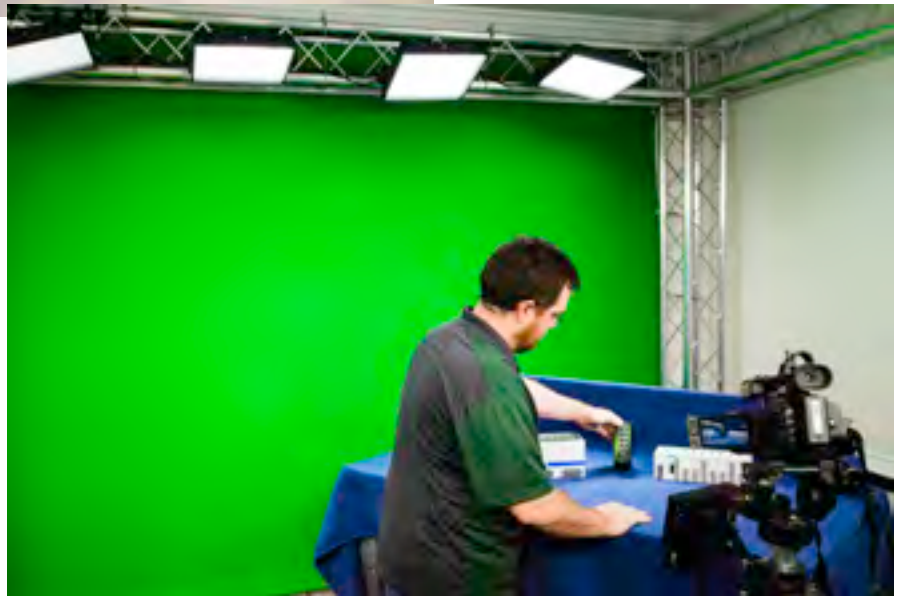
AutomationDirect's ability to offer low prices on quality industrial control products is based on a direct sales model supported by highly efficient teams and processes. By keeping overhead low, we can pass the savings on to our customers. AutomationDirect recently completed the first phase of a major warehouse expansion that has already increased order picking throughput without the need for additional staff. An automated shuttle system delivers parts on demand to pick stations where staff quickly remove the parts from the storage containers and load order boxes with retrieved parts. The same shuttle robots automatically return the part containers to their storage locations. The new system uses much less space than the more traditional flow rack system where pickers move up and down aisles retrieving parts manually, meaning we can add many new products to our mix within the existing footprint. This system streamlines restocking operations as well. These improvements allow us to continue to fulfill all customer orders for same-day shipping at peak order times even as we accommodate substantial growth.

Additional bulk storage capacity is also being added adjacent to the existing warehouse. Designed to be an automated storage and retrieval system when fully operational, it will increase receiving capacity and speed by a factor of 10 or more. The new structure has already created a stir among nearby residents who have a view of our lighted logo in the evenings!

OFFICE AND LAB EXPANSIONS IMPROVE EFFICIENCY AND COLLABORATION

The success of the business model does keep our teams growing, and with it the need for new facilities. The Engineering building completed in 2015 houses software developers, product managers and product engineers. Our developers engineered and continue to improve the Productivity series PLC programming software. Our product managers and engineers search out and work with suppliers to continue expanding our product offerings. The testing and inspection labs ensure all products meet our high quality standards.

Next on the agenda is a new facility to house primarily marketing as well as other teams. With staff currently scattered throughout various buildings, the new space will bring the team together to facilitate collaboration and interaction. It will also update and expand the photography studios, video production suites, electronics lab and storage for educational donations. We expect to break ground spring of 2017 with projected completion in mid-2018.



AUTOMATIONDIRECT IN THE PRESS

Every year, several industry magazines present awards to outstanding companies who provide innovative technological advances, and/or exceptional customer service.

AutomationDirect has once again been honored by some of those publishers.

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SIX YEARS AND COUNTING

January 2017 marked the sixth consecutive year that Automation World readers have voted for their "FIRST TEAM" suppliers in PMMI Media Group's 2016 Leadership in Automation program. Automation World, a leading business magazine serving automation professionals, asks their subscribers to vote for their favorite automation vendors in unaided-recall surveys. Jim Chrzan, Publisher of Automation World, says "Our First Team Honorees represent not only best-in-class product innovation but also superior customer service."

More than two dozen categories are featured which represent a wide variety of automation technologies, software and products in use by today's manufacturing professionals across the discrete, batch and continuous process manufacturing industries.

In two categories, HMI Hardware and PLCs/PACs, AutomationDirect was awarded "First Team" status. Bill Dehner of AutomationDirect says, "We are honored to receive this recognition; our goal is and has always been to not only provide innovative, yet affordable, products to our customers but also the exemplary service and support they deserve". And, we say a word of thanks to the end-users who took the time to vote for us. What a great way to begin 2017.

To read the full press release from PMMI Media and AutomationWorld, or for more information about this program, visit:
https://www.automationworld.com/industry-news/2016-leadership-automation-first-team-honorees

2017 ENGINEERS' CHOICE

Control Engineering magazine's annual Engineers' Choice award highlights some of the best new control, instrumentation and automation products as chosen by CE's readers and online subscribers. Respondents are asked to select products based on technological advancement, service to the industry and market impact. These products must have been first available for purchase in the North American market between November 1, 2015 and October 31, 2016.

On October 13, 2016, the editors of Control Engineering announced two products from AutomationDirect and Koyo Electronics as Engineers' Choice Finalists. In the category of Machine and Embedded Control, the CLICK Ethernet PLC was selected; the C-more Micro EA-ECOM was named as a finalist in the category of Network Integration and Ethernet hardware.

Online voting was opened to qualified subscribers of Control Engineering products (magazine—print or digital, e-newsletters, white papers, etc.). These qualified subscribers were encouraged to vote in as many categories for which they felt qualified and details including photos were available for each product.

