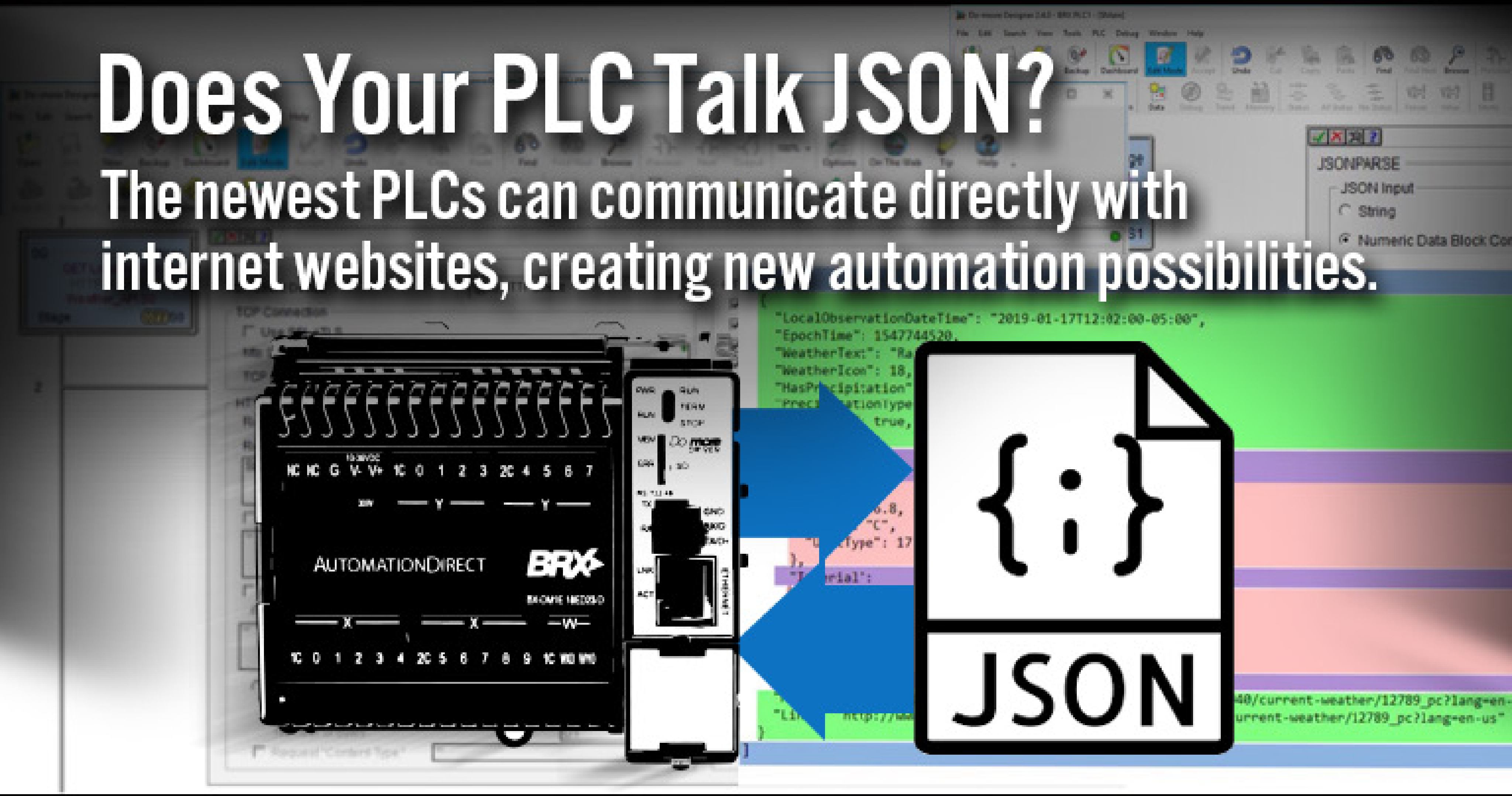
Automation NOTEBOOK®

Your guide to practical products, technologies and applications

Does Your PLC Talk JSON?

The newest PLCs can communicate directly with internet websites, creating new automation possibilities.



Industrial Automation with a Mission

Automation NOTEBOOK®

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.

The Boeing CST-100 Starliner spacecraft at the company's Commercial Crew and Cargo Processing Facility in Florida, undergoing inspection after its Orbital Flight Test. (Photo Credit: NASA/Frank Michaux)

It was dark, early morning, and as I drove my daily commute I suddenly became aware of a long white streak forming across the black sky. Is something on fire? Are we under attack? I immediately tuned to the local news station which was receiving numerous calls from concerned listeners. The news station reported that Boeing was testing their new Starliner astronaut delivery spacecraft. It had launched that morning from Cape Canaveral and was visible for a large part of the eastern coast. It's awesome how space travel is being revolutionized by companies like Boeing and SpaceX and pretty cool to get to see it, even if by accident. But it got me thinking about the many innovations that have changed our everyday lives. How many people have VCRs today or know the name Blockbuster? When's the last time you turned a key to start a new car? Who knows where the nearest pay phone is or has the change in their pocket to use it? I could go on and on and that's just the consumer world. Industrial automation has also changed quite a bit over the years with many advancements still to come. But no matter what new innovations develop in the industrial automation realm, you can trust AutomationDirect to make them affordable and accessible to everyone.

