Automation NOTEBOOK®

Your guide to practical products, technologies and applications

The Best Automation HMIs Keep Things Simple

Design standards and best practices for human-machine interfaces continue to evolve, but simplicity and clarity never go out of style.

Improvise, Adapt, Overcome

Water Utility Successfully Standardizes Automation Practices

Automating the Hendrick's Gin Grand Garnisher

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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.

2020 - Is it over yet?!

For many of us, 2020 held a lot of promise and was expected to be a good year. After all, 2019 ended on some pretty great high notes. A soaring economy, skyrocketing 401k's, LSU headed to another NCAA National Title (Geaux Tigas!) and Marvel's best superhero yet - Fat Thor, were just a few bright spots of 2019. But perhaps we should've seen the writing on the wall when Burger King released a meatless hamburger made from plants. Now I'm not saying that the Impossible Whopper is the cause of 2020's mess, but then again I haven't seen any evidence to prove otherwise.

In all seriousness, 2020 has had some major events that have gripped the nation. Because of their impact, these events capture our complete attention. However, in the face of all the adversities that surround us there have been some positive occurrences. As I write this, the economy and job market seem to be recovering, Space X made a giant leap for commercial space exploration, wireless carriers are rolling out their 5G networks (which some believe will begin an era of augmented reality, AI, and self-driving vehicles), the USSF (United States Space Force) is not only real but they're hiring, and the demand for US-made products has been re-ignited. Even though this year has bombarded us with bad news and at times we're ready for it to be over, 2020 still has a lot of potential so don't give up on it just yet.

This issue of NOTEBOOK is loaded with informative content such as the Tech Thread, which shines a light on our training partner, Interconnecting Automation, and their newest venture – live, online PLC training classes. We have a great Cover Story on the evolving design standards for human-machine interfaces (HMIs). The User Solutions shows how the Grand Garnisher is using Do-more PLCs to add the finishing touch to the perfect cocktail, and how the Helix Water District improved operations by standardizing on AutomationDirect components. Our Student Spotlight showcases Auburn University's emergency ventilator project which helped curb a national supply shortage. In the What's New section, we touch on our 3D CAD in native formats and you can learn a little about our new customer community. The New Product Focus details universal analog options for BRX PLCs, ProSense process controllers, Murrplastik cable entry solutions, enclosure thermoelectric coolers and more. The Business Notes section discusses many of the happenings here at AutomationDirect and the Break Room is stocked with fun brainteasers. See how many puzzles you can solve and compare your answers at **www.automationnotebook.com**.

Expanded communications and analog I/O capabilities for the BRX PLC

New expansion I/O modules from AutomationDirect for the BRX stackable micro brick PLC include communications modules, universal analog I/O modules, and universal temperature combination I/O modules. Expansion modules snap onto the side of any BRX Micro PLC Unit (MPU) or BRX Remote I/O controller, creating a sturdy and rugged PLC platform.

Added BRX serial communications modules ($159.00) provide four isolated RS-232 ports that support communications flow control or RS-422 serial ports. Also available are BRX single-channel RS-232 (with flow control) and RS-422 Pluggable Option Modules ($49.00). Supported protocols include Do-more! Protocol, Modbus RTU (Master/Slave), K-Sequence, and ASCII (In/Out). Data rates are 1200 to 115,200 bps.

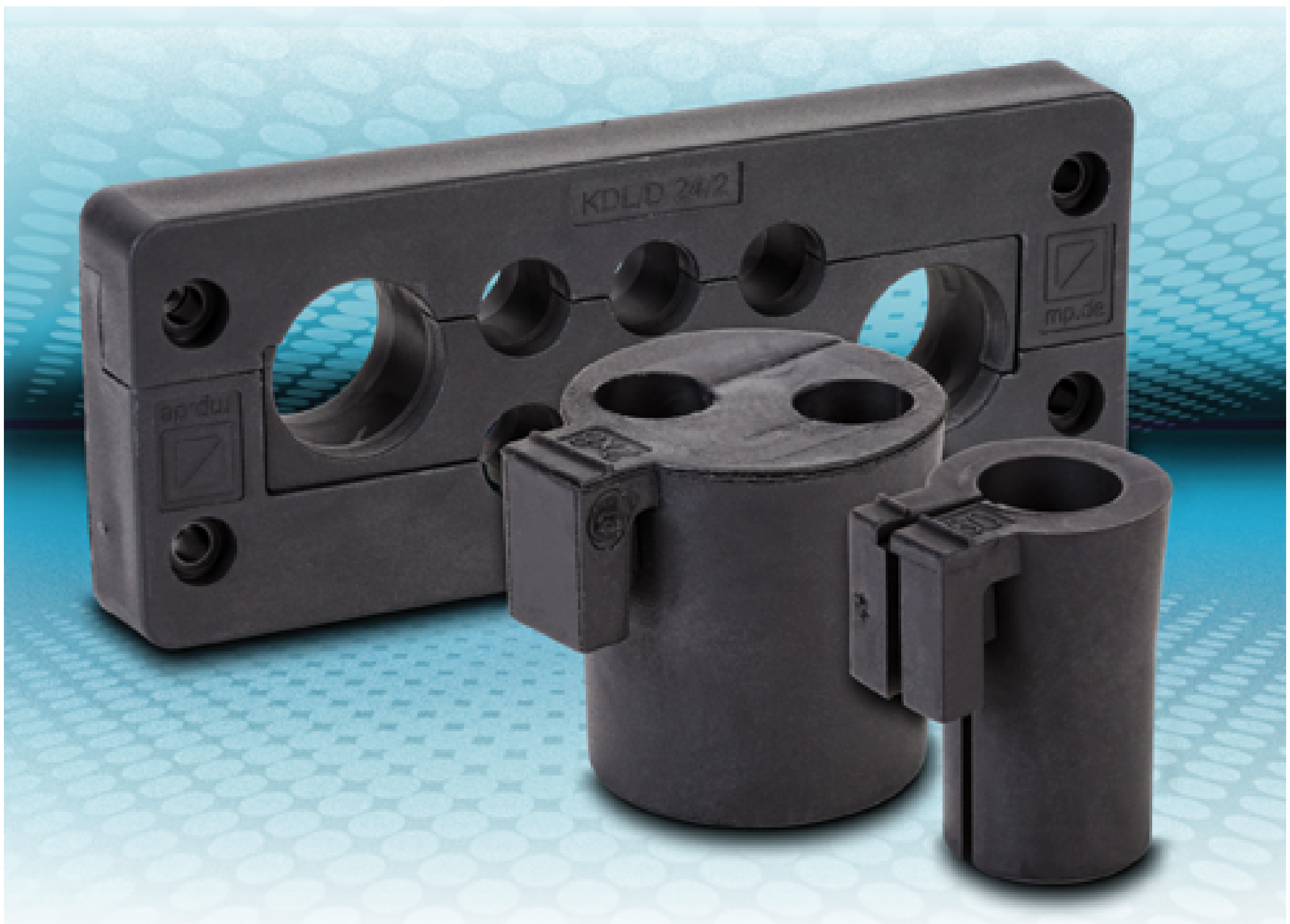
Universal analog I/O modules (from $159.00) have combined current and voltage options. Universal temperature modules provide thermocouple, mV level voltage, RTD or thermistor selection with 24-bit resolution. The 4-channel combination temperature I/O expansion module ($349.00) has universal temperature inputs and analog outputs. Four-channel combination temperature input / discrete output modules ($199) provide universal temperature inputs and discrete sink, source or relay outputs.

The AutomationDirect BRX PLC system is engineered, manufactured and supported in the U.S. and backed by a 2-year warranty.

Go here to learn more about the new communications and analog I/O capabilities for the BRX PLC

**Prices as of August 2020. Check www.automationdirect.com for most current prices.*

Control cabinet cable entry systems



The KDL/D cable entry system allows cables to be installed through enclosures or other bulkhead surfaces, with the added benefit that pre-made, terminated cables can be installed without disassembling the connectors. The split-frame system enables the quick and simple installation of up to 48 cables in a single frame. Four frame sizes, starting at $16.00, fit standard cut-out dimensions and provide integrated strain relief. The KLD/D system's robust multi-part frame design gives better mechanical stability while achieving a high degree of environmental protection.

The multi-part split-frame system clamps together with a grommet block and grommets to provide a high-density cable entry point with an IP65 environmental rating. Small and medium size grommets (from $6.00) accept cable diameters from 0.08 to 0.87 inches (2 to 22mm). Double cable and multi-line grommets accept more than a single cable. A blank grommet is also available for any unused medium openings in the grommet block.

Optional discharge plates ($29.00 each) install directly to the cable entry frame on the inside of the control cabinet and eliminate interference that can occur on cable shields.

The KDL/D cable entry system from AutomationDirect is cURus approved and backed by a 2-year warranty.

Go here to learn more about control cabinet cable entry systems

DURApulse GS20 Series high performance AC drives

The DURApulse GS20 Series of next generation high-performance VFDs provide many standard and advanced functions in a compact reduced size unit. The new GS20X series of AC drives is IP66/ NEMA 4X rated for operation in harsh environments.

The drives include many of the same standard features as our GS family of drives including dynamic braking, PID, removable keypad, and RS-485 Modbus communication. The GS20 drive expands the DURApulse family by adding single-phase input capability (ALL 230VAC drives can be supplied single-phase), a built-in PLC, and optional EtherNet/IP and ModbusTCP communication card. An available GS2 mode duplicates exact parameter configuration of GS2 series mini AC drives.

GS20 drives are available from 1/4 to 30 hp in single-phase 120VAC input, single-phase/three-phase 230VAC input, and three-phase 460VAC and 575VAC input. GS20X NEMA 4X drives are available up to 10hp.

Several speed control modes are available including standard V/Hz control with pulse input feedback, sensorless vector control (SVC) for induction motors (IM) and permanent Motors (PM), and precise Field Oriented Vector control (FOC) for maximum open loop speed regulation control.

DURApulse GS20(X) drives start at $135.00 and have a two-year warranty.

Go here to learn more about DURApulse GS20 Series high performance AC drives

ProSense® Advanced Process Controllers

Made exclusively for AutomationDirect by Yokogawa, ProSense® PPC5 series advanced process controllers handle temperature, pressure, level, flow, and other process variable control applications and offer a variety of control, input, output, alarm and communications options.

These 1/4 DIN controllers accept inputs directly from thermocouple, RTD, and analog mA, mV, V signals. Remote setpoint and contact input options are available.