Voting was open through December 21, 2016, and AutomationDirect's C-more Micro EA-ECOM received an honorable mention award. There were more than 100 finalists across 28 categories and we are elated to receive accolades for our product.

NEW EQUIPMENT DIGEST INNOVATION AWARDS

Finalists have now been announced for the 2017 NED Innovation Award.

Each December, editors and advisors of Penton Media's New Equipment Digest (NED) survey the 2,000+ new products published during the previous 12 months to find the most disruptive examples of product innovation they have seen.

Product innovations they seek cover a wide range, including: cutting-edge high-tech to no-tech tools, 3D printers, and wearables, such as safety gloves and goggles.

This year, our Wera Joker Ratcheting Combination Wrench has been named as a finalist, making a perfect addition to this mix.

NED publishers take innovation very seriously, so finalist selections are not taken lightly. They have posted an online voting form, along with the finalist announcement, to allow their full global readership to decide which products will take this year's awards. Votes will be tallied in April and NED will announce the official NED Innovation Award winners at the 2017 Manufacturing & Technology Conference & Expo.

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WHAT YOU NEED TO KNOW ABOUT MACHINE LEARNING

By Dan Hebert, PE

There's lots of talk about machine learning, but can it help you improve the performance of your machines? It's becoming easier and cheaper to gather and store data related to the operation of your machines installed at customer sites, but this creates a problem which we'll label as Data Rich, Information Poor (*Figure 1*). Machine learning is being promoted as the solution, and the cover story in the May 2016 issue of Control Design magazine titled "Is machine learning smart enough to help industry?" investigates these claims by examining the experiences of machine builders and their suppliers.

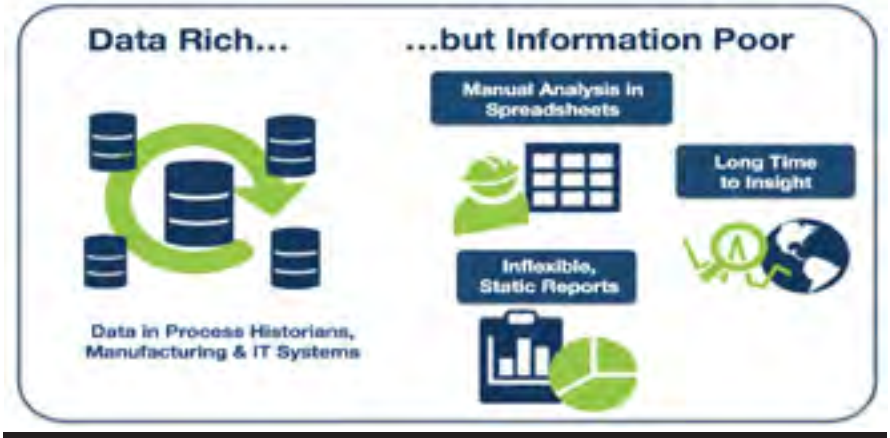

Figure 1: DRIP. Many machine builders find themselves data rich but information poor, struggling to create value from the data flooding into their control systems. (Source: Seeq)

As related in the cover story, "From the industry or manufacturing side of business, machine learning can be applied to just about any control system smart enough to actually alter how it controls a machine in response to changing conditions."

Can machine learning address issues?

"Machine learning will help machine builders, integrators and end users by allowing the machines to solve the problems that typically can only be done by humans and, in some cases, can't even be done by humans," said Matt Wicks in the cover story. Wicks is the vice president, product development, manufacturing systems for Intelligrated (www.intelligrated.com), a provider of automated, intelligent conveyance and robotic handling systems in Mason, Ohio.

"When discussing machine learning, the top item is the ability to process large amounts of data analytics to identify patterns and trends not readily visible using traditional statistical tools. This information can be leveraged for preventive maintenance and/or machine and system optimization improvements. When considering machine learning for robotic and computer vision tasks, such as object recognition, pose estimation and complex motion involving perception, it provides improved robotic operation and performance (*Figure 2*)", related Wicks.

Machine-learning techniques can be applied to the aspects of perception, allowing the equipment to respond to changing and novel scenarios, continued Wicks. "Perception is a component and, relatively speaking, low-hanging fruit for AI," he said. "Coupling vision, motion and machine learning can provide more impressive results, allowing not only the perception tasks to perform at a higher level, but allowing the perception to be combined with the machine motion, yielding performance levels that may be more optimal and capable of functioning in a much wider variety of scenarios."

While we are still a long way from leveraging machine learning to help design material-handling equipment, in the short term, it's feasible to see AI/machine learning techniques applied to optimize certain operations, explained Wicks. "Robotic technology is moving away from the traditional 'program it and let it do the repetitive operation over and over again' to a 'move, see, think, act' model," he said. "This roughly translates into machine vision, processing algorithms and physical motion. Machine learning can help individually with each of these steps, but, when taken as a whole, it can yield some very impressive results."

Figure 2: Intelligrated robots. Vision-guided robots are a good application for a type of machine learning. (Source: Intelligrated)

Not only is machine learning being developed at the machine level, interest is increasing across industry, claimed the cover story. "One thing you might want to take a look at is the Google Trends comparing the search volumes for machine learning vs. artificial intelligence vs. neural networks vs. latecomer deep learning," noted Michael Risse, vice president and CMO at Seeq (**www.seeq.com**), in the cover story.

"There might be other terms to consider—prescriptive analytics, for example—and then there are the process-industry-specific analytics tools such as advanced process control (APC), statistical process control (SPC), multivariate analysis and even application performance management (APM)," added Risse. "It's a long list. What is machine learning exactly? Is it one thing, or is it all of these things? And why the resurgence of interest?"

The IoT, cloud and big-data technology are likely pushing the interest in machine learning and how it will be used, according to the cover story. "Without machine-learning techniques, the future of IoT solutions would certainly be limited," noted Nikunj Mehta, founder and CEO at Falkonry (www.falkonry.com) in the cover story. "IoT solutions are complex in the way biological systems are complex. Systems are composed of large numbers of interacting things, each possessing their own complex behaviors; structure and behavior are not fixed, but evolve over time. IoT systems are great at producing data, but without automated learning techniques, the data volumes drown effective use. Builders and users of IoT solutions need systems that learn and that are adaptive."