This issue of NOTEBOOK is loaded with informative content such as the Tech Thread, which takes a closer look at open-source controllers and the new ProductivityOpen CPU. We also have a great Cover Story on the benefits of connecting PLCs to the Internet. The User Solution shows how the CLICK PLC brought new life to an ageing roller coaster, and our Student Spotlight showcases the University of British Columbia (UBC) Student Rocket Team and their Productivity2000-based rocket design test stand. In the What's New section, you can see a roundup of our newest eBooks and video content, the New Product Focus details the new ProductivityOpen controller, cut-to-length cable additions, and thousands of newly added Hammond enclosures, and the Business Notes section discusses many of the happenings here at AutomationDirect. As always, the Break Room is stocked with fun brainteasers so see how many puzzles you can solve. Don't forget to check out our library site (**library.automationdirect.com**) for more amazing content and visit our store (**www.automationdirect.com**) to see all our current and new product offerings.

Headless C-more Remote HMI without attached display

Intended for the user who doesn't require a built-in HMI display, needs a larger display, or would rather strictly use the C-more mobile app, the C-more® EA9 series remote (headless) HMI unit provides all the functionality of an EA9 touch panel without the extra cost of a touchscreen interface. The headless unit supports an HD1280x720 pixel screen resolution with an HDMI output that supplies both video and audio out.

The EA9-RHMI has an 800MHz CPU and 82MB of project memory, includes (2) serial ports, USB 2.0 Type A and B ports, a built-in SD memory card slot and one Ethernet port. The Ethernet 10/100 Base-T port supports program download, remote Internet access, and communications to PLCs and PCs.

USB port A can be used to connect various USB devices to the panel such as a touchscreen, mouse, keyboard, flash drive and barcode scanner. The RHMI is compatible with EA9-PGMSW programming software.

Priced at $399.00, the DIN rail mountable C-more EA9-RHMI from AutomationDirect is 12-24 VDC powered, has a 0 to 50°C (32 to 122°F) operating temperature range, and is UL, cUL and CE approved. The C-more remote HMI mobile app is available to download from your preferred app store for only $4.99.

Go here to learn more about the Headless C-more Remote HMI without attached display

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

Continuous Flexing Profinet Cable

DataMax Extreme® Industrial Profinet cables are a two-pair shielded construction with 22AWG twisted pair conductors and 7/30 stranded tinned copper with color coded high-density polyethylene insulation.

Shielded constructions include both a tinned copper braid shield and aluminized polyester foil overall shield. The cable's outer jacket is pressure extruded Thermoplastic Elastomer (TPE) with excellent moisture, chemical, UV and weathering resistance, exceptional low temperature flexibility, and good flame and fire resistance.

DataMax Extreme Profinet cable supports Profinet conformance classes B and C, is UL Type PLTC rated, and designed for use in EtherNet/IP™ systems. The continuous flexing Profinet cable from AutomationDirect is available in cut-to-length 1-foot increments starting at $1.04 per foot (20-foot minimum) and has a 3-year warranty.

Go here to learn more about Continuous Flexing Profinet Control Cable

Productivity®Open Arduino Compatible Controller

The open-source Productivity®Open platform provides all the great features of a standard Arduino plus the added power and reliability of an industrial controller. The processor circuit of the P1AM-100 Arduino-compatible CPU is designed to mimic the Arduino MKRZero microcontroller. The P1AM-100 is compatible with most available Arduino MKR format shields, and/or the industrially-hardened ProductivityOpen shields, and can utilize most Arduino sketch programs found on open-source websites.

Using the readily-available Arduino integrated development environment (IDE), the P1AM-100 is programmed using C++ code; the ProductivityBlocks graphical programming interface uses a more visual approach that simplifies coding and reduces syntax errors.

The P1AM-100 CPU supports the full suite of Productivity1000 I/O expansion modules, including: discrete, analog, temperature, relay, high-speed input, pulse-width-modulation. The industrial-grade P1AM-100 Arduino-compatible CPU is $49.00.

Priced from $32.00, available ProductivityOpen UL-certified shields include the P1AM-ETH Ethernet shield and the P1AM-GPIO MKR-pins Extension Shield. The P1AM-PROTO is also available for creating customized shields in the MKR form factor.

The Arduino-compatible ProductivityOpen Controller from AutomationDirect is cULus listed, CE approved and backed by a two-year warranty.

Go here to learn more about the open-source Productivity®Open

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Hammond Industrial Enclosures

Hammond Manufacturing® enclosures, including disconnect, stainless, commercial, console and other enclosure styles, are now available along with our existing AttaBox®, Hubbell-Wiegmann® and Integra enclosure lines.

A wide variety of metal and non-metal enclosures, rated NEMA 1, 3, 3R, 3S, 4, 4X, 6, 6P, 12 or 13, are available in wall-mount, floor-mount and freestanding form factors. NEMA 1 enclosure units are an economical choice for basic protection. NEMA 12, NEMA 4/12, NEMA 4 and NEMA 4X enclosures are gasketed to add a significant amount of protection for indoor or outdoor use.

Enclosure types and styles include wall-mount enclosures, junction boxes, pushbutton enclosures, floor-mount and freestanding enclosures, disconnect enclosures, consoles and consolets, and wireways. Many door and window configurations and latch/lock options are available.

Enclosure prices start as low as $8.50. Hammond enclosures drop-ship directly from Cheektowaga, New York.

Go here to learn more about Hammond Industrial Enclosures

Productivity®Open - Maker In, Industrial Out

By Bill Dehner, Technical Marketer, AutomationDirect

One of the most talked about new trends in industrial automation is the use of single-board microcontrollers. These controllers, along with their open-sourced programs, have begun to show up in industrial applications. Many up-and-comers, introduced to this type of control early on, are fueling this trend but if you come from the established PLC world, you may be wondering what the buzz is all about.

The term "open source" is used to describe a program or software created by one developer that is available to be used and/or modified in any way by other developers and users without licensing fees, royalties due, or restrictions on the use of the source code. This is sometimes referred to as "copyleft" as opposed to "copyright". Open source has evolved to also include hardware, shared schematics and PCB production files that are often readily available to anyone. This type of shared development has spawned an enormous "Maker" community. Numerous Maker sites can be found online with a vast collection of simple, helpful and most of all reusable, DIY projects.