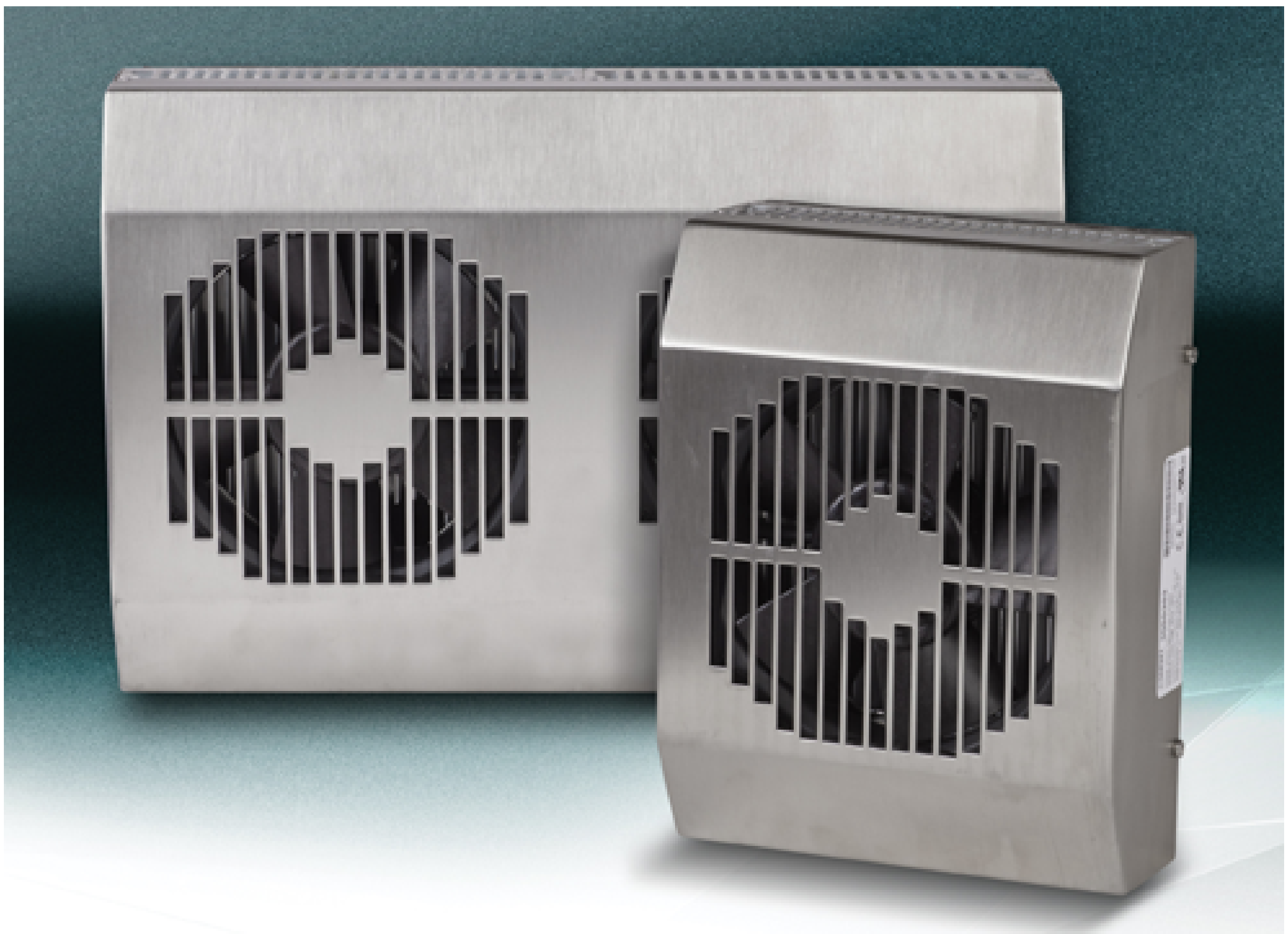
Control outputs include relay, voltage pulse, or linear current. An analog output to represent the PV, SP, target SP, remote SP, or output signal is available. Three alarm contact outputs can be configured for 30 alarm types and 10 alarm functions.

Control modes include single loop, loop control with PV hold, and cascade. Control types available are PID, On/Off, batch PID and manual control. PPC5 series controllers are available with no communications or with RS-485 Modbus ASCII/RTU, or Ethernet+RS-485 gateway Modbus TCP/IP communication options.

Priced from $325.00, ProSense PPC5 controllers are configured with the keypad/display or free downloadable configuration software is available. ProSense advanced process controllers are UL, CSA, CE approved and have a 3-year warranty.

Go here to learn more about ProSense Advanced Process Controllers

Enclosure Thermoelectric Coolers



Seifert SoliTherm® Thermoelectric Coolers from AutomationDirect use the Peltier Effect for closed-loop cooling. The only moving parts are axial fans so there is virtually no maintenance. The Seifert Peltier thermoelectric cooling units can be mounted in nearly every position (except roof mounting) because they don't have a compressor or any moving parts aside from the fans.

These thermoelectric cooling units are resistant to extreme ambient conditions and can operate effectively in dusty and oily environments and both indoor and outdoor applications. Cooling capacities range from 170 to 680 BTU/H (50W to 200W); the operating temperature range is -4°F to 149°F (20°C to 65°C).

Priced from $649.00, SoliTherm thermoelectric cooling units are CE, RoHS, cURus listed and washdown friendly NEMA 4X, IP66 rated.

Go here to learn more about Enclosure Thermoelectric Coolers

Improvise, Adapt, Overcome

By Bill Dehner, AutomationDirect

If you know us well, then you know our training partner Doug Bell and his company Interconnecting Automation. Doug has been with us from the beginning and offers several services that our customers, and many others, gladly take advantage of. Whether it's free online PLC training videos, on-site/hands-on PLC classes, or control system consulting and integration, Interconnecting Automation does it all and has been doing it for decades.

INTERCONNECTING AUTOMATION

In fact, one of our most recent application stories, **Modern Controls Automate Rock Crushing**, discusses how Interconnecting Automation upgraded an aging and highly manual rock crushing control system into a modern and easy-to-configure design. Over the years, Doug and now his son Nick, have built an impressive resume and a robust offering of services…Enter 2020.

This year has been rocked with many unforeseen disasters, with Coronavirus having the longest lasting effect…at least so far. While many industries are suffering the consequences of this pandemic and the associated lockdowns, on-site education and training services, like Doug's, were hit particularly hard. Luckily, Doug is not just an educator but an innovator at heart, and he refused to let this virus destroy what he built and stop him from doing what he loves.

That brings us to the reason for the title of this piece. "Improvise, Adapt, Overcome" is an important mindset with the United States Marine Corps made well-known by Clint Eastwood's movie, Heartbreak Ridge. Marines are about as tough as they get, and this mentality prepares them to overcome any obstacle that may confront them on the battlefield. It's imperative to their survival when faced with unforeseen disasters. This same mindset can be extremely valuable in the civilian world, and although Doug may not have realized it, his newest venture teaches us one of his best lessons yet.

In the current environment, where there is much uncertainty about how to stop the spread of Coronavirus and many differing opinions on who is or isn't at risk, some may not want to attend in-person hands-on classes. So, what was Doug to do about that? Give in and let that part of his business die off? Of course not. Doug adapted his training and used today's technology to meet people where they are and continue providing valuable training to those who seek it.

Interconnecting Automation's new service, live-lecture online training sessions (**www.liveplctalk.com**), provides live PLC training classes and discussions that can be attended from anywhere. These classes were created to better serve those who need training but want to avoid in-person hands-on classes. With these live sessions, you can access the same high-quality training as the in-person classes, directly from your home or office.

Live lecture training tutorials have these advantages:

- PLC training within the comfort and safety of your own location, at a low cost per session.
- Limited number of attendees per session, with plenty of opportunities to ask questions during and after the session.

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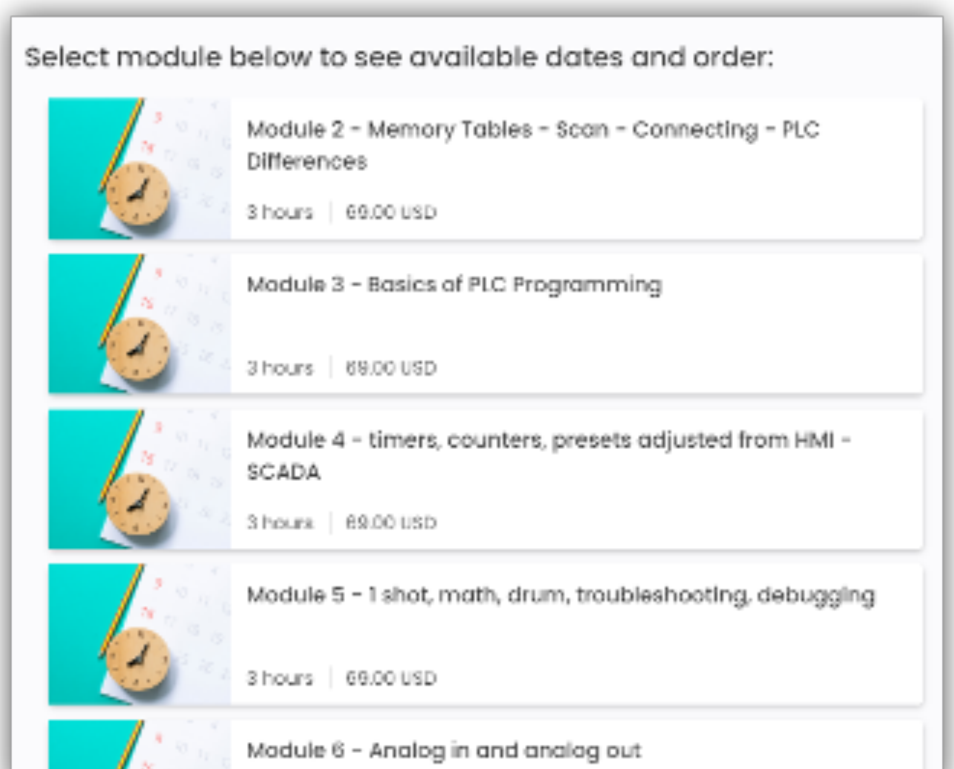
- No special hardware required and no prerequisites to attend. Material covered will be applicable to DirectLOGIC, CLICK, Do-More/BRX, and Productivity PLC families - attendees determine what families are covered.
- Modules start at 10:00 AM Central Time and are three hours long with one 15-minute break.
- Train as often as you want on seven key areas of PLC programming.
- Access a recording of your session after it is over for future review.



Signing up for live training is easy; instructions can be found at **www.liveplctalk.com**. Give it a try today and remember, just as Doug showed, it's up to us whether we accept our fate, or we improvise, adapt, and overcome.