Machine learning defined

As related in the cover story, "How machine learning will influence and improve machines and manufacturing is a tough question, but the definition of machine learning is not science fiction, and it depends on who you ask.

Machine learning is any number of algorithms that use an optimization objective function to help a computer interpolate or extrapolate trends from a learning data set to apply to unknown data, explained Anthony Skjellum, PhD, professor of computer science and software engineering at Samuel Ginn College of Engineering, Auburn University (**www.eng.auburn.edu**) in Auburn, Alabama. Skjellum's view is more computational. "Correlations can be determined. Identifying causation—that the correlations mean something— is still the human's job." "Humans make and break models constantly," said Skjellum in the cover story. "That's a key aspect of human intelligence. Machine learning tries to show correlations. Humans then abstract models, do further experiments and determine if the model is a useful abstraction. It is a closed-loop process. There can't, at present, be a purely AI data scientist."

But as the cover story reveals, others prefer a wider software view of machine learning. "To us machine learning is the ability for software systems to use observations of the world around it," said Mike Haley, senior director, emerging products and technology at Autodesk (**www.autodesk.com**) in the cover story. "The physical, virtual and textual worlds are used to understand and predict behaviors and semantics that the program was never explicitly programmed to understand. In that way, these machine learning systems are truly dynamic."

The cover story said perhaps the better way to look at machine learning is to consider the computer and market angles separately. "There is a computer-science and a market answer to what machine learning is," commented Seeq's Risse. "The computer-science answer is machine learning uses automated and iterative algorithms to learn patterns in data, so you don't program the endpoint solution at the outset. Instead the algorithm adjusts itself—by learning from one data point to the next—to solve a particular problem as part of the process, using either a supervised, training-set or unsupervised starting point."

The market answer is that machine learning is on the cusp of joining big data and the IoT as a marketing necessity for modern software offerings, such that the technical definition or correctness of any particular solution is lost in the hype, continued Risse. "And that is just within machine-learning offerings," he explained. "There are many other computer-aided insight tools vying for attention at the same time: deep learning, machine intelligence, artificial intelligence. The answer is getting more marketing-focused over time, given the competition within and across the ecosystem."

Machine learning is here to stay, said the cover story, and David White, senior research analyst at ARC Advisory Group (**www.arcweb.com**), agreed. "Machine learning is going to be an essential technology moving forward," he predicted. "In practice, data from the Industrial Internet of Things is going to be big data for industry. We have reached the point where data visualization and the human eyeball aren't going to be enough. We are generating a much greater volume of data at a much greater speed than ever before. This presents challenges and opportunities."

The challenge is to make sense of all the data in time to make the right management or operational decisions, explained White. "Machine learning can help here," he said. "For example, machine learning algorithms executing close to assets and processes—at the edge—will be able to work with this complex data and make intelligent decisions in real time. The opportunities then are to improve productivity by reducing scrap or cut maintenance costs by moving to predictive maintenance, rather than preventive maintenance. This is a clear benefit to end users. However, machine builders can also take advantage of machine-learning technologies to gain competitive advantage."

Applying machine learning

"The key thing about machine learning is that the performance of the algorithms improves over time," added White. "There is a long-standing rule of thumb among machine-learning experts that a weaker algorithm with more data will ultimately outperform a stronger algorithm with less data. In this way, I think machine learning can help to make control systems much more agile and responsive in meeting changing needs."

But adoption of machine learning in heavy industrial settings is still very limited, largely due to its only recent emergence as a viable control method, notes the cover story. "You're seeing it begin to appear in some robotic systems—mainly related to computer vision and path planning—and object-avoidance drone technology, but it's only just beginning," said Autodesk's Haley. "Perhaps the biggest uptake in machine

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learning is in the IoT sector, where learning predictors of failure modes in devices is of significant value. In all of these cases, the inherent ability of new machine-learning systems to find and predict patterns in many often-messy data signals is driving the state of the art."

Human intuition is limited; machine learning can point out correlations that are subtle and that humans can't see; it makes people smarter when used wisely, explained Auburn's Skjellum.

"If you start with a big bunch of data, and machine learning gives you a correlation, the scientist or engineer hypothesizes a causation, does experiments, maybe more machine learning, and concludes whether the hypothesis, concept and relationships are real or coincidental," said Skjellum.

Autodesk's Haley saw benefits mainly by accelerating the design and development process through learning from everything that has already been done. "In this way designers and engineers can rely on a smart system to guide them through a design, making sure they are incorporating the best approaches, avoiding duplication and tracking most closely to the desired solution," he explained. "One simple example here is the amount of duplication of designs or components that can occur over many years in a large firm. This can be almost entirely eliminated through machine learning and real-time guidance provided to a designer."

As sensors become cheaper, along with networking hardware and storage, machine learning offers more opportunities. "Well-understood patterns discerned via machine learning from product-usage data can point to design and operational improvements," pointed out Falkonry's Mehta. "Likewise, machine learning can use data collected from production processes to identify conditions and guide process improvements."

Most manufacturers struggle with creating and maintaining accurate process data, such as production time standards, yields, run times and setup times, said Jim Cerra, cofounder and CEO of PlanetTogether (**www.planettogether.com**). "This data is instrumental in creating optimized production plans and schedules and driving higher productivity and on-time delivery," he noted. "Predicting machine downtime, absenteeism and other probabilistic data is even more difficult, but it would be helpful in assessing the risk of customer-service issues due to delayed delivery and revenue-attainment shortfalls for the company."

If the computer can learn from watching these manual changes, systems can then begin to suggest or even automate the work, freeing more of the planner's time to make the tough decisions that only a human can make, said Cerra.