The microcontrollers used to run these DIY programs are inexpensive, small and typically consist of a single integrated circuit containing a processor, memory and I/O. A brand of single-board microcontrollers that has become one of the most well-known is the Arduino.

What is Arduino?

Arduino products were originally created for students without backgrounds in electronics or computer programming. Arduino consists of a family of single programmable circuit boards (Figure 1) and the IDE (Integrated Development Environment) that uses a streamlined version of C++ to write and upload code to the boards.

Many pre-configured circuit boards, called "shields", are available to expand the functionality

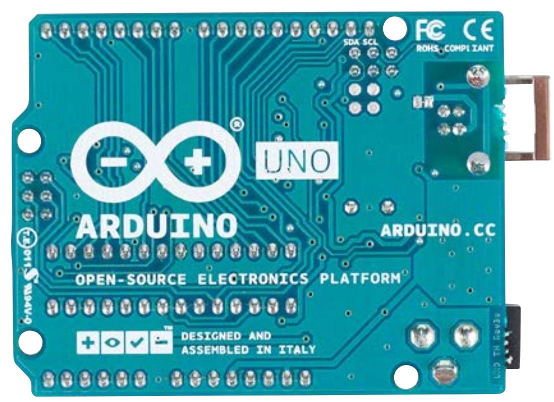

Figure 1: Consumer-grade Arduino Uno microcontroller

of the Arduino controller (Figure 2). These shields can provide Ethernet, WiFi, GPS, LCD displays, and motor controls, among others, by simply "stacking" or connecting the shields to the Arduino controller board.

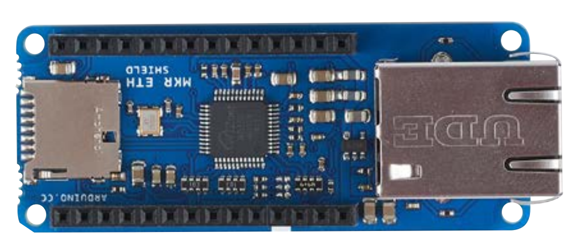

Figure 2: Ethernet shield – provides Ethernet communication for Arduino microcontrollers

Open-source communities

Sharing of ideas and finding innovative ways to solve complex problems is facilitated by open-source communities and the websites dedicated to them. Sites like MakerPro and GitHub allow hobbyists and professionals to work together to create interesting solutions for difficult or everyday problems. Thousands of programs can be found on these sites to be used freely in new applications however the user chooses. This open-source concept is favored heavily by hobbyists and students, but recently the

continued >>

industrial controls industry has also taken notice, partially due to this open concept but especially due to the extremely attractive price tag of single-board controllers.

Reducing the risk of open source

Industrial applications using "off-the-shelf" Arduinos are being deployed now, but there is a risk with installing these single-board controllers in industrial environments. Many of these controllers are not field tested and in most instances are just downtime waiting to happen. Vibration, noise, and temperature fluctuations can have a negative effect on consumer-grade microcontrollers, causing unexpected equipment failures and costly production shutdowns.

The need for an open-source controller that can hold up in the most extreme conditions is what prompted AutomationDirect, in conjunction with FACTS Engineering, to produce the ProductivityOpen controller. The $49, UL and CE certified P1AM-100 CPU combines the best of both worlds - Maker ingenuity coupled with the Productivity controller family's proven reliability.

What's inside?

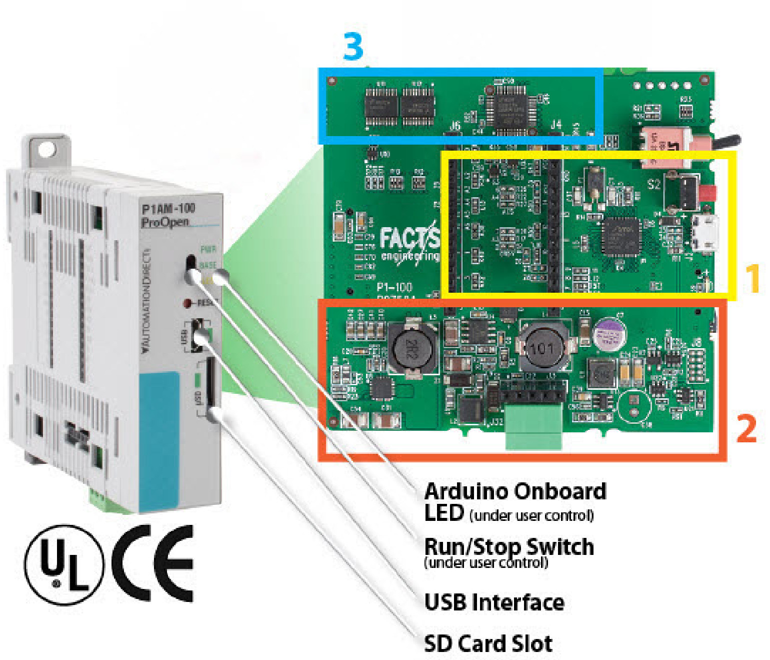

Figure 3: ProductivityOpen industrial-rated, open-source CPU

1. Arduino within - The processor circuit of the P1AM-100 is designed to mimic the Arduino MKRZero microcontroller. By doing this, the P1AM-100 is able to recognize most available Arduino MKR format shields, and/or all of the industrially-hardened Productivity shields and can utilize most Arduino sketch programs found on open-source websites. Using the same IDE, the P1AM-100 is programmed using C++ code, or you can use the ProductivityBlocks graphical programming interface to quickly code the controller to operate your application.
2. Industrial power supply stage - The robust power supply filtering stage produces a regulated 5VDC output from a 24VDC input, isolating the CPU and I/O power. To generate the 24VDC input, use any of the field-proven Productivity1000 industrial power supplies or supply your own using the terminal block connection.
3. Productivity1000 industrial I/O interface - The I/O interface chipset supports the full suite of Productivity1000 I/O expansion modules, including:

- Discrete
- Analog
- Temperature
- Relay
- High-speed Input
- PWM

Things to consider when choosing between a PLC and Maker controller

Let's be honest, a $49 CPU is definitely something worthy of a closer look. But for those coming from a strictly PLC background there are some things to be aware of. Besides the obvious difference of programming methods (C++ vs. Ladder Logic) there are some other functional differences that also need to be addressed and we've included them in Table 1 on the next page.