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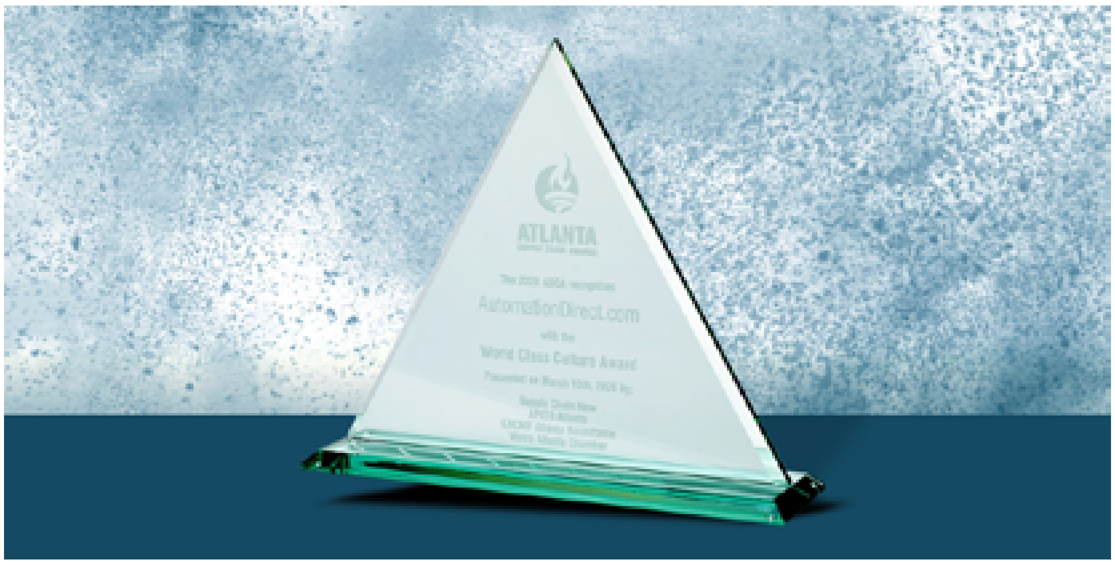
AutomationDirect Earns "World Class Culture Award" at Atlanta Supply Chain Awards

AutomationDirect was recently honored with the 2020 Atlanta Supply Chain World Class Culture Award. This award honors a company in the Metro Atlanta area that has an empowering culture internally for team members, a leadership approach that engages the entire organization in a forward-thinking way, and a commitment to engaging and giving back to the community and the industry in which they serve.



AutomationDirect was nominated for the award by Fred Tolbert of Demand Solutions, supply chain solutions provider for AutomationDirect, who noted that he has seen the company's culture in action throughout the 20 years he has done business with them.

Page Siplon, CEO of TeamOne Logistics, presented the award to AutomationDirect and said that he has "personally seen the community and culture that your company demonstrates." He also noted the company's long-standing involvement with FIRST Robotics having spent more than 10 years as a judge for the student robotics competitions. "I am especially pleased to be presenting this award to AutomationDirect on behalf of the committee and award judges as I have observed first-hand how the company consistently gives back to the community and our industry."

AutomationDirect Team Captain Tim Carroll accepted the award. "It's an honor for our team and the whole company to have our culture recognized in this way. Day in and day out, our team members work hard to serve our customers, the community, and each other. This award is an amazing validation to all our team members for their efforts."

About Atlanta Supply Chain Awards:

The Awards began in 2019 to recognize a wide variety of supply chain leaders and organizations in the Atlanta area for their contributions to the industry. For more information, visit **https://www.atlantasupplychainawards.com**

The Best Automation HMIs Keep Things Simple

Design standards and best practices for human-machine interfaces continue to evolve, but simplicity and clarity never go out of style.

By Bill Dehner, AutomationDirect

Whether we think about it or not, most of us as everyday consumers have developed opinions about how human-machine interfaces (HMIs) should look and feel. This is because we constantly use smartphones, websites, and even controls on our cars featuring digital HMI interfaces. As we interact with them, we intuitively understand what is clear to comprehend and actions that are easy to perform, as well as those that are awkward or downright difficult.

For factory equipment and systems, specialized industrial HMIs have been around for many years. The hardware and software have improved to offer extensive options, but sometimes there are so many choices that configurations can become more complex than necessary. Comprehensive standards, on the other hand, are a more recent development. However, standards are not always a clean fit for every industry, system type, or preference, and they may not be specific enough for all the unique items HMIs must represent.

Industrial system and original equipment manufacturer (OEM) developers need HMIs and want them to be useful, but they may not have time or dedicated staff for creating their own extensive HMI standards and styles. To address this issue, the best choice is often simplicity and clarity, a proven approach for delivering the best situational awareness and usability for HMIs. This article offers some basic tips and best practices for planning and implementing an effective factory automation HMI.

Investigate Resources

As with most engineering endeavors, it is important to check out available resources before creating any designs from scratch. Industry documents and standards, such as ISA101 and those produced by other organizations, provide HMI design guidance. However, many of these are focused on process, petrochemical, and nuclear industries.

Many HMI developers find "The High-Performance HMI Handbook" by Bill Hollifield, Dana Oliver, Ian Nimmo, & Eddie Habibi to be a helpful resource. Not only does it present many best practice concepts, but it also depicts poor designs which are all too common. But again, this book is somewhat process-oriented.

Depending on the HMI platform being used, the development environment may offer standard or optional object libraries, along with other aids, for creating new projects, and these are always worth a look. Keep in mind that it is very common for these library objects to require some modifications before deployment as a company standard.

Creating an effective factory HMI for a new application is typically an iterative process, simplified if one starts with applicable standards or samples. A good starting point is defining building block objects.

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Break it Down into Building Blocks

Each end user is likely to have a mix of typical industry elements, like valves and pumps, along with specialty components, all of which must be represented on the HMI. An early step should be to identify the elements that will be used repeatedly and create a standard design for each (*Figure 1*).

Figure 1: Typical HMI objects. HMI development environments typically provide many design elements representing physical devices, like valves and pumps, and logical devices, like analog meters. Some samples of the AutomationDirect C-more development software are shown here.

Not all HMI design elements relate to physical devices. HMI objects like start/stop buttons, on/off indications, recipe values, and data entry tags are all logical constructs necessary for the HMI to interact with the controller, but are not necessarily depicted on any mechanical or electrical design document.

Speaking of the controller, often a programmable logic controller (PLC), the HMI must be developed in close coordination with the PLC code. If the PLC has special device alarms, or other derived values such as motor runtimes, these must be accommodated in the HMI.

Build it Up with Story Boards

Story boards are a way of mapping out a creative process. They are most often associated with movies, but also can play a role in creating novels, architecture, and software. In the context of developing a factory HMI, story boards allow the designer to pre-plan how many screens are needed and their hierarchy so the team can review the flow before significant HMI configuration effort.

Designers may create story boards using a text-based outline, spreadsheets, sketches, or a combination of techniques (*Figure 2*). Whatever method is employed, it should be flexible and allow the review team to understand and help produce a good arrangement.

Figure 2: Story board image. Story boards allow HMI designers to pre-plan interface requirements and get approval before expending significant configuration effort.

The story boards should indicate how the systems, subsystems, and other detailed information are related to each other, typically in the sense of what will be shown on each screen. This arrangement is highly dependent on the complexity of what is being automated, and on what building block objects must be displayed.

A very basic machine may only have one or two screens to depict all operating conditions and provide a few objects for operator interaction. More complicated equipment will have more screens, including some that provide detailed operator-entry values, historized data trending, alarm/event logs, and derived performance and diagnostic information.

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Once factory automation reaches a certain level of complexity, it may be useful to introduce an HMI organization concept of levels such as:

- Level 1 Dashboards: Provide summary "at a glance" operating information
- Level 2 Typical Control: Streamlined operating screens, provide the essential monitoring and control options
- Level 3 Detailed Control: Detailed operating screens, with more options than Level 2
- Level 4 Specific Control: Very detailed popup, configuration, or diagnostics screens, not regularly used

During the story boarding process, keep in mind that team members include not just programmers, but also those from other engineering disciplines, along with operators, maintenance members, and management. Each member will contribute corresponding to their role.

Define the Style

The style for an HMI encompasses many look, feel, and functionality aspects. While current "high performance" HMI concepts call for minimized colors and very simple objects, each user must adopt what is suitable for their specific application (*Figure 3*). Here are some considerations for creating an HMI style guide.

Figure 3: Image of a configured HMI in use. Developing and following an HMI style guide will allow designers to configure intuitive HMI screens which operators can easily navigate to monitor and control factory automation systems.

Navigation and Availability

Common sense indicates that the most important controls, typically start and stop commands as well as navigation buttons, should always be easily available. A common way to do this is by reserving a portion of every screen for these controls.

Pop-ups are smaller windowed screens appearing in front of a full-display screen, usually used briefly for viewing and/or entering very specific information and then dismissed. Sometimes it is helpful to allow a pop-up to persist, such as for a PID tuning faceplate. However, while pop-ups may be useful for infrequent detailed tasks they can be a distraction for normal operation, consume space on the display, and should often be avoided.

Password protection security should be applied as needed, but judiciously to avoid locking down a system and impeding operators. It is often useful to consolidate machine tuning parameters on a single password-protected screen.

Be Careful with Color

Colors are used for backgrounds, fonts, static elements, and animated objects, but they can be a debated HMI topic. Most standards recommend light grey backgrounds and greyscale objects, with colors reserved for abnormalities. This provides easy visibility and guides users to what is important. However, an industry or equipment may dictate the use of color. Power industries often use red for energized (danger) and green for de-energized (safe). If an item of equipment has three color-coded subsystems, perhaps it makes sense to include those colors on the title bar for easy recognition.

Another point is to avoid relying only on animated color-coding of objects. Where possible, it is better to provide a secondary supplementary symbol indication of a state or condition.

Defining Text Data

Style also extends into what fonts are used and how text is capitalized. Plan on defining just a few fonts to cover the necessary scenarios. Reserve larger/bolder versions for titles and important things, and smaller types for details. Make it clear which values are display-only, and what can be

continued >>

operator-entered. Include engineering units and allowable ranges.

Streamline Graphics for Simplicity

A key benefit of digital HMIs is the ability to present graphical images and icons which can be quickly recognized by users without requiring reading or possible misunderstanding due to language barriers. However, that doesn't mean the graphics should be detailed engineering drawings, complex photographs, or highly animated.

Instead, the contemporary best practice is to provide simplified iconic graphics where possible. Constant animation may be useful in limited cases, but it consumes processing resources and is usually considered a distraction.

While bitmap-type images are usually discouraged, there are many good reasons to include them in factory automation. Designers can include images of equipment and parts with arrows, for instance, to clearly indicate to users where trouble is occurring.

Usability First

Investigate other advanced features that help operators do their job. Don't just show the current level of a vessel, but instead make the level available as a trend so the operator can understand how the system has recently operated. Even better, embed critical indicated values as mini-trends right on a screen.

A similar concept applies to alarms. For most systems it is important to indicate currently active alarms. But a detailed historical alarm/event logs with date/time stamps can assist troubleshooting efforts by letting users review how an issue developed.

Situational Awareness is the Goal

The concept of situational awareness developed out of military theory and more recently the aviation industry, but it is applicable for industrial factory automation designs. The end goal for the HMI portion of an automated system is to provide all relevant information so users can understand what is happening and know what action is required.

Large engineering firms or process facilities may have significant resources available to develop their HMIs. However, smaller organizations, system integrators, and OEMs can take advantage of the latest design concepts. A design process considering all of the preceding topics, and involving the key personnel as development begins, will ensure creation of a clean and useful HMI experience.