"As computers get faster and algorithms continue to be refined for machine learning, greater inferences become possible in near real time or real time," related Auburn's Skjellum. "Combining machine learning with predictive simulation and feedforward and feedback control can help to address complex control-system objectives, while also enhancing the potential for detecting cyber threats or other kinds of disturbances."

Lots of system designs done with machine learning produce results that are not intuitive to the best human designers, explained Skjellum. "There are many process variables and figuring out the most important ones—a kind of identification problem—is not new; it is an important part of systems and control," he said. However, looking at the vastness of historical data or the vast number of sensors in a plant for correlations and failure prediction is a new and emerging machine learning example.

"Autodesk is experimenting with robotic systems that watch and learn from skilled craftspeople, and then work alongside these people to add precision, repeatability and/or safety to their work," said David Thomasson, principal research engineer at Autodesk. "As the new breed of collaborative industrial robot arms, such as the Universal Robots models designed to work in close proximity to people, become more common, there is a need for more intuitive interaction with these machines (*Figure 3*). This is being enabled by machine-learning systems that automatically determine the best course of action based on their understanding of human preferences and abilities, along with a more complete awareness of the design and the situation in which it is to be realized."

The right tool for the job

According to the cover story, "Seeq provides an application dedicated to time-series data investigation. It allows Google-like searches, collaboration in real time and interaction with analog data series like never before. Seeq is intuitive; it's visual; and it connects to just about any process historian to find answers in the data."

"A CoPilot software feature uses available server computational capacity during idle times to find a better schedule for

continued p. 24 >>

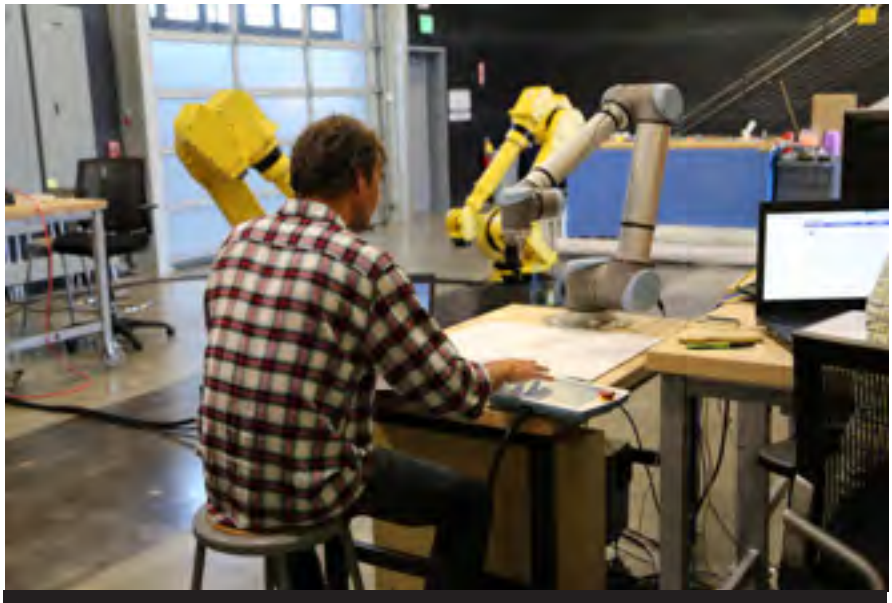

Figure 3: Robots can learn to adjust their movements based on interactions with human operators. (Source: Autodesk and Universal Robots)

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companies automatically," noted Cerra at PlanetTogether.

As the cover story relates, "If plans are found that result in higher KPIs, such as better on-time delivery, increased cash flow or reduced costs, then the new scenarios are automatically presented to the planners who can compare the scenario to the current plan and choose the best option. This requires massive amounts of computer computations, especially in complex factories with tens of thousands of orders in the schedule and quadrillions of possible solutions to choose from."

"There is a wealth of information available on the techniques associated with machine learning," noted Intelligrated's Wicks. "Google has recently open-sourced its machine-learning software called TensorFlow. Google believes machine learning is a key ingredient to the innovative products and technologies of the future. The research in this area is growing fast but lacks standard tools. By sharing, Google believes it can create an open standard for exchanging research ideas and putting machine learning in products."

Machine learning can certainly accelerate the design process all the way through to physically realizing a product, said Haley at Autodesk. "It will mean less time designers or engineers spend on tasks not directly related to the creative aspects of their jobs," he said. "One of the most important aspects of machine learning is to have a sufficient quantity of data for it to learn from. Making sure the data in your company is gathered somewhere, reachable and understandable will go a long way to successful adoption of future machine-learning technology. Most of the human-computer interaction models that relate to machine learning strive to avoid any particular understanding or skills on the part of the user."

The functionality surfaces as suggestions, recommendations, alerts or even something completely transparent to the user, explained Haley. "The design and engineering software world is still working on this, so just keeping up to date on the latest software available would be a good start," he added. There are a lot of packages that will help, and the fundamental algorithms are well documented, said Auburn's Skjellum. But the cover story cautions, "However, it is as important or more important for engineers to understand the limitations of machine learning and how to interpret results, compared to learning to use canned packages."

"Fortunately, it has never been easier to get educated on machine learning," said David White at ARC Advisory Group. "First, there are some great courses available online, offered by organizations like Coursera and edX, which are mostly free. Second, open-source software and the cloud make it much easier to experiment with machine learning at little or no cost. There are a number of cloud-based platform-as-a-service (PaaS) solutions where you can just sign up and get started with machine learning for free. Most of the solutions have tutorials, and they are quite modern and visual, as well. If you're cloud-phobic, as an alternative, there are open-source solutions you can also download and play with for free."

Machines as mentors

Several of your work colleagues may be computers in the future and will possibly be great mentors, the cover story speculated. "I think that cognitive AI can certainly be a source of mentoring, and IBM Watson could certainly be giving advice sooner than later in specific niches," said Skjellum from Auburn University. "Also, machine learning that helps you to discover patterns that are constructive and destructive to personal and professional success, such as procrastination and eating poorly, are on the near horizon. This is not a long-term thing; it is coming shortly—months not years."