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Industrial Controller Comparison	P1AM-100 (Arduino-compatible CPU)	P1-540 (PLC CPU)
Programming language	• C/C++ • ProductivityBlocks • Other Community	Ladder Logic
Development environment	• Arduino IDE • Other Community - Blank slate no native functions like PID	Productivity Suite - Built-in instructions like PID, communication drivers and support functions
Form factor	Productivity1000	Productivity1000
Right-side expansion (I/O modules)	Productivity1000	Productivity1000
Left-side expansion (shields)	• P1AM Family • Arduino MKR form factor shields	N/A
Interfaces	• USB Programming • Arduino MKR expansion bus	• USB Programming • RS232/485 • Ethernet
CPU toggle switch	User controlled	Run/Stop system controlled
User LED	User controlled	System controlled
Memory: project memory	256kB flash	50,000kB
Memory: data retentive	N/A	500kB
Memory: removable media	µSD	µSD
3rd party expansion	Yes, using Arduino MKR expansion bus	N/A
Project stored on CPU	No, only binary executable file is stored on CPU; executable file cannot be retrieved from CPU	Yes, optionally
I/O update control	Typically immediately within program instructions	Typically at beginning/end of scan loop
GUI FW updates	Controlled by Arduino.cc	Ugraded by user
Board and library updates	Auto update based on user settings	Manual SW/FW updates from AutomationDirect.com
IDE updates	Arduino IDE from Arduino.cc and others	Productivity Suite Software from AutomationDirect.com
Community sharing	Open source; community driven sharing of programs and support	N/A
Online/runtime edits	N/A	Yes
Auto-configured I/O	N/A	Yes

Table 1: P1AM-100 ProductivityOpen controller vs P1-540 Productivity1000 PLC

Those of you who are very familiar with open-source controllers, like the Arduino, may be wondering what an industrial controller could provide. Besides the ruggedness and survivability, there are many other benefits as well, some of which are covered in the Table 2 on the next page.

continued >>

Arduino/Industrial Controller Comparison	Arduino (MKR ZERO)	P1AM-100 (Arduino-compatible CPU)	P1-540/550 (PLC CPU)
Power Supply	5VDC	• 24VDC AUX-in • DC power supply (P1-01DC) • AC power supplies (P1-01AC, P1-02AC)	
Agency Approvals	CE	UL / CE	
Analog and Digital I/O	3.3VDC tolerant MKR	• 3.3VDC tolerant MKR • Productivity1000 I/O • P1AM-GPIO (3.3VDC)	Productivity1000 I/O
Analog Input Resolution	8,10,12 bit MKR	• 8,10,12 bit MKR • Productivity1000 analog inputs	Productivity1000 analog inputs
Analog Output Resolution	10 bit MKR	• 10 bit MKR • Productivity1000 analog outputs	Productivity1000 analog outputs
Interrupts	Yes MKR		No
Serial Communication	• MKR UART 3.3VDC tolerant • 3rd Party Shields RS232/485		RS232 and RS485 onboard
Ethernet	MKR shield	• MKR shield • P1AM-ETH shield	• (1) on P1-540 • (2) on P1-550
I/O Direction Control (GPIO)	Yes MKR	• Yes MKR • P1AM-GPIO shield	No
Mounting Options	Breadboard	• DIN rail • Screw mount	
Watchdog	Internal	Internal and secondary onboard	
IDE Debugging Tools	Serial monitor / plotter		• Data View • Monitor View • Debugger • Graphing

MKR: Arduino MKR expansion bus

Productivity1000 I/O: A full line of I/O modules including 12-24 VDC inputs, 3.3-24 VDC and 6-120 VAC outputs, and relay outputs

Productivity1000 analog: A full line of A/D, D/A, and temperature input modules, in 12, 13 and 16 bit resolutions

Table 2: "Off-the-shelf" Arduino controller vs ProductivityOpen and Productivity1000

continued >>

Ideal for the Industrial Maker

The P1AM-100 CPU is designed to reliably take open-source control into the industrial realm. Along with the CPU is a collection of industrial shields that can add needed functionality to the controller. Options including Ethernet can easily be added to the left side of the CPU. Readily-available Arduino shields can also be added to that side if needed. On the right side of the CPU, you can expand the system with low-cost Productivity1000 discrete, analog and specialty I/O modules. Up to 240 discrete I/O points are possible on the right-side, with virtually unlimited I/O on the left.

It's your choice to select any configuration that meets your needs:

1. 100% Industrial

Figure 4: ProductivityOpen controller using all industrial-grade hardware

Ensure that all aspects of your open-source controller are protected from harsh environments with industrially-rated power supplies, shields, CPU and I/O modules.