About the Author

Bill Dehner has spent the majority of his fourteen-year engineering career designing and installing industrial control systems for the Oil and Gas, Power, and Package Handling industries. He holds a bachelor's degree in Electrical Engineering with an associate's in Avionics from the USAF and is currently working for AutomationDirect as a technical marketing engineer.

CAD in over 60 native file formats now available

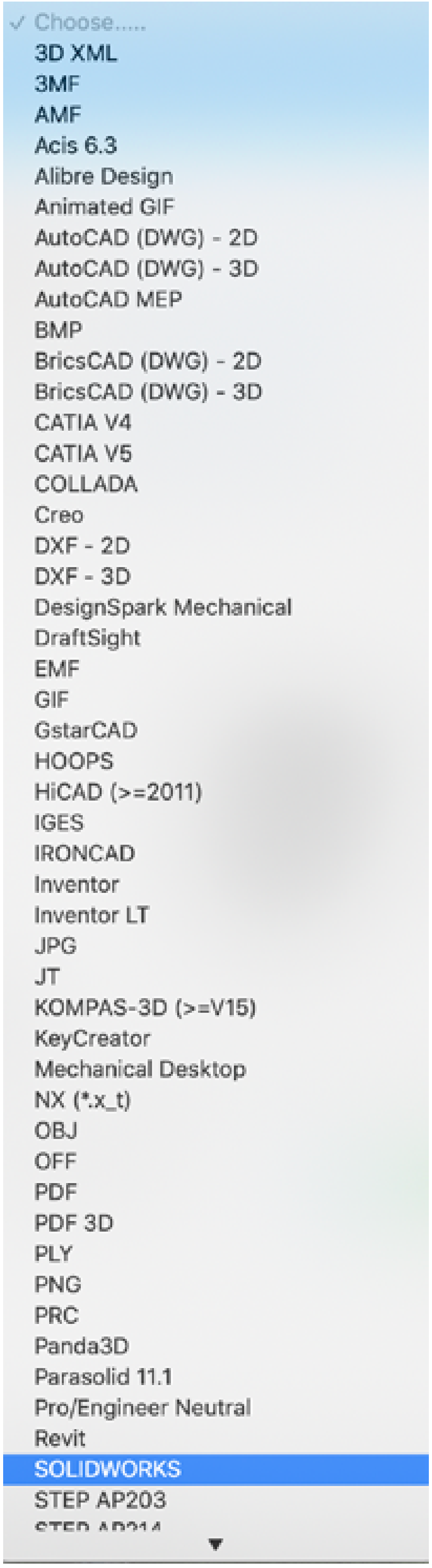
When designing a new system or updating an existing 3D CAD design, it often helps to obtain existing models from suppliers to speed up the process of development. This helps in several ways: saves time, more accurate specifications directly from vendor and additional product information within the model to help in accurately assessing if the part is the right fit for your design.

AutomationDirect.com now offers native CAD files in over 60 formats to assist in this process. In addition to native file formats (SOLIDWORKS, Inventor, and Pro-E) there are several generic 3D formats - STEP, Parasolid, STL, and more. There are many 2D options as well to help users create project documentation and BOM generation.

Once the 3D CAD model is placed in your design, AutomationDirect has made sure there's basic product and purchasing information right in the model metadata for quick acquisition of the part if you choose to purchase. No more going to vendor site, hunting down part number, verifying it's the same part number as in the model. All the information you need to make an accurate decision is right in the model.

At AutomationDirect we believe in helping our current and future customers make the best decisions they can with as much information as we can provide - for FREE. Before, during and after purchase users can download CAD, manuals, technical specifications, and even complete catalogs in order to make an informed decision.

Try it for yourself at http://go2adc.com/3DCAD



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It's quick and easy to get your CAD in native file format

How it works:

- Go to [www. AutomationDirect.com]() and navigate to product page of part number you are interested in
- On that page, click the 3D CAD button (*Figure 1*) under photos or scroll down to Documentation and Drawings tab
- Select the CAD format you need (*Figure 2*)
- Once file type is selected, if you are logged into AutomationDirect simply hit "Create File" button (*Figure 3*)
- If you are not logged in or not a current customer, simply provide some basic information, then select "Create File" button
- Shortly, your file will be generated. When it is ready, click the "Download" button (*Figure 4*) and the file will be placed in your downloads folder.
- That's it, you're done! If you want more formats or CAD for other part numbers, they're available for you to download as much as you want. It's all FREE!

Try it for yourself at
http://go2adc.com/3DCAD

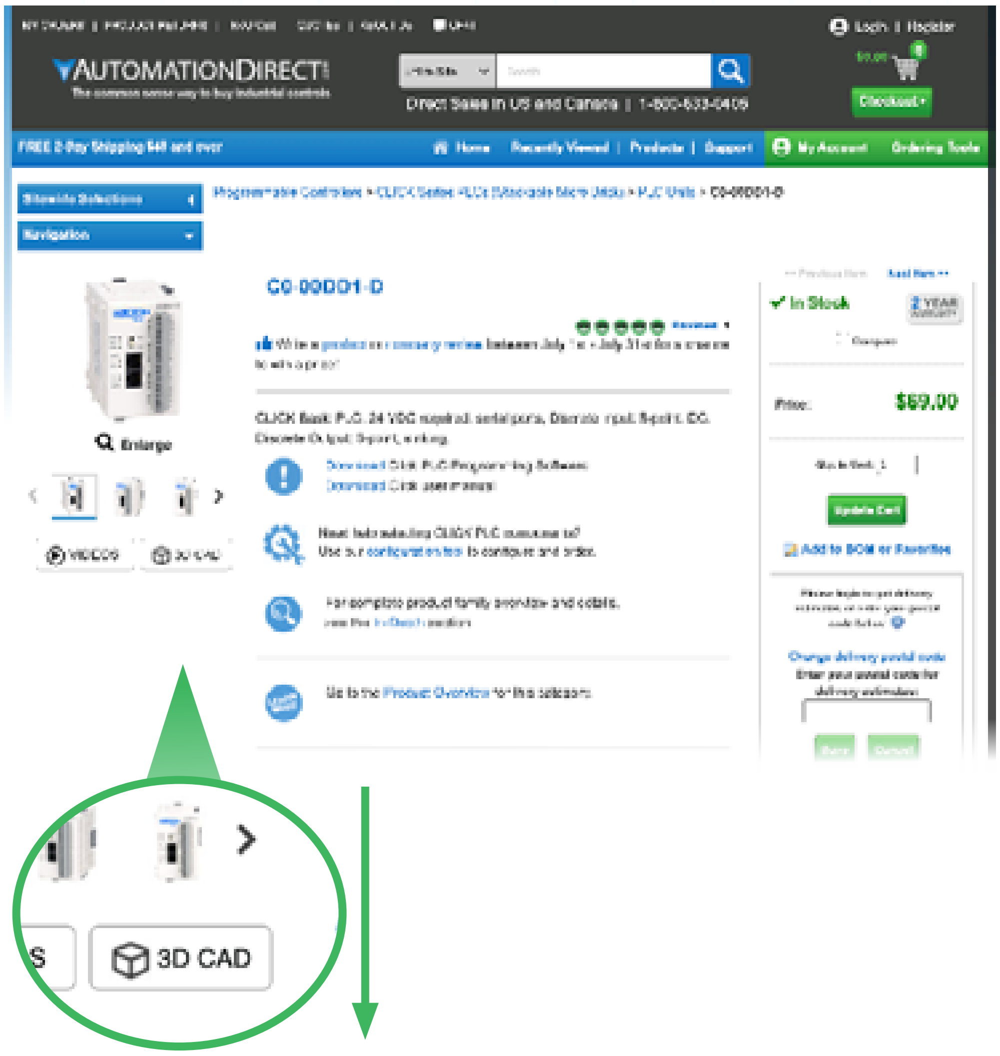

Figure 1

Figure 2

Figure 3

Figure 4

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New Customer Community Forum

The new AutomationDirect Customer Community is a place where like-minded professionals can engage with each other and share knowledge, offer advice or exchange ideas. Inside the community you'll find technical forums that are active with thousands of users including hobbyists, engineers and even some of our development partners. There is also a Knowledge Base which provides numerous resources including example programs, FAQs and how-to videos. The General Community Information section includes read-only topics such as new product announcements, firmware/software updates and includes a place for community forum feedback and suggestions.

Here are just a few recent discussions from the community technical forum:

- How to program a P2-HSI to show Rate (RPM)
- Wiring banner indicator light to P1000 P1-08TD2
- Send EA7 program to new EA9 HMI screen
- BRX to HMI via onboard RS-232

The Customer Community page is always available - 24/7/365. Check it out and bookmark it now at:
https://community.automationdirect.com/s/

Water Utility Successfully Standardizes Automation Practices

This utility standardized and defined best practices for their applications, improving operations while saving time and money.

By David Reagan, Helix Water District

Industrial automation installations come in many shapes and sizes. Applications vary from standalone machines up to large processes, and the operating organization may have just one maintenance person or field an entire engineering group. But a common theme is the need for standardization to streamline design efforts, simplify support, and reduce costs.

Figure 1: Inside a typical pump station.
Helix Water District realized many benefits by standardizing on AutomationDirect products and best programming practices for this new pump station, and they then applied similar concepts to retrofitted stations.

As these control projects are designed or upgraded, the standardization challenge spans many disciplines. Process and equipment control schemes, design and engineering practices, hardware and software product selections, and programming and configuration methods all play interrelated roles—and standardization efforts must thus integrate all these and other areas.

There is no single best method for executing these tasks because of the number of variables for each area. Furthermore, many automation projects are implemented and upgraded over years or decades, adding to the difficulty.

Because end users don't always have access to large engineering departments able to churn out optimized standards and procedures, they must look at other options. This article shows how a water utility with a moderately-sized staff was able to recognize the increasing difficulty and expense of supporting numerous operating sites of varying vintages, and to then internally take action to implement standardization. Just a few practical steps resulted in many benefits for new and retrofit projects, and for ongoing operations.

A Water District Controls its Future

Helix Water District is a public water district in east San Diego County, California. Helix's operations include a 106 million of gallons-per-day water treatment plant, along with 25 pump stations supplying about 270,000 customers. As is typical for these operations, the pumps stations are geographically distributed over a wide area (*Figure 1*).

A supervisor and four technicians support the existing supervisory control and data

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acquisition (SCADA) system. The technicians use their control system and electrical expertise to work on motors, instruments, controls, and the networked SCADA system.

With some installed assets over 40 years old and showing their age, the Helix engineering department created a 10-year capital improvement plan which included pump station rebuilds and the replacement of several of the oldest motor control centers (MCCs). These projects were typically performed by engaging outside design and contracting entities to execute the detailed work.

Previous experiences had informed the SCADA group that even for straightforward MCC replacements, each design consultant might choose different equipment and ways of doing the work, even as they complied with the general specifications. This problem extended to the associated controls and theory of operation. These variations from site to site made it difficult for the SCADA group to maintain and troubleshoot the systems.