These same things can apply in industry, continued Skjellum. "Mining the behavior of a company over time to show success and failure patterns in hiring, promotion and business processes seems likely," he speculated. "Now, to mentoring, that is simply a decision support approach based on what works versus what fails. That can be not only for a given company but also learned over comparable industries and cross-correlated with successful firms in adjacent spaces."

So mentoring of sorts from machines is a logical thing, predicted Skjellum. "In control systems, which depend heavily on math modeling and understanding nonlinearities of systems and also the complexity of human interactions, there is clearly room for operators to be mentored by computers in complex decision making scenarios," he said. "Collision avoidance systems for aircraft, and coming now for cars, are a kind of decision support. Humans deal only with a few variables at a time; while control operators gain intuition over time, they don't necessarily make the right choices under stress, or even the right choices when confronting situations that are uncommon. Think Chernobyl."

Brave new world

As more and more computing power emerges and computational elements are also optimized for the machine learning algorithms—such as special-precision massively parallel general-purpose graphical processing units are doing nowadays—faster and faster machine learning will become a reality, said Auburn's Skjellum. "Distributed learning on handheld devices will complement that for quick and dirty decision making under uncertainty, right at the user's fingertips," he explained. "Technologies such as Siri and Cortana will become digital assistants that help more and more, while engineers will build the machine learning directly into the online processes of industrial systems as integral, rather than off-line or near-line."

Machine learning will gradually become more competent at sensing—taking lots of signals, including video and sensor data and understanding patterns in them—to the point that they're far better at it than humans could ever be, predicted Autodesk's Haley.

The cover story concluded: "This will allow software systems to more seamlessly understand and interact with the world around them. That said, this is only a tiny step toward realizing a machine-learning future where the systems themselves can perform truly intelligent reasoning. That's still a long way off, but, along the way, there will be a lot of interesting and useful solutions such as generative design systems, adaptive industrial systems and cognitive computing." ■

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A PERFECT CIRCLE – IMPROVING PIVOT IRRIGATION SYSTEMS WITH AUTOMATIONDIRECT

By Dan Carter, Carter Pivot Service

If you've ever taken a long road trip, you've probably passed large fields of crops, which every now and then contained odd looking metal pipe structures on wheels stretching across the fields. These metal monsters, known as pivot irrigation systems, are used extensively in agriculture and have greatly improved the efficiency of the crop irrigation process.

As Dan Carter of Carter Pivot Service explains, "Pivot irrigation systems were designed to take a large portion of the manual labor out of irrigation and make it easier on the farmer to manage the process at multiple locations. Previous forms of irrigation systems were very labor intensive and required the water to be shut off to allow for movement through the field. The pivot irrigation system allows the farmer to start irrigating and only monitor the operation until the cycle has ended (pivot has made a complete or partial circle).".

Sow Much Better with Automation

Over the years, pivot irrigation systems have gone through various improvements and many options are available today including water, hydraulic and electrically driven versions. This application story, provided by Dan Carter, demonstrates how the controls for these pivot systems are being improved with automation with a pivot irrigation system upgrade in Morton, Texas.

In the fall of 2013, my dad, Tommy Carter, called me and asked if it would be possible to install a PLC in the control panel of a pivot irrigation system. I told him that it would definitely be possible and over the next few weeks we had several discussions which led to a list of components necessary to build the system. I have worked with AutomationDirect components throughout the last 15 years of my career as a controls specialist with great success. The cost effectiveness of components available at AutomationDirect, coupled with my previous experiences using the DirectLOGIC 06 (DL06 PLC) and the C-More (EA7-T8C) HMI, drove our decision to use their components to build our system.

AutomationDirect also provides shipping options for their products that keeps downtime to a minimum, a key parameter that made the decision to use them very easy for us.

The development of this system was ignited by the need for a control system built entirely out of off-the-shelf parts. Most of the major pivot irrigation system manufacturers use proprietary control systems that are built in-house at their factories. Unfortunately, they do not manufacture enough spare components to make them readily available when an emergency arises. To address this issue, we built our core control system entirely out of components from AutomationDirect. Most of the parts in our control system can be delivered overnight, and many within two to three days. This is crucial where crop irrigation is concerned. Waiting two or three weeks for control system components can damage a crop to the point that it cannot recover.

Our control system was designed around the DL06 PLC and C-More HMI. The controls were developed and improved while observing other major manufacturers' systems in operation. The C-more HMI comes equipped with a web server and remote access capability. We leveraged this technology to control or monitor the operation of a pivot from anywhere in the world where internet access is available. Given this ability, to see what the operator sees without being onsite, a technician can work with the operator via phone to diagnose problems quickly and efficiently. Remotely accessing status screens (*Image 1*) will enable the repair technician to have the necessary parts before he drives to the customer's location.

Pivot Position

We designed the control system to be completely configurable to any standard non-specialty pivot irrigation system; it can be configured in a matter of minutes

Image 1: The C-more HMI's remote access capability allows a technician to see what the operator sees without being onsite. The technician can work with the operator over the phone to diagnose problems quickly and efficiently.

Image 2: The pivot irrigation system can be easily configured, based on the package data provided with the system and selections made by the operator.

based on the package data provided with the system and selections made by the operator (*Image 2*). Before the pivot begins moving, it waits for water pressure to be verified. The operator can choose water pressure from a pressure transmitter or water flow from a flowmeter to indicate when the machine is ready to run "wet", or ready to irrigate. In some cases, it is necessary to dead head the pivot back to a specific point which clears the way for farm implements or harvest equipment. This is an example of running "dry".

Image 3: The Carter pivot irrigation system makes use of a zero lash coupler to attach the systems sprocket shaft to an absolute encoder.

Much like the (older) control systems from most of the major manufacturers, our system uses an absolute encoder to determine the current position of the system [0° = North, 90° = East, 180° = South, 270° = West as displayed on the Status Page of the HMI]. Our system makes use of a zero lash coupler (*Image 3*) to attach the system's sprocket shaft to the absolute encoder.