2. Double duty

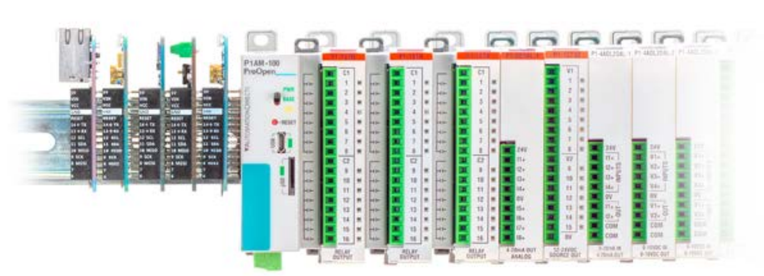

Figure 5: ProductivityOpen controller using Arduino shields with industrial-grade I/O

Got a specific Arduino shield you want to use in your process? No problem, simply attach any compatible Arduino shield(s)* to the left side of the CPU and use Productivity1000 industrially-hardened I/O modules to give your controller added protection from field equipment.

3. Mix and Match

Figure 6: ProductivityOpen controller using Arduino shields along with industrial-grade shields and I/O

You can mix and match any combination of compatible open Arduino shields* and industrially-rated ProductivityOpen shields to achieve the control you're looking for.

4. DIY all the way

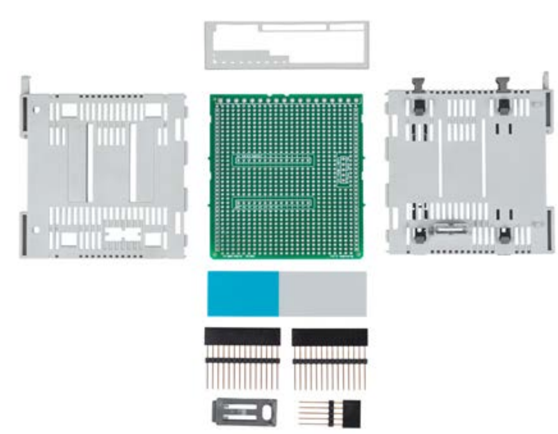

Figure 7: ProductivityOpen Proto board

Build custom electronic circuits and interfaces for your control system with our proto board. The P1AM-PROTO is a generic perf board with 100mil thru-holes for your own prototype designs.

**Use discretion, since many of the consumer-grade Arduino shields are not suitable for industrial applications.*

continued >>

Figure 8: ProductivityBlocks graphical interface

C++ made easier with ProductivityBlocks

For the PLC crew, ladder logic is still a very popular programming method. But due to low-cost microcontrollers like the Arduino, other programming methods, including C++, are making big inroads into industrial automation.

If you are a novice with C++ programming, the ProductivityBlocks interface can help you correctly code your controller. Based on the ArduBlock concept, ProductivityBlocks is a graphical programming interface and add-on to the Arduino IDE. Those familiar with C++ know how tedious it can be hunting down syntax errors like a missing semicolon or bracket. ProductivityBlocks helps build your sketch program by allowing you to drag and drop interlocking program blocks from which the associated C++ code is generated for you.

ProductivityBlocks works with either MAC or PC systems and the custom blocks use terminology common to industrial controller functions so their purpose is easily understood. Many are customized for Productivity1000 I/O modules, ProductivityOpen CPU and shields, creating an easier interface for coding that will save you time and debugging headaches.

AutomationDirect Community Forum

AutomationDirect's technical/community forum at www.go2adc.com/P1AM is the place to go for help with your P1AM-100 project. There you will find:

- Links to GitHub repositories - Library, Board Support and Mechanical
- Arduino IDE install link
- ProductivityBlocks interface download
- Links to numerous helpful videos
- Most of all, ideas and advice from over 29,000 industry professionals with various backgrounds and expertise

You can even find sketch programs, like the one shown on the next page, created by AutomationDirect to help you with your implementation.

If you need product information like specifications, agency approvals, inserts, manuals, or 3D CAD files, head on over to www.automationdirect.com where you'll also find convenient starter kits for anyone looking to get started right away.

P1AM-START1 - A kit for the devoted Maker.
Includes:
(1) P1AM-100 CPU
(1) P1AM-ETH Ethernet shield
(1) P1AM-GPIO MKR-pins Extension Shield
(1) P1-4ADL2DAL-1 analog combo module
(1) PSL-24-030 power supply
(1) USB-CBL-AMICB6 programming cable
(1) 3-wire power cable
(1) P2-RTB terminal block
(1) P1-10RTB terminal block