For these reasons, the SCADA group proactively teamed up with their internal engineering department and an external electrical engineering firm to ensure standardization of their upcoming projects.

Template for Success

The goal of the teaming effort was to create an MCC design template that could be retrofitted at all current pump stations and implemented for any new stations. This template would include sufficient detail to ensure a highly standardized result for the design, hardware, and software—but with enough flexibility to adapt to field variations.

Existing sites generally used MCCs with automation components installed within them for a compact installation minimizing field wiring. This concept was desirable moving forward for new installations. However, for retrofit locations the new automation elements also had to be arranged so they could be installed into existing MCCs. Because pump stations come in various sizes, the MCC and automation components also had to accommodate different size motors, varying pump quantities, and sometimes optional I/O signals.

After a detailed review, the team specified the most crucial automation items without allowing substitution. This included the core AutomationDirect programmable logic controllers (PLCs), input/output (I/O) modules, human-machine interfaces (HMIs), and associated components. AutomationDirect was the preferred vendor for other more commodity-oriented components, but substitutions were allowed.

The resulting standardized layout was a compact arrangement of terminal blocks, power distribution, and PLC components that could fit in any typical MCC while still providing plenty of working space (*Figure 2*).

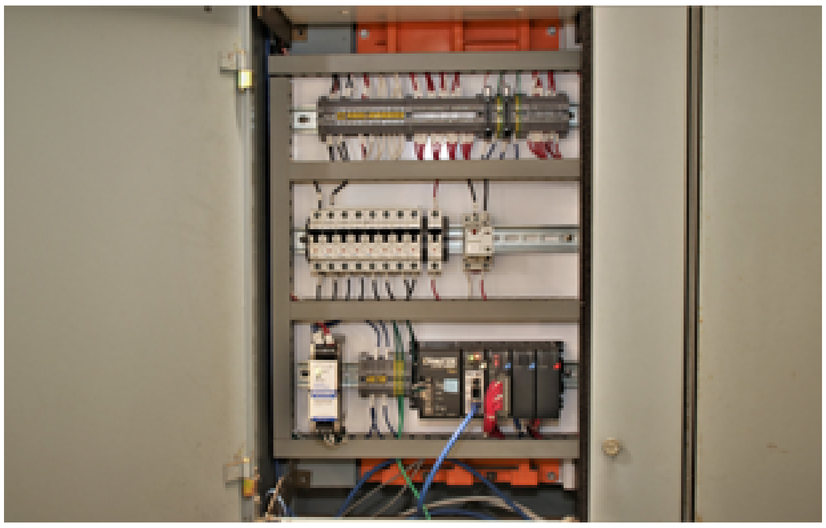

Figure 2: Inside a typical retrofitted PLC panel.
Retrofitting standardized PLC panels into MCCs allows Helix technicians to more easily troubleshoot and maintain their control systems, as well as stock fewer parts while remaining ready to deal with any issues.

Consistent components and designs enable Helix technicians to be instantly familiar with the automation at any pump station, making it easier to troubleshoot and maintain the control systems. They can stock fewer parts at the maintenance office and in their trucks, yet still be prepared to deal with any issues in the field.

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Codifying Code

Standardizing the hardware served to simplify physical design efforts for subsequent projects, both new and retrofit. However, the team wisely applied significant effort to software design as well. Specifying the AutomationDirect PLC and HMI families was just the first step. How those platforms were programmed would play a crucial role for implementing, deploying, and maintaining these projects.

Software programming and configurations are intangible compared to physical designs, and if the code is not arranged logically and documented thoroughly it can be downright inscrutable to all but the original programmer. Helix's first task was to define the PLC logic to reliably handle the basic functional needs of a general pump station.

The team then went to great lengths architecting the logic so that a typical program could be used for different pump quantities, signal ranges, and even network technologies simply by making minor adjustments. Memory locations and I/O address assignments were also standardized to promote consistency from site to site.

HMI graphics development received the same level of attention. Standardizing the graphical objects made the configuration effort more efficient and consistent. In turn, the resulting screens are easier for operations personnel to use regardless at each of the pump stations.

With all the software design pieces coming together, the next step was testing to validate the entire concept.

The Big Picture

For a water utility like Helix, there is one main operational site and many distributed remote sites. Significant wired and wireless networking infrastructure is in place to bring all of this together into an integrated whole under a single SCADA umbrella. Each of the remote locations must be capable of operating locally as an "island" of operation in case of communication failure, yet under normal circumstances they must integrate seamlessly.

Local control at any given site was straightforward. The first level of complication was ensuring that PLCs could communicate peer-to-peer, which was needed if a pumping PLC required information about a downstream tank level handled by another PLC. Because this communication impacted pump starting and stopping, it required the utmost reliability.

Another required attribute for the automation architecture was a centralized data collector PLC at the main plant for monitoring system values, handling start/stop setpoints, logging other events like communication failures, and alarming on faults. This data collector would also support more advanced systemwide functionality such as identifying time-of-use periods for shedding load during peak hours to reduce energy costs.

Knowing the necessary characteristics, Helix performed preliminary testing. They were able to individually prove out all basic communication, control, and visualization functionality, with the assistance of available documentation, online videos, and free support from AutomationDirect. This gave the team confidence that the pieces could be integrated into a whole as required.

This multi-tiered approach of local control, peer communications, and centralized data collection wasn't deployed to the field in a single effort. Instead, careful benchtop testing was performed in advance to ensure the concept would perform as expected (*Figure 3*).

By assembling multiple PLCs configured as local stations, and networking them with a data collector PLC and each other, the team was able to simulate and pre-test all levels of control functionality and communications to their satisfaction. HMI operation was also verified during the test phase. Extensive benchtop testing was key to ensuring success for initial and subsequent field installations.

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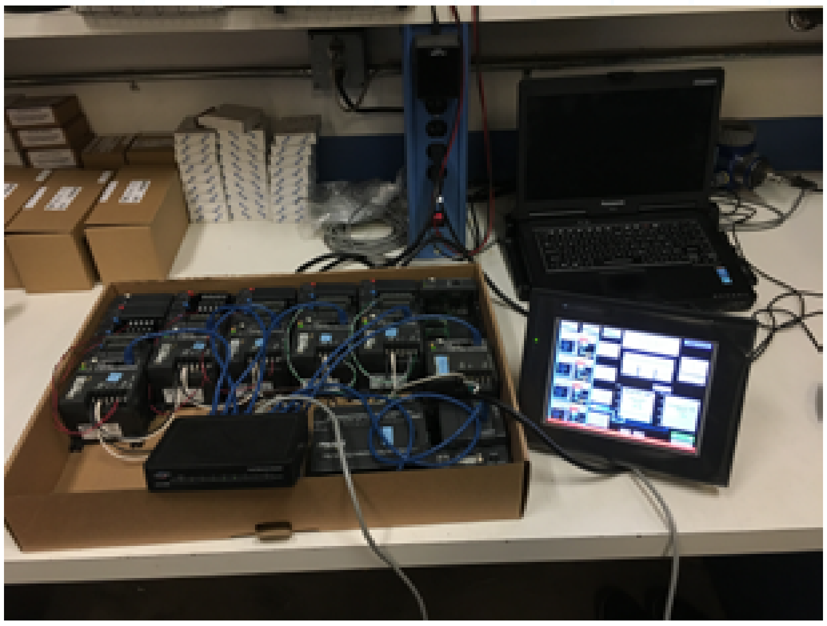

Figure 3: PLC/HMI test bench.
Helix performed extensive bench testing to ensure their AutomationDirect PLC programming and HMI configurations would control locally as needed while communicating as required.

Proof in Deployment

Helix's standardization efforts, using AutomationDirect hardware and software in particular, have been a solid success for the entire team for both new construction and retrofit situations. They have effectively developed a hardware and software template adaptable to their varied sites, and the team has now completed multiple deployments.

A completely new pump station was built by a subcontractor following the template, and three existing pump stations were retrofitted with new MCCs and PLC controls by subcontractors using the same approach. Helix also self-performed the retrofit of an existing pump station with new PLC controls. This proves not only the technical suitability of the standardization work, but also how the work can be executed in multiple ways from a commercial standpoint.

The new installations have worked reliably with no significant functional or component faults, but the team knows that eventually there will be some sort of problem requiring troubleshooting.

An added benefit of the new designs are the many options for remote monitoring and notification. The team has built in provisions so local or system failures can be alerted through the SCADA system. During the course of normal operation, or when trouble is indicated, team members can remotely connect to the PLCs and HMIs to inspect the situation, troubleshoot as necessary, and initiate a course of action. This provides a substantial time and cost savings compared to older pump stations where a site visit by a technician was required.

Standard Automation Practices are Attainable

Most industrial automation end users understand the benefits of incorporating standardization, but they may be concerned as to whether they can implement it based on their staffing, organization, and the types of automated processes involved. The Helix Water District efforts to proactively upgrade, standardize, and improve their automation systems are a case study in how to approach the task methodically from the bottom up, starting small and adding value at every level.

There are many options along the path to standardization. End users can do as much of the work as they like or can retain the assistance of contractors. Because each end user company knows their operations and practices the best, it is recommended for them to play a strong role in specifying the most crucial control platforms, components, and architecture aspects.

Another key is pre-testing basic automation elements, and then performing integrated testing on the bench to ensure functionality and buy-in of all stakeholders. A staged deployment can then be undertaken with confidence. Even once the system goes to the field, there is still an opportunity to learn and improve the defined standards.

All end users will benefit from incorporating standardization, following practical and common-sense steps to define and achieve their goals.

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Figures, all courtesy of AutomationDirect and Helix Water District

Author Bio

The Helix Water Disctrict team is made up of a number of operations, maintenance, and engineering personnel, each of whom were involved in the standardization efforts and continue to operate and support the system on a daily basis. The SCADA team consists of Henry Palechek, Bobby Fortuno, Gary Richardson, David Reagan, Kyle James, and Jeremy Boone.

Automating the Hendrick's Gin Grand Garnisher

The Grand Garnisher has been turning heads as it tours the United States and Europe. AutomationDirect hardware and software automation underpins the attractive, steampunk contraption.

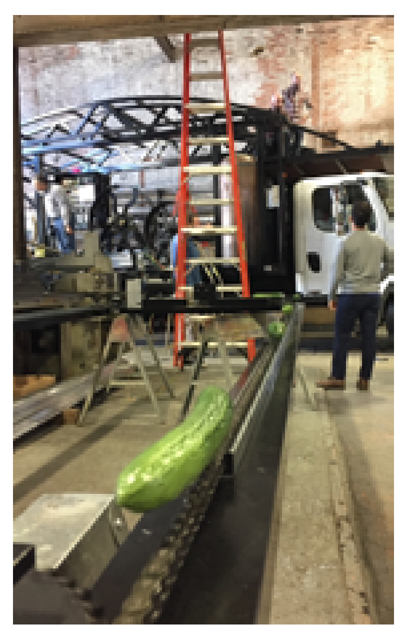
By Stuart Ostroff, Salmon Studios

Picture this: you are in the back garden of the grand duke's estate, enjoying social hour with great company, a botanical cocktail in your hand. You think, "the only element that could make this better would be a garnish for my drink." As if reading your mind, a retro-futuristic truck and crew—seemingly out of a sci-fi magazine—come to life from a billow of steam, drawing gin-enthusiasts with their promise of the perfect cucumber garnish.