This coupling greatly improves the accuracy and repeatability of our position indication system and is a far better solution than the piece of rubber hose being used as an encoder coupling by some manufacturers. The absolute encoder in our system provides reliable position detection which is used to:

- Stop the pivot
- Reverse direction of the pivot
- Change the speed of the pivot
- Switch from wet to dry operation
- Switch from dry to wet operation

When viewing the aerial photo (*Image 4*), you can see one place where the center and the east pivots overlap territory. This is a perfect scenario for speeding up the pivot when it enters the overlap and running dry until the opposite edge of the overlap is reached.

Image 4: An aerial photo shows one place where the center and the east pivots overlap territory. This is a perfect scenario for speeding up the pivot when it enters the overlap and running dry until the opposite edge is reached.

Sometimes a farmer will grow different crops on the two halves of the circle. In this instance, one side of the circle might need more water than the other. The control system could be configured to slow the pivot down while tracking through the half of the circle that requires more water.

Controlling Crop Circles

This system provides five user configurable programs with five steps in each program. The system is capable of using both position and mechanical input to advance the steps within each program. The pivot can reverse or stop while executing a program using a mechanical input from the tower that is equipped with the auto-stop / auto-reverse trigger.

Although there are five user programs available, sometimes a program will only need one step; other times all five will be utilized. An example of a one-step program would be as follows:

> Run [Reverse][Dry] at [100%] of speed until position [270.5] is reached and [Stop]

The user will add steps as necessary until the program contains a [Stop] command in the Transition selection (*Image 5, next page*).

When the operator is ready to execute a program, he/she selects [Program] under the [Control Method] selection on the control page and then selects the desired program (1 through 5). This will begin execution of the program. If the operator wishes to abort the sequence, they simply switch the [Control Method] back to [Direct] and press the stop button (*Image 6, next page*).

Alarms are captured with the time and

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Image 5: Carter's system provides five user configurable programs with five steps in each program, capable of using both position and mechanical input based program step advancement within each program.

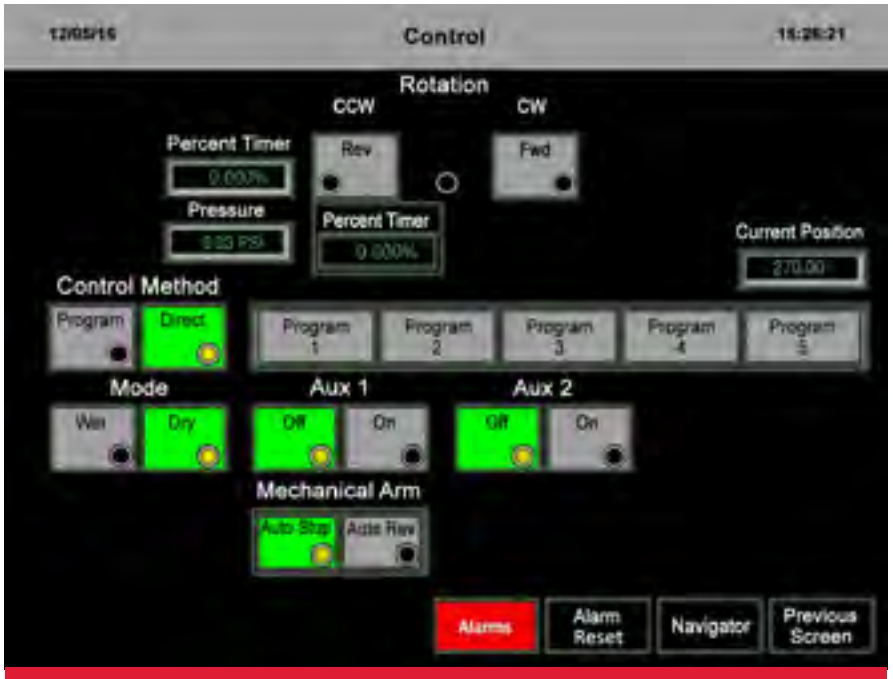

Image 6: If the operator wishes to abort running the program, they simply switch the [Control Method] back to [Direct] and press the stop button.

date, and stored on the operator interface to make troubleshooting easier when a problem occurs.

While this feature may exist on new systems, it is a great enhancement for older systems that are still mechanically sound, but the factory control system is no longer operational.

Green Thumbs on the Go

Where more than one pivot exists on a farm, our system uses Ethernet radios to create a field network connected to the internet via a cellular internet modem. On farms that happen to be the homestead, our system can be configured such that all of the pivots on the farm network can be managed over the network even if the internet is down.

Our control system allows user's access via the internet on multiple devices:

- Windows based Laptop/Desktop
- Apple iPhone, iPad and iPod
- Android phones and tablets

The connectivity using Apple and Android devices is made possible by the C-more application that is available for purchase on the App Store (Apple) and the Google Play Store (Android).

While our networking and remote connectivity uses the same basic infrastructure as the competition, the defining difference is that our technicians will also use the internet connection to the machine to help customers troubleshoot problems in real time without having to be onsite. Our technicians will also leverage the technology by taking control of the system remotely and showing the customer what steps are needed to successfully operate the system. This will reduce downtime for the customer.

At Carter Pivot Service our primary focus is to provide a highly reliable alternative to a basic control system, as well as a cost effective replacement for control panels that have become obsolete. We are solely focused on control systems and pivot service and do not build pivot irrigation systems. We are currently enhancing our control system's capabilities and we hope to have it available for purchase in the near future.

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BEAM TESTING AT PORTLAND STATE

By Thomas Langston,
PSU Mechanical Engineering Bachelor of Science pursuing MS in Materials Science

For their undergraduate senior capstone project, a team of Mechanical Engineering students at Portland State University (PSU) recently designed an electronic system upgrade for the control system of a 100-year-old beam testing machine. Using a range of AutomationDirect parts, the purpose of the project was to make the operator experience comparable to modern machines.