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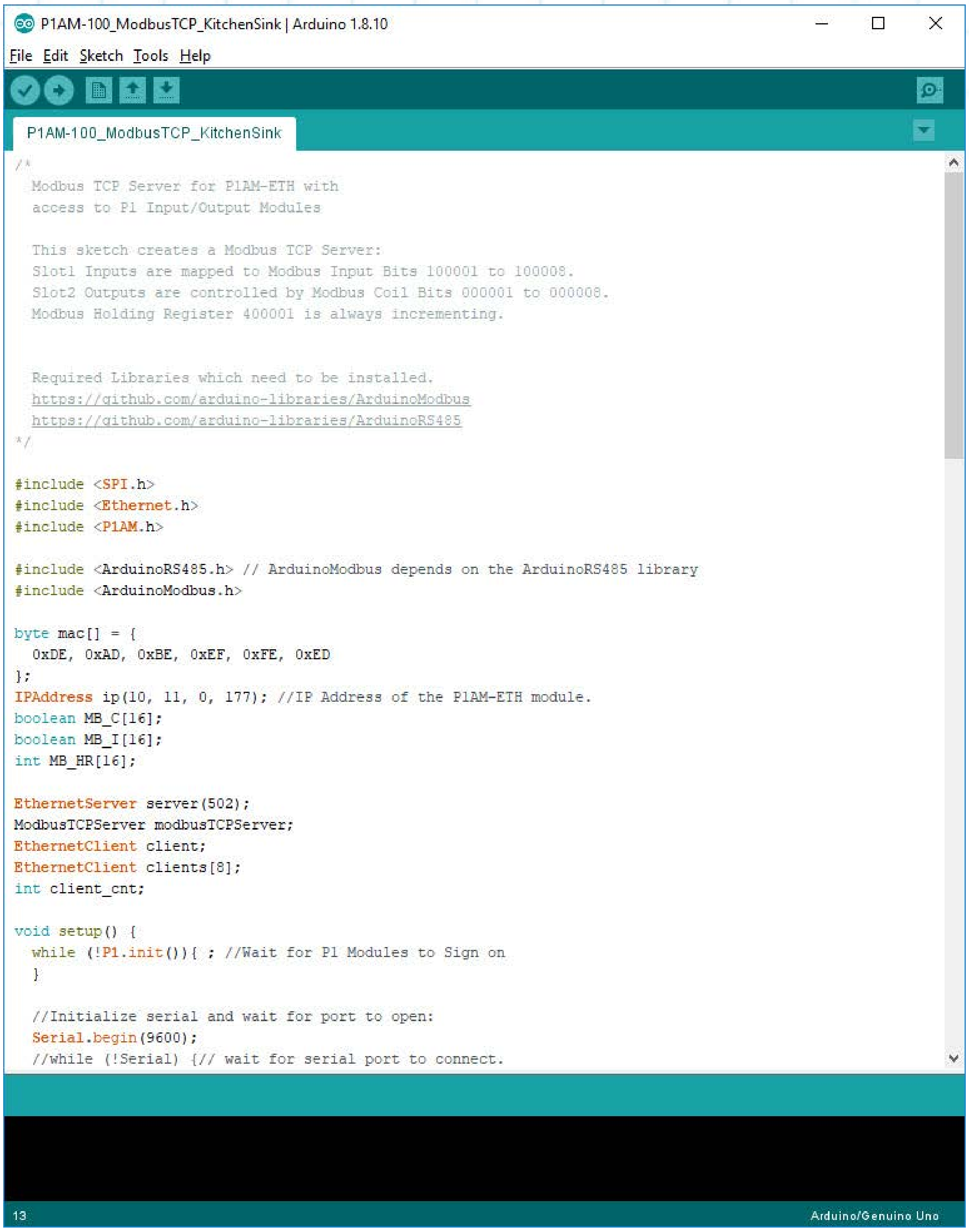

Figure 9: Modbus Communication Sketch – Modbus TCP Server for P1AM-ETH with access to P1 Input/Output Modules.

Figure 10: P1AM-START1 Starter Kit

The P1AM-START2 - A kit for the PLC'er wanting to learn Arduino. Includes:
(1) P1AM-100 CPU
(1) P1-08TRS relay output module
(1) P1-08SIM simulator input module
(1) P1-01AC power supply
(1) USB-CBL-AMICB6 programming cable
(1) 3-wire power cable
(1) P2-RTB terminal block

In modern-day industry, it's believed that up to 20% of plant operating expense is maintenance related. Although a consumer-grade microcontroller's initial cost is very attractive, in an industrial environment it can quickly become a drain on your operating budget. The ProductivityOpen controller can help you avoid unwanted maintenance issues by providing the open-source control you want with the industrial-rated hardware you need.

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AutomationDirect Employees Enjoy Helping Students in Internship Program

A key AutomationDirect value is to be a responsible, involved citizen of the communities where team members live and work. That's one of the reasons the company has served for the past two years as an employer for Internship Forsyth which gives students the opportunity to learn real-world skills by working at local companies.

Mentor and AutomationDirect employee Tim Wheeler (left) and intern Nolan McGinley

The program, formerly called Work Based Learning, pairs Forsyth County high school students with structured work experiences that connect their career goals and pathways with a productive work environment. When the students enter ninth grade, they choose a career pathway that gives them some advanced knowledge of their field of interest, including marketing, healthcare, criminal justice and engineering. They are matched with an employer for an internship in the field of their choice. This experience gives them a chance to translate what they learn in school into an actual worksite, enabling a smooth transition into the workforce and/or education beyond high school.

Company is Prized Work Location

In addition to giving back to the local community, another reason AutomationDirect participates in the program is that employees love sharing their knowledge and skills with students – and it shows!

"AutomationDirect is a prized work location for interns as the employees provide great work experience, communication and feedback to the students," said Debra Moore, Career Development Coordinator with Internship Forsyth."

Interns Work in Marketing and Engineering

AutomationDirect has two interns from the program working at the company right now in marketing and engineering. The students get to put what they learn in their career classes to practice in a real-world setting.

For two years, Rick Folea, Senior Technical Marketer-Training Coordinator has been coordinating the internship program for AutomationDirect. He commented: "Work based learning students are a total win-win for everybody. These are highly motivated students that we have come to rely on to help us be more productive. We get more work done without hiring an extra employee and they get priceless real-world work experience (and extra cash!). We have even heard stories from colleges about how blown away they were by how much these 'high-school' kids knew because of the work experience they got at AutomationDirect.com!"

Tim Wheeler, Senior Technical Marketer-Training Coordinator, also works with the interns. He said "Supplementing 'Work-Based Learning' students into our workforce is a resounding success for our company. They bring a positive energy that really bolsters the entire team. With their help we are able to get the job done without extra head count, while helping the next generation spring into the labor force."

continued >>

Students Apply Learning to Future Careers

County wide, there are 450 students in Internship Forsyth. Approximately half of them go into a college major related to the field in which they did their internship. However, what is just as important is that the program also gives students the chance to rule out career pathways.

"By the end of the internship, they either love that path or want to change careers," Internship Forsyth's Moore said. "That's important, because changing majors in college can be expensive."