Hendrick's christened this machine the "Grand Garnisher". It has toured the U.S. coast-to-coast twice and more recently completed a circuit in Europe, delivering wondrous cucumber garnishes and leaving awestruck patrons in its wake. Although at first glance it may appear the contraption is driven by a steam generator, the sensation is made possible by a lineup of AutomationDirect automation equipment in the back.

A Most Unusual Garnisher

Hendrick's Gin—distilled in Scotland—is known for its rose, cucumber, floral, and botanical flavor notes. The marketing group contracted Salmon Studios in Florence, MA to develop a functional and aesthetically-pleasing garnishing apparatus to set on a 20-foot, flatbed truck. Keeping with the steampunk theme reminiscent of Hendrick's marketing, all visible wiring and electrical devices would be hidden away behind the retro aesthetic of steam-powered machinery.



The flatbed-mounted visuals include six motorized parts:

- a steam engine with dual flywheels, driven by a hidden gearmotor
- two separate chain conveyors whisking artificial cucumbers around the bed
- a rotating cucumber slicer
- a reciprocating mechanical arm to

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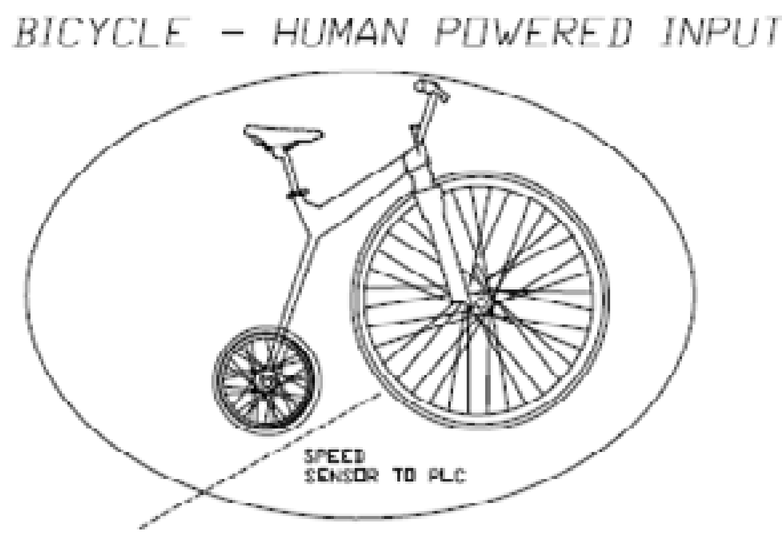
control the slice frequency

- a product discharge conveyor to where patrons can hold out their drinks to receive the garnish

Atop the truck cab on a whimsical penny-farthing bicycle, a cyclist in period attire controls the system operating speed based on the rate of pedaling.

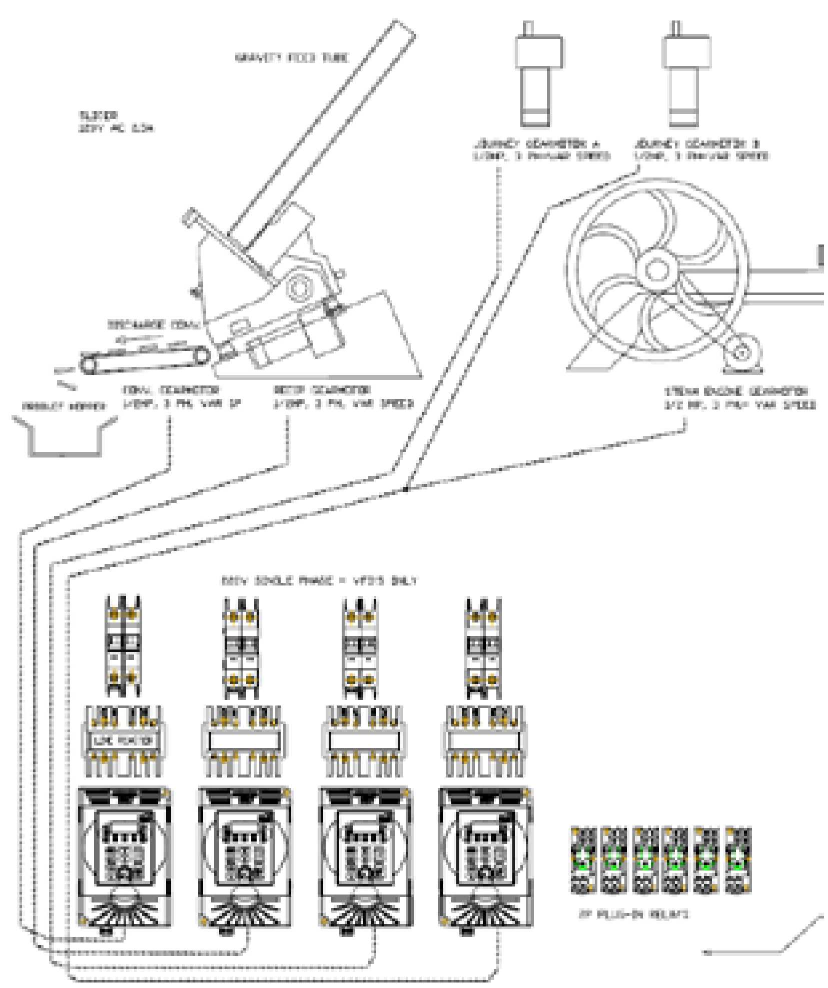


A proximity sensor is mounted on the front wheel of the penny-farthing, which sends a digital input signal to the PLC with each wheel revolution. Pedal rate is calculated by a PLC-programmed timing circuit, which is scaled and transmitted to the VFDs via the AO voltages.

The Magic Behind the Curtain

Though it is conceivable to create a purely mechanical steam-powered machine such as this, it would be incredibly impractical—the year is 2020, not 1820. If we pull back the literal curtain concealing the equipment making this spectacle possible, we find a complete electrical automation system driven and controlled by AutomationDirect components.

The conveyors, steam generator, and recip-rocator half-horsepower gearmotors are driven by four AutomationDirect GS2 230VAC VFDs with single-phase input and three-phase output. The VFD frequency is controlled by 0-10 volt analog outputs (AOs) from the AutomationDirect Do-more PLC rack. Each VFD's speed can be independently set in "manual mode" by entry on the AutomationDirect C-More 8-inch touchscreen HMI, or the system can be placed in "pedal mode", in which the AOs are synchronized to a speed determined by the bicycle pedal rate.



For cucumber slicing, technicians removed the meat tray from a commercial meat slicer, replacing

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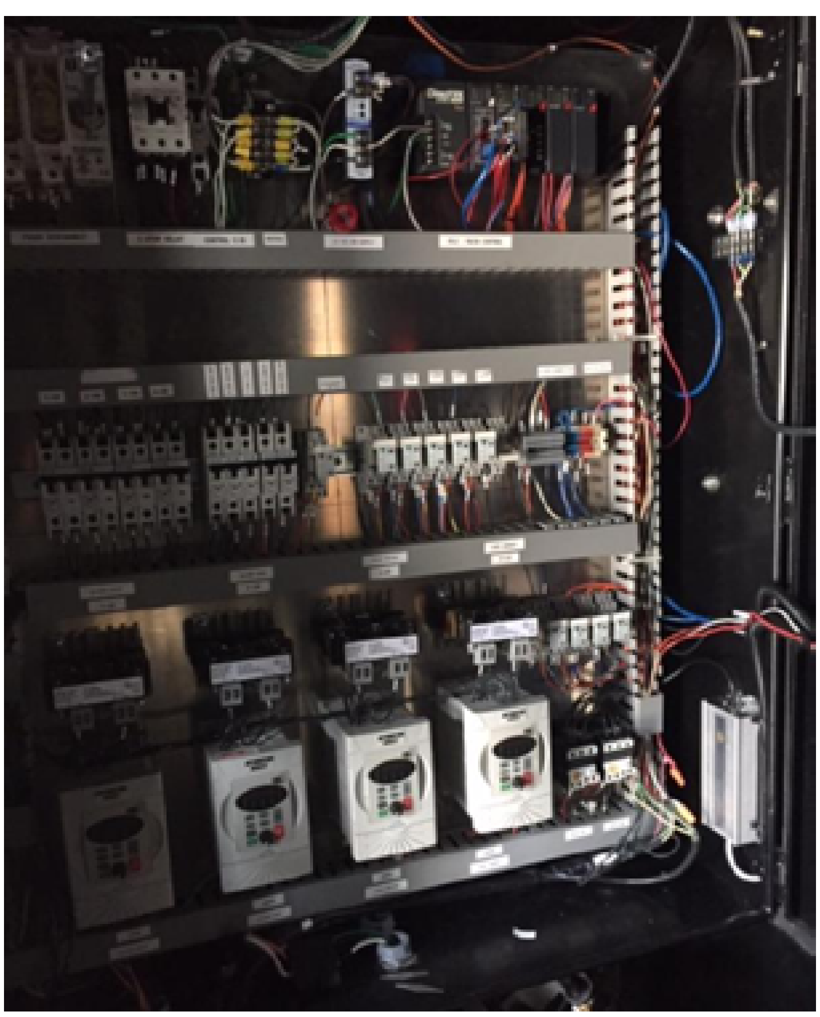
it with two vertical, plexiglass tubes through which cucumbers are manually loaded by an operator for gravity feed. As the 120-volt continuously-rotating slicer operates, the VFD-driven reciprocator mechanical arm drives the slicing carriage back-and-forth. Each stroke produces two, thin cucumber slices, dropping onto the product conveyor for delivery to the eager consumer. Unused slices fall into a stainless-steel bar container to later be used for garnishing if desired.

To power the system, a 230VAC feed is supplied by an onboard diesel generator or by external "shore" connection—the engineering team created provisions for using both U.S. and European utility industrial standards. Initially concerned with generator-induced current or voltage fluctuations causing VFD damage, the team worked with support staff at AutomationDirect to specify line reactors installed on the incoming side of the VFDs for protection.



With further assistance from AutomationDirect, the engineering team generated an automation system bill of materials calling for parts exclusively sourced by AutomationDirect: PLC, HMI, VFDs, motors, transformer, power supply, line reactors, relays, circuit breakers, terminal blocks, wiring and cables, and other panel components. During the Garnisher's three seasonal tours, there has not been a single automated equipment incident or failure.

Retro Garnisher, Modern Automation

Back in the grand duke's garden, you line up with your friends to receive the perfect, fresh garnish for your cocktail, marveling at the creativity that automation makes possible. Using AutomationDirect hardware and software, the engineering team at Salmon Studios creatively animated what has become a staple image of Hendrick's Gin.