The project was proposed and guided by PSU Mechanical and Materials Engineering (MME) staff William Wood, Professor, Robert Turpin technical and fabrication specialist, & Tae Kyu Lee, Associate Professor. The project team, led by Thomas Langston, included fellow students Giovanni Castillo-Martinez, Moonsu Park, Hassan Alherz, Ian Winter, Thanh Truong, Jaime Meza-Martinez, & Ben Vorobets.

During the summer of 2015, a Riehle Beam Testing machine was donated by the City of Portland Materials Field Testing Laboratory to PSU to support the university's MME research and education. PSU's office of Graduate Research then relocated the system to PSU's Materials Research High-Bay lab located in the Oregon Museum of Science and Industry's (OMSI) PEPCO building.

Image 1: Riehlé Brothers beam testing machine with belt-driven counterweight.

Image 2: A SureServo servo system moves the counterweight to maintain balance.

Manufactured in 1916 by the Riehle Brothers Company in Philadelphia, Pennsylvania, the beam tester is a triple-beam balance load scale with an electric motor-driven lead screw-type force applicator capable of compression, tension and three-point bending tests with a load capacity of 150,000 lbs.

Since the scale mechanism is a large version of a classic triple-beam balance lab scale used in classrooms, laboratories and manufacturing facilities, the machine requires the operator to move the counterweight out on the balance beam to keep the increasing load in equilibrium. A Riehle Brothers design to automate this process is shown (*Image 1*) using a belt driven counterweight. It uses an electric motor driven by a signal from an analog position sensor, likely a type of potentiometer, located at the end of the beam.

Most beam testing machines from this era have been replaced with modern systems utilizing electronic controls, load cells and complex servo hydraulic loading mechanisms. These systems offer greater speed, modularity and ergonomics for the operator over the lead screw designs of the past.

The modernization project accomplished the same function using AutomationDirect's Productivity® 2000 PLC control, a direct-drive servo motor at the counterweight crank wheel, and a non-contact laser displacement sensor at the end of the beam. The Productivity2000 PLC is used to process the position signals and output the desired motion parameters to keep the beam balanced and machine forces in equilibrium.

A new motor and VFD controller were chosen to replace the existing motor. The VFD allows continuously variable feed rates of the crosshead. The original machine had a limited number of discrete feed rates available through the transmission,

and tests were run at a single speed. A VFD motor combination allows for both lower and higher speed operation without loss of torque needed for a given test. Additionally a low RPM motor was sourced to provide even lower feed rates which are desirable for certain tests. Mounts were designed to install the direct-drive motor.

Auto-Balancing Mechanism

A SureServo servo system from AutomationDirect was used to maintain balance of the beam. The system takes a direct position input from a Wenglor photoelectric laser distance sensor at the end of the balance beam to create a set point for the PID controller integrated into the amplifier and controller system. The servo motor is directly coupled to the shaft of the counterbalance drive crank. This allows the servo to move the counterweight to keep it balanced. (*Image 2*)

The Riehle machine may be old, however there is nothing deficient about the testing method that it employs, and using the modern equipment listed above, the results the machine provides are comparable to the continuous stress/strain data produced by a modern machine.

In addition to being a student educational project, and a testing platform for the PSU MME Department, the retrofitted Riehle testing system was presented at the 2016 OMSI Maker Faire. This annual event attracts many specialists and interest groups in the area of design, engineering, manufacturing and materials. This event was timely in that it occurred during the machine's 100th anniversary and provided an opportunity to publicly highlight the history of metallurgical study and its current state of development.

Mechanical Description

The Riehle's triple-beam balance mechanism functions similarly to a laboratory balance scale except that it uses two additional lever mechanisms over a single one. The machine will be described in three parts: the loading assembly, the drive train and the balance beams system.

Loading Assembly

Capable of tension, compression and bending tests, force is applied to the loading assembly by the crosshead driven by two vertical lead screws (*Image 3*). The loading frame pivots on the larger balance beams that connect to the intermediate and scaled balance beams. Multiple attachment heads allow for multiple types of specimens to be loaded and tested. The loading assembly consists of the following parts:

Tension test frame
Lead screw driven crosshead
Loading platform
Side arm supports for long beams

Image 3: The loading assembly consists of the tension frame, lead screw-driven crosshead, loading platform, and side arm supports for long beams.

Image 4: The beam testing machine drive train features 4-speed transmission, ring and pinion gear assembly, V-belt pulley drive, 5 hp AC motor with VFD, and a reversible gearbox.

Drive Train

The drive train (*Image 4*) powers the lead screws and consists of the following:

Ring and pinion gear assembly
4 speed transmission
V-belt pulley drive
Forward reverse gearbox
5 hp AC motor w/VFD

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Image 5: The balance system provides the final mechanical advantage that keeps the system in equilibrium.

Balance Mechanism

The balance system, consisting of the counter balance on the balance beam (*Image 5*) and the counterweight crank drive and the dial indicator showing 10lb increments (Image 6), provides the final mechanical advantage that keeps the system in equilibrium.

In addition to the electronic control system upgrades the team had to design and manufacture a steel support undercarriage to support and anchor the Riehle machine to the floor. They also identified the following five objectives for the control system retrofit:

1. Load calibration of the 150,000lb capacity bending and axial load frame
2. Upgrade the AC motor to an AC motor with Variable Frequency Drive (VFD) for improved speed control
3. Design and implementation of an auto load balancing operation, using an AutomationDirect supplied SureServo servo system
4. Re-installation and operation of the Riehle in its original operating condition with its gear driven applied load mechanisms highlighted and visible for OMSI museum visitors to demonstrate how structural materials properties were obtained 100 years ago.
5. Design and implementation of a control and data acquisition system using an AutomationDirect PLC to control the machine AND acquire, display, store, and post process load, crosshead displacement and strain outputs from system mounted sensors.