Former program participants have seen great success. One student who completed the program opened his own law firm in Florida, while others work in marketing at Coca-Cola and Victoria's Secret.

"My internship experience at AutomationDirect has been nothing but amazing for me," said Marketing Intern Nolan McGinley. "Having the ability to work for one of the best companies in Metro Atlanta has brought an infinite amount of possibilities to me. I am learning real-world skills that can translate over to future jobs I have as well. Because of Internship Forsyth, I have put myself in a great place to excel in the future business world with the tools I am acquiring at AutomationDirect. "

Nine Years Strong | First Team Honoree

FIRST TEAM LEADERSHIP IN AUTOMATION 2020 Presented by AutomationWorld

For the ninth year in a row, Automation World readers have voted for their "First Team" suppliers in PMMI Media Group's 2020 Leadership in Automation program. This year, AutomationDirect made "First Team" in the following categories:

- HMI Hardware
- HMI Software
- PLCs/PACs

First Team Honoree

Automation World, a leading business magazine serving automation professionals, asks their subscribers to vote for their favorite automation vendors in unaided-recall surveys. Kurt Belisle, Publisher of Automation World, says "We're pleased to recognize the First Team Honorees who offer both excellent customer service and best-in-class product innovation." Over two dozen categories are featured, representing the wide variety of automation technologies, software and products in use by today's manufacturing professionals across the discrete, batch and continuous process manufacturing industries.

Bill Dehner, Technical Marketer for AutomationDirect says, "It's great to know that customers are not only finding our products but that they are extremely pleased with their quality and capabilities. To be a preferred supplier for any product is a big deal but when the products are highly technical and take years of development, like PLCs and HMIs, the recognition is extra rewarding. We couldn't be happier and thanks to all who took the time to vote for us."

Stay tuned for more great product innovations from AutomationDirect in 2020 and beyond.

ADC + Community Outreach + STEM = Student Success

In 1992 twenty-eight ***FIRST***™ Robotics teams met in a high school gym for the inaugural ***FIRST***™ competition event. Now almost three decades

continued >>

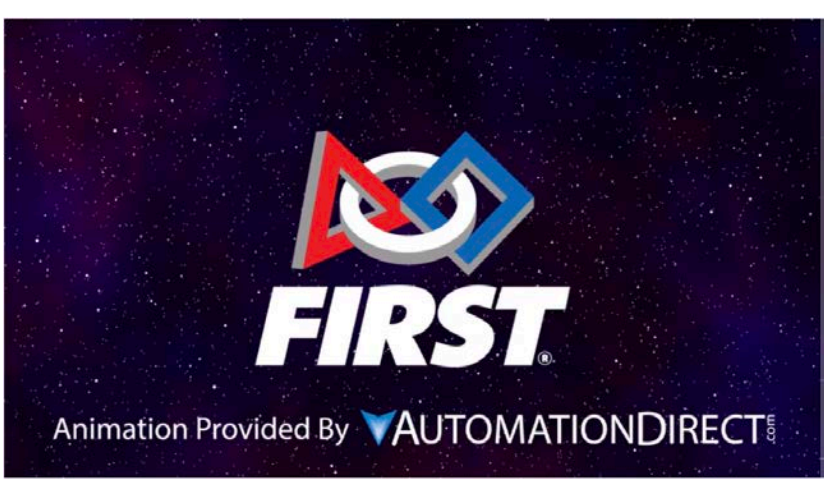
later it is the largest robotic competition of its kind in the world.

AutomationDirect loves supporting ***FIRST***™ because of the incredible impact it has in getting young minds engaged in learning skills they can use to build a bright future for themselves.

Each year ***FIRST***™ announces a new challenge. The high school students then have six weeks to create a 120-pound robot that can effectively accomplish that challenge which looks a lot like a 3v3 sporting event. Six robots at a time on a playing field about the size of a basketball court. The challenge might be shooting balls into a goal, overcoming obstacles, hanging, balancing, etc.

Game Animation

The entire world waits with great anticipation each year for the announcement of the new challenge the first week in January and it is AutomationDirect that produces the animation of the game that everyone is waiting to see!



https://www.youtube.com/watch?v=gmiYWTmFRVE)

The annual game animation is a huge task that takes several months to complete and over 2000 hours of computer time to render the final animation.

This year's competition is inspired by Star Wars Force for Change which is a Star Wars-themed charity program run by Lucas Film and the Walt Disney Company that collects donations to fund solutions for world problems.

https://www.youtube.com/watch?v=bPY9Mfj7eRU)

Virtual Reality Simulation of the Competition Field

The *FIRST*™ Robotics competition has grown from that original 28 teams into a worldwide phenomenon with around 4000 competition teams. That's great, but it poses a new problem. In the early days ***FIRST***™ would setup example competition fields around the country for teams to examine. It's incredibly important for teams to be able to walk around the field and get a feel for the challenges before they start designing their robots. But today, with 140 official kickoff locations (and a bunch of unofficial locations) around the world it has become impossible to create that many example fields for teams to experience.

AutomationDirect to the rescue! In addition to producing the annual game animation, AutomationDirect also produces a Virtual Reality simulation of the competition field so any team anywhere in the world can put on a VR headset and literally walk around the field and interact with the various obstacles. They can also stand in their respective driver stations to see what the field looks like when they are running a competition. This is a fantastic use for Virtual Reality and is the wave of the future.