From the project outset, the engineering group has been pleased with the simplicity of selecting, acquiring, installing, and programming the automation system components. Following three successful tours, the question is now, "what will we build next?" The Grand Garnisher is an inspiring piece, showcasing excellence in practical function and an extravagant aesthetic.

Figures, all courtesy of AutomationDirect, Salmon Studios, and Hendrick's Gin.

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Author Bio

Stuart Ostroff is a machine designer, builder, and installer. With nearly 50 years of industrial application experience, he has successfully completed projects in mechanized machining, automated assembly, paper converting, industrial baking, and cryogenic tank fabrication. He has employed PLC automation technology since its advent in the early 1980s. Once AutomationDirect products became available, he has depended on these almost exclusively due to their excellent quality, remarkable technical and sales support, and unbeatable prices.

CPAPs RE-INVENTed into Emergency Ventilators Using PLCs and HMIs

A team at Auburn University converts a CPAP machine to a high-functioning emergency ventilator, answering the call of a national ventilator shortage in the midst of the COVID-19 pandemic.

By Dr. Tom Burch, Auburn University

With the COVID-19 pandemic disrupting life as we know it throughout the world, health care facilities not only faced the grueling challenge of caring for an influx of virus-affected patients, but also contended with projected shortages of necessary life-saving supplies. The ventilator—a machine providing respiration for patients unable to breathe on their own—has one of the highest media profiles of potentially scarce medical devices.

In an attempt to curb supply shortages, various organizations called on developers to build "emergency ventilators" with varying specifications. One such call was issued by the U.S. Air Force for the design of an emergency ventilator—using available, commercial off-the-shelf (COTS) components to avoid interference with medical supply chains.

A team at Auburn University's Samuel Ginn College of Engineering responded with the RE-INVENT emergency ventilator, representing American innovation at its finest in a time of need. Several emergency ventilator creations have popped up recently, but some are unable to provide warm, moisturized air to help a patient breathe while utilizing proven hardware for the reliability required in life-critical applications. RE-INVENT does both, with an assist from AutomationDirect components.

Planting the Seed

The narrative began when engineer Ryan Hill at Integrated Solutions for Systems (IS4S) caught wind of the Air Force "Hack-a-Vent" challenge, calling for the use of COTS parts totaling $300 or less to build an emergency ventilator. As a former Auburn engineering student, Hill approached Dr. Zabala at the Samuel Ginn College of Engineering with the thought that IS4S could manufacture ventilators if provided a proper design. Zabala shared the information with Dr. Burch and Joe Reagan, and they began working on rudimentary concepts to fulfill the Hack-a-Vent requirements.

However, the team soon shifted away from their early ideas, as it did not seem possible to build a practical ventilator at the required components cost of $300. They were more interested in creating a device for reliable application alongside medical staff in the emergency room. Hack-a-Vent spurred development into motion, but the engineers ultimately abandoned some of the challenge's constraints in order to build a purposeful device able to provide life-support when called upon. Functionality and robustness became the primary design objectives, while keeping the price-point at a reasonable level.

Iterating Through the Generations – in Hyperspeed

A team member was already personally familiar with using continuous positive airway pressure (CPAP) machines, and figured a standalone CPAP could be used as a temporary breathing aid for COVID-19 patients in the absence of a ventilator. The two devices perform a similar primary function, with the ventilator adding pressure control for inhalation (inspiration) and exhalation (expiration). If the CPAP—available in larger quantities and at cheaper cost than a ventilator—could be modified to take over respiration for the affected patient, it could operate as a ventilator.

By itself, a medical-grade CPAP provides warm, moisturized air to the lungs, but the team needed a robust, reliable method to control air pressure to induce inspiration and expiration. They established a setup with two electrically-actuated valves for breathing control and an additional valve to blend additional oxygen with the air. Dr. Burch was able to acquire solenoid valves from maintenance personnel

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at the university for initial prototyping. For this first-generation, he enlisted the help of his son to create a simple integrated circuit to control the valve operation and timing cycling between inspiration and expiration phases (*Figure 1*).

With its promising results, the first-generation device gave the team confidence to continue design. Though effective for testing the initial concept, the integrated circuit was cumbersome to adjust, and the engineers needed to be able to modify the inspiration to expiration (I/E) ratio. To speed development efforts and enable rapid testing and adjustment, the developers introduced a programmable Arduino prototype board to replace the integrated circuit. This second-generation configuration gave the team the tools it needed to greatly refine the mechanical, electrical, and controls components of the system, but it still lacked the reliability necessary to function in a life-critical capacity.

Figure 1: For early-generation CPAP-based ventilator designs, the team prototyped with basic and readily available parts.

At this point in development, Dr. Burch enlisted the expertise of his friend Jim Chapman, an industry controls engineer. Chapman quickly specified the use of the AutomationDirect CLICK programmable logic controller (PLC) to replace the prototype board (*Figure 2*). This commercially available PLC would make it easy to program and modify the configuration, while delivering the reliability and robustness demanded by the application. This third-generation device formed the basic automation architecture for RE-INVENT.

With the further addition of an AutomationDirect C-More human-machine interface (HMI), users could better interact with the automation, so making adjustments to settings like the I/E ratio during testing became even simpler.

Development up to this point transpired of a matter of days, literally over a weekend. Such results represented a turbo-charged pace compared to the rate at which most machines—let alone medical devices—are developed.

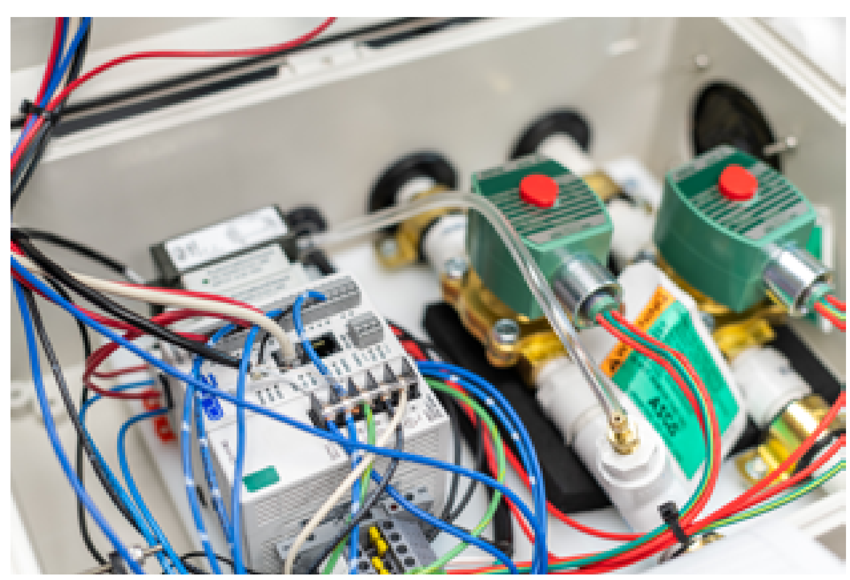

Figure 2: The readily available and economical AutomationDirect CLICK PLC made it easy to develop the ventilator, and delivered the reliability needed for such an application.

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Prototype Board vs PLC

There have been other recently-produced "emergency ventilators" using prototype controller boards like the Arduino, and it would be reasonable to wonder why the Auburn team replaced their Arduino with a PLC. Prototype boards are perfect for education and proof-of-concept: they are quick to procure, cost-effective, easy to program and modify, and ready for I/O out of the box. However, they are commonly mistaken to be suitable for all applications. For critical applications, however, the hardware and software simply do not offer the needed reliability.

PLCs, from a hardware standpoint, are built to withstand large variations in temperature, high-vibration, and other harsh environmental factors. As far as software goes, PLCs run real-time operating systems (RTOSs) that execute all logic and scan inputs and outputs hundreds of times per second. AutomationDirect CLICK PLCs provide cost-effectiveness and ease of configuration in addition to the robust hardware and RTOS qualities of PLCs.

Prototype boards, by comparison, are not manufactured to endure harsh environments. From a software-standpoint, they operate primarily as cyclic execution systems, requiring received or output commands to fully complete prior to moving to the next line of logic. While there may be workarounds to reduce the risk of these systems "hanging" in the event of an error, these factors make prototype boards unfit for use in critical systems.

Design Details

Auburn University's RE-INVENT integrates an unmodified CPAP machine with the following elements:

- Oxygen-blending valve
- Actuated valves
- Viral filter
- Hoses
- Pressure transmitter
- AutomationDirect CLICK PLC
- AutomationDirect C-More HMI

The team sourced many of the COTS automation components through AutomationDirect. Excluding the CPAP machine, each RE-INVENT unit utilizes about $950 worth of parts, coming in well over the Hack-a-Vent's constraint but still a very reasonable cost (*Figure 3*).

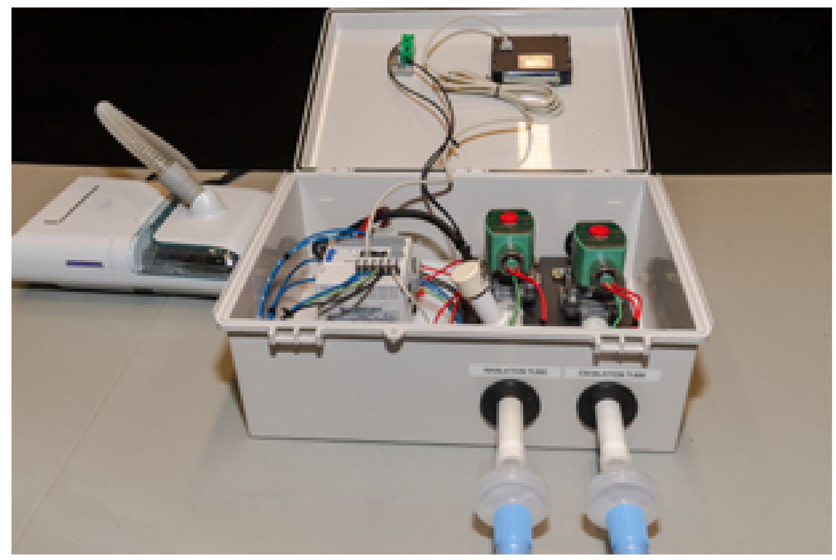

Figure 3: Excluding the CPAP machine itself, the RE-INVENT ventilator assembly is configured from less than $1,000 of commercial off-the-shelf parts.

When Chapman came on board, he quickly specified the AutomationDirect CLICK PLC and C-More HMI as the perfect candidates for RE-INVENT, citing their ease of use and reliability. For many years he had used CLICK PLCs under harsh environmental circumstances without failure, so had no hesitation recommending their use in a life-critical application. Additionally, their ready availability, quick procurement, and reasonable cost made it an easy choice for the application's PLC.

Chapman used the AutomationDirect free PLC software to program the control logic and the low-cost HMI software to configure the user interface. In Chapman's experience, the AutomationDirect products are also effective as a teaching tool because the new programmers can immediately begin creating ladder logic without user-interface distraction or an excess of prerequisites to configure.