Conclusion

Installation of the major design components was completed in time for the 2016 Maker Faire event. During the event, a 4" x 6" x 12' beam was loaded to 5,000 lbs showing visitors the deflection at which this load and beam span. Both makers and event visitors alike were intrigued by the machine and fascinated by the tremendous mechanical advantage the drive-train applied to the beam using only a 5hp VFD motor.

Engineers and advanced makers recognized the parallel between the original automated design and the current system as well as the advantages provided by modern PLC equipment. Particularly useful in this application, the Productivity 2000 provided a control hub for multiple digital I/O communications to separate components of the system. From this PLC, control of the balance mechanism is managed, but also integrated control of the VFD motor and data acquisition systems are made possible making the P2000 the primary test control module for the 2016 upgraded Riehle System.

Image 6: The counterweight crank drive and dial indicator displaying in 10lb increments

Given the short amount of time for project completion, the engineering team accomplished an ambitious set of goals. The project surpassed all course requirements with excellent review ratings and all students received passing grades. The success of the project was made possible by the collaborative support from AutomationDirect, the stellar assistance from their Productivity2000 technical support team, and the advanced technical capability of AutomationDirect-supplied products.

BRAINTEASERS

By Chip McDaniel

1.) Fence Me In!

The puzzle factory has twenty robots on the factory floor, laid out as shown on a grid. The safety manager wants to install fencing on the plant floor to isolate the robots into separate work cells. The plant manager agrees, but only if it can be done with six (and only six) straight sections of fence. Can you determine where the six straight fence sections should be placed?

3.) Month of Sundays

There have been a number of (false) rumors going around the internet about how rare it is for a certain month to have 5 weekends. The time frame of 823 years is often quoted, and you will purportedly get rich that month IF you forward the email to 5 or 10 of your friends. That last part is a dead-give-a-way that something is rotten in Denmark, right? Five-week-end-months happen pretty often – April (2017) will be one (and with only 30 days in that month). If you want to include 5 Fridays with those 5 weekends, you only have to wait until this December (2017).

On a related note, we've seen questions and posts asking about years that have Februarys with five Wednesdays (or any other day of the week, for that matter). Obviously, that requires the year in question to be a leap year, and February 1st of that year must fall on a Wednesday (or your favorite day-of-the-week). One question that is often posed, "Find the probability that the month of February may have 5 Wednesdays in A) a leap year, and B) a non-leap year." Not a bad question, but not really a difficult problem to solve either. Let's make it more of a challenge: What is the probability that ANY given year will have a February with five Wednesdays? (Remember that leap years don't fall EVERY four years – just mostly every four years.:))

Puzzle concepts credited to:
Henry E. Dudeney

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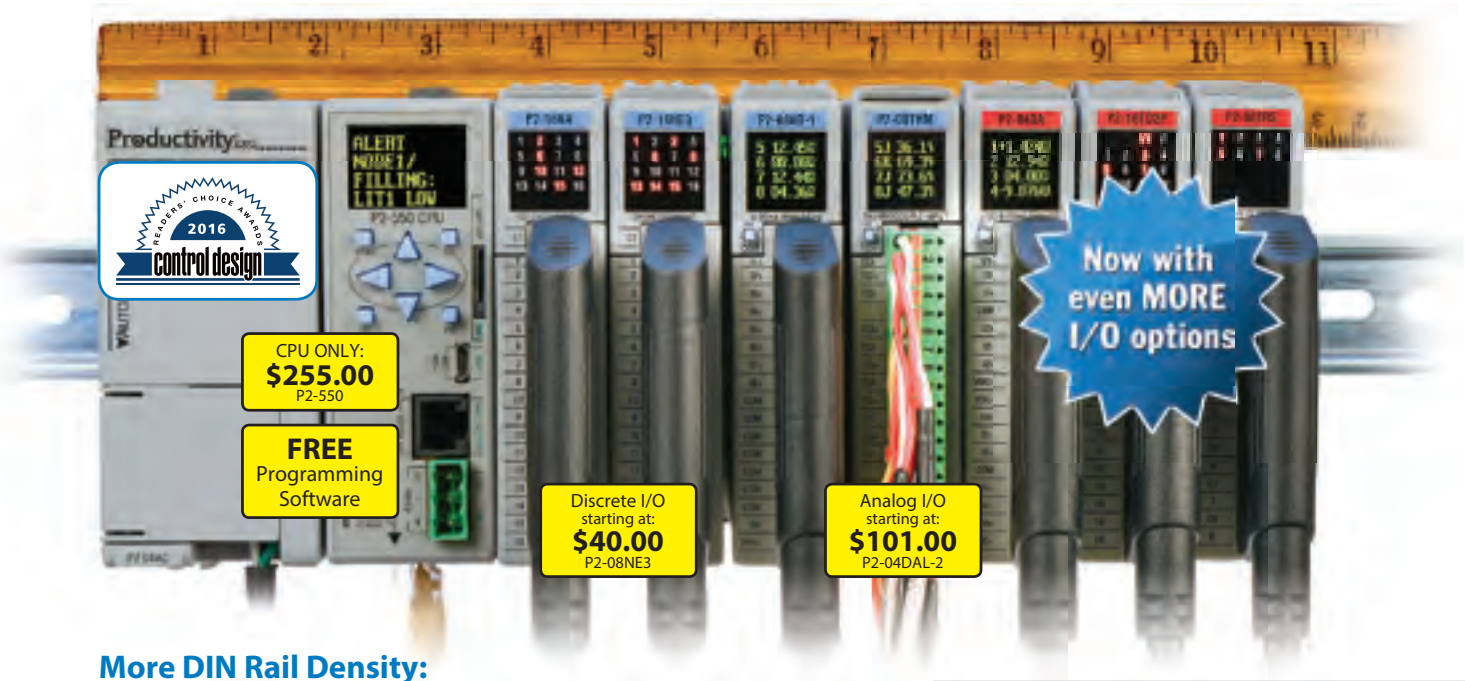

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