In addition to the PLC and HMI, the Auburn team purchased power supplies, circuit breakers, zero-cross relays, terminal blocks, DIN rail, wire, and cables directly from AutomationDirect. AutomationDirect also provided world-class customer

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service and technical support, and worked with Auburn throughout the project to help ensure success on the automation and controls side of the application.

With a project lifecycle which included quality control, prototyping, planning, and development, the team created a system ready for use in the emergency room.

The operation of RE-INVENT is designed to be easily understood by medical staff familiar with CPAP machines and ventilators (*Figure 4*). The technician begins by turning on the CPAP and configuring all initial settings on the CPAP machine itself. On the separate box containing the added components, the technician enters the I/E ratio and breaths per minute rates on the touchscreen HMI. The system will alert medical personnel via an on-screen alarm in the event of high or low differential pressure between inspiration and expiration phases as sensed by the 4-20mA, 0-20" H2O pressure transmitter.

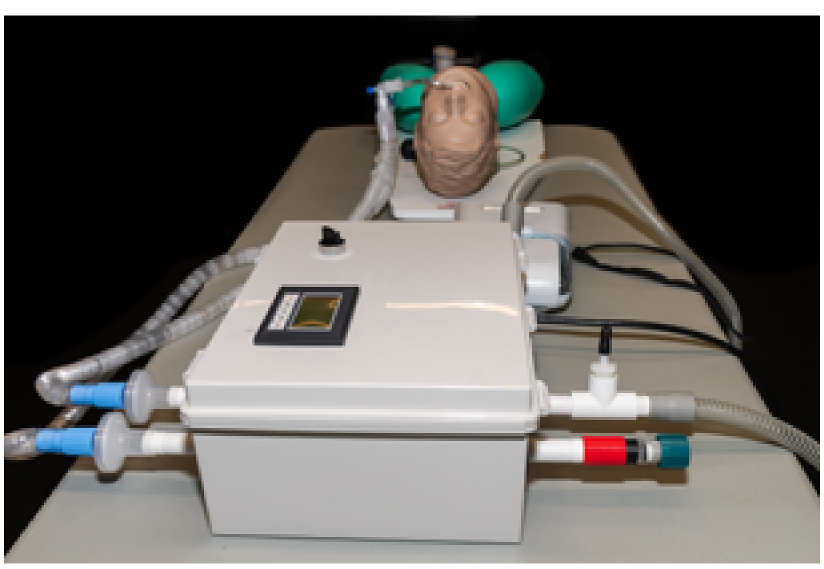

Figure 4: The RE-INVENT ventilator is designed for easy operation and configuration by medical staff.

What Lies Ahead

After rigorous testing and measurement with a simulated lung apparatus, it was time for the RE-INVENT's first real-life trial. The engineering team partnered with Auburn University's College of Veterinary Medicine to test the machine on a 200lb, anesthetized male Boer goat. With the CPAP set to a pressure of 20cm H2O, the test team varied the I/E ratio, breaths per minute, and oxygen supply levels. Veterinarians monitored the goat's arterial blood gases, which remained within normal reference ranges throughout the test. At the test's conclusion, the goat regained consciousness as expected and was verified to be healthy and fit.

At the time of writing, there is still some testing to be done in order to more accurately capture the maximum and minimum pressures during operation, which is a difficult task considering the low pressures and high breaths per minute rates. In the meantime, Auburn University has assembled 12 RE-INVENT machines, and IS4S has built an additional 89. The flagship machine will remain in the lab at the engineering college for further testing and software refinement—code updates are easily applied to field units as the PLC control logic is improved.

Auburn University estimates that hundreds, and perhaps a few thousand, of these devices can be assembled without a large strain on supply chains, although it would not be possible to obtain components for tens of thousands. Finding parts is not without its challenges, as it is difficult to find sufficient oxygen-rated valves in a short time-span. It is important to note, however, that production of RE-INVENT avoids interrupting the supply chains of classic ventilator components. In the meantime, hospitals have requested deliveries of the machine. Auburn University and IS4S are seeking appropriate approvals for deployment.

Ready to Answer the Call

Tough times put people to the test. The team at Auburn University's Samuel Ginn College of Engineering rapidly responded to the pandemic situation, putting their skills into action to help address a global need (*Figure 5*). Though the time to develop RE-INVENT was short, the undertaking demonstrates how resourcefulness and the use of commercially available components can play a key role in product development to successfully address a need.

For such a critical project—patient's lives depend on this machine—the importance of specifying robust, reliable components cannot be understated. AutomationDirect helped the team supply large quantities of reliable automation components in

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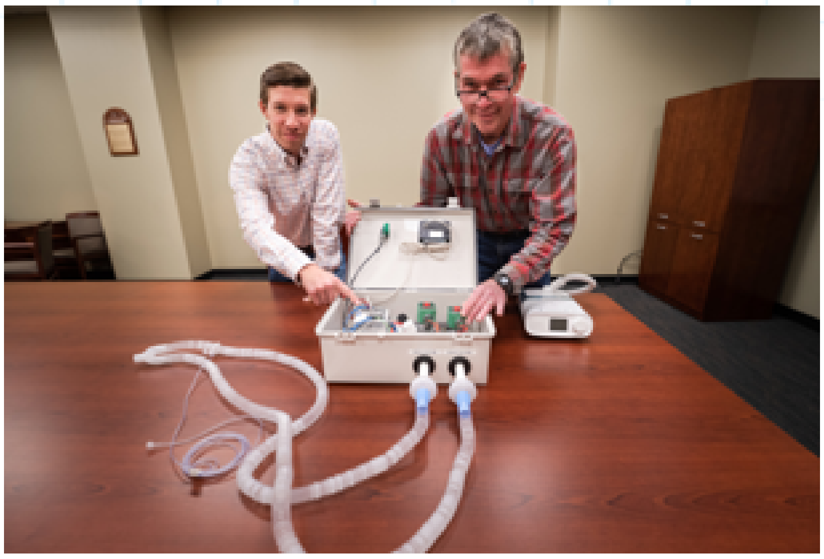


Figure 5: Dr. Michael Zabala (at left) and Dr. Thomas Burch (at right) demonstrate the RE-INVENT, which is built from commercial off-the-shelf parts to adapt a common CPAP machine into a ventilator.

a short span of time, delivering products ready for development right out-of-the-box. Should circumstances require it, RE-INVENT is ready to save lives.

Figures, courtesy of Auburn University

About the Author:

Dr. Tom Burch received his BSME and MSME degrees in Mechanical Engineering from Auburn University and after completion of his PhD from Louisiana State University he returned to Auburn and began his teaching career in 1992. He is currently a Senior Lecturer in the department of Mechanical Engineering. He has also been a principal in the Boiler Efficiency Institute (BEI) since 1990. His consulting work in energy conservation and usage has spanned four decades, three continents and eight countries. During this time he has delivered hundreds of workshops and seminars on energy related topics and consulted with numerous industries, institutions, and government agencies. He is a registered Professional Engineer in the state of Alabama.

Brain Teasers

By Chip McDaniel, AutomationDirect

1.) Pallet Puzzle

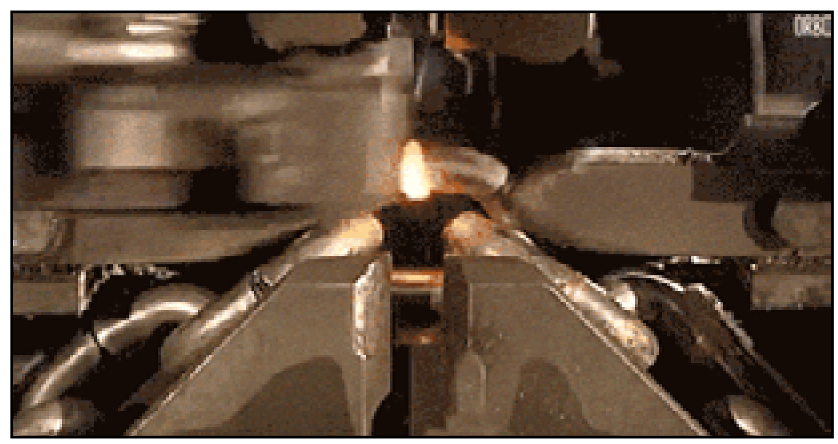
The puzzle factory cranked out 100 of their new giant floor puzzles and placed them on five pallets for shipping. The shipping clerk didn't have the count for the individual pallets – but was told that there were 52 puzzles on the first two pallets, 43 on the second and third combined, 34 on the third and fourth, and 30 on the fourth and fifth. *Can you help the clerk determine the quantity of puzzles on the individual pallets?*

Did you know our FREE 2-day delivery for orders over $49 even applies to palletized shipments? If you order heavy or large/bulky items – we may recommend (or even require) that the shipment be sent via LTL freight, but our logistics dept and freight carriers still strive to get the products to you within two business days. Restrictions apply (we don't guarantee our carrier's performance) - please see our business policies for all the details.

2.) Chain Gang

A chain factory has three chain making machines of varying capability. The first two machines can process a certain job in forty-five minutes. The first and third machines can process the same job in an hour, but the second and third machines require 90 minutes to complete that same amount of work. *If all three machines were to tackle the job at once, how long would they take to complete it?*

3.) Lone Welders



The same factory also has three chain welding machines. Machines A and B can weld a given length of chain in 10 minutes. Machines A and C can weld the same length of chain in 9 minutes and machines B and C can weld it in 8 minutes. *How long would it take each machine to weld that exact length by itself?*

Didjaknow? We offer weld-slag resistant sensors in both standard and Factor 1 sensing with a special coating to reduce buildup of weld slag. These DC-powered (10-36V) harsh-duty inductive proximity sensors detect the presence of ferrous and other metallic objects. They have rugged stainless steel or brass threaded-barrels with LED indicators, and are available with 3m pigtail cables or quick-disconnects.

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Brain Teaser Answers

1.) Pallet Puzzle

The counts for the first, third and fifth pallets can be found by subtracting the "other" two distinct pairs of counts from 100. For example – the third pallet count is 100 – (52 + 30) = 18. Once those three are known the 2nd and 3rd are easy to deduce. From 1-5 respectively: 27, 25,18, 16, & 14.

2.) Chain Gang

The first two machines can complete 1/45 of the job in a minute, the first and third complete 1/60 of the job in a minute, and the second and third only complete 1/90 of the job in one minute. Some algebraic substitutions reveal that the first machine can complete 5/360ths in one minute, the second 3/360ths, and the third 1/360th. Together they complete 9/360ths per minute – which completes the entire job in 40 minutes.

3.) Lone Welders

Very similar math to the above: the machines A & B complete 1/10 of the job in a minute, A&C complete 1/9 of the job in a minute and B&C complete 1/8 of the job in a minute. So A by itself completes 49/720ths in one minute, or 14.7 minutes for the whole job. Machine B completes 41/720ths in a minute, or 17.6 minutes for the job, and machine C completes 31/720ths per minute – or 23.2 minutes for the entire run of the chain.