Go here to learn more about the virtual reality

continued >>

A view of the Virtual field produced by AutomationDirect

simulation and download the free app to try on your headset. https://library.automationdirect.com/vr-simulation-of-the-2020-first-robotics-infinite-recharge-game-field/

3D Printable Field

Sometimes it's helpful to be able to touch the field elements and see a 'real' version of the field. To help teams better understand the challenge, AutomationDirect also produces a 3D printable 20:1 scale model of the field. In addition to learning about the challenge, teams also take this with them when doing community outreach, so folks can see what the game looks like; they use it to educate their parents and school system and use it for developing game strategy with other teams.

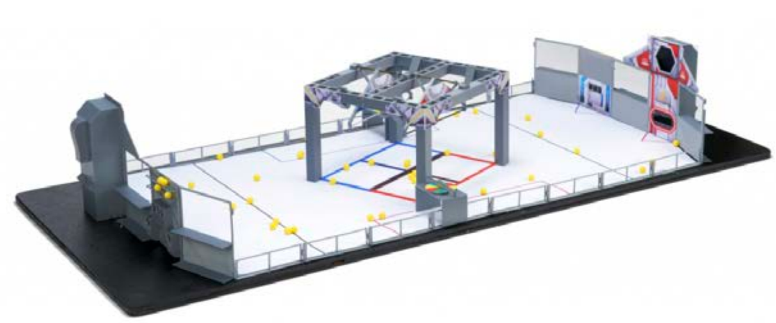


Image of the 20:1 scale model of the field - completely 3D printed!

A young student getting engaged in the 2018 ***FIRST***™ Robotics game "Power Up!"

Championship Support

The ***FIRST***™ Robotics Season culminates at the Championships in April where the best teams from all over the world come to compete for the title. Of course, AutomationDirect is there working in the Robot Service Center helping teams fix there robots and showing them new products they can use to build even better robots!

Offseason Support

After the Championships, teams can finally relax and start dreaming of what next season's challenge has in store for them. In the Fall, most regions have Offseason Events where teams can come compete one more time using the prior year's challenge. This is a great way to get new students excited about the program and get them involved. Of course, AutomationDirect is there to support our local Georgia FIRST teams! But in addition to supporting the event, AutomationDirect designs and builds the trophies each year for the offseason even using AutomationDirect parts.

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These automated trophies from the 2017 "Steamworks" season are unique and serve as the big prize that all the teams want to win!

Another Season

Another season is upon us. We encourage you to get involved in this amazing program. If you have kids in any level of grade school ***FIRST***™ has a program that will get them engaged in learning starting in elementary school with Lego Robots. Or you just want to volunteer it's a great way to give back to the community and get young minds excited about learning - no experience required! Learn more about FIRST here: **www.FirstInspires.com**.

Meanwhile, you can find AutomationDirect at any of the following 2020 events – please stop by and say "Hi!" Event details are posted at **www.gafirst.org**.

2020 FIRST Robotics Events Supported By AutomationDirect.com

Feb 29-30	Gainesville GA
March 6-7	Dalton GA
March 13-14	Columbus GA
March 21-22	Carrollton GA
March 27-29	Albany GA
April 2-4	Macon GA - State Championships!
April 16-18	Houston TX – Championships Part I
April 30-2	Detroit MI – Championships – Part II

Does Your PLC Talk JSON?

The newest PLCs can communicate directly with internet websites, creating new automation possibilities.

The July 2019 issue of Control Engineering magazine featured a cover story describing how modern industrial controllers are now able to interact directly with internet resources. Titled **Benefits of Connecting a PLC to the Internet**, this article shows how users can enhance their automation systems to obtain live data directly from the internet. The following sections are adapted from that story.
By Eric Witcher, AutomationDirect

Programmable logic controllers (PLCs) have long been the preferred technology for reliably and quickly executing the control logic necessary for performing industrial automation. PLCs originally worked just with their local hardwired input/output (I/O) connections, and eventually gained networking capabilities so they could communicate with human-machine interfaces (HMIs) or other smart devices.

But even more is possible. End users are familiar with the wealth of information available from various websites, viewable using browsers or dedicated apps. What if there was a way for PLCs to connect to the internet and obtain this type of helpful data? The latest generation of AutomationDirect Do-more PLCs (BRX PLCs) includes the PLC instructions and features to accomplish this task.

For example, irrigation, cooling tower, and HVAC applications could use the current and forecasted precipitation, humidity, and temperature conditions found online to fine-tune operation without needing operator interaction. A solar installation could determine the suns azimuth and altitude for any known location and time. Information obtained from the internet may not be necessary for live control but could help operators in other ways, such as an HMI displaying live commodity prices.

Many useful websites already provide a programmatic way for users to obtain raw data. This is called an application programming interface (API). PLCs with the right instructions can be configured to communicate with these kinds of internet resources using the API definition. The following PLC tools make this possible:

- Instructions for accessing hypertext transfer protocol (HTTP)
- Instructions for handling and parsing JavaScript object notation (JSON)

Using these instructions, PLCs can initiate HTTP communications with various websites and receive JSON data from them. The received JSON data must then be parsed to extract the desired information.

Browser Basics

Most people have used a web browser to navigate the internet. They are familiar with typing a website name into the browser address bar, sometimes preceded by “http://” (or “https://” for a secure site). A website address is formally known as uniform resource locator (URL), and this points to a specific domain and webpage. The HTTP protocol defines how applications can communicate over the world wide web (www). Specifically, HTTP describes how messages are formatted, transmitted, and handled.

When a user types a URL into a browser, an HTTP request is generated to the target web server, and the corresponding HTTP response is used to populate the browser display. Both HTTP requests and responses are lightweight text files, which are easy for software to create and parse.

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PLCs can interact with the internet in a similar manner, but with a few key differences.

APIs in Action

While many websites offer all sorts of API definitions, the PLC community is probably most interested in those websites offering hard data useful for automated machines, equipment, and systems. To obtain this type of information, a PLC needs outbound internet access so it can connect to the desired websites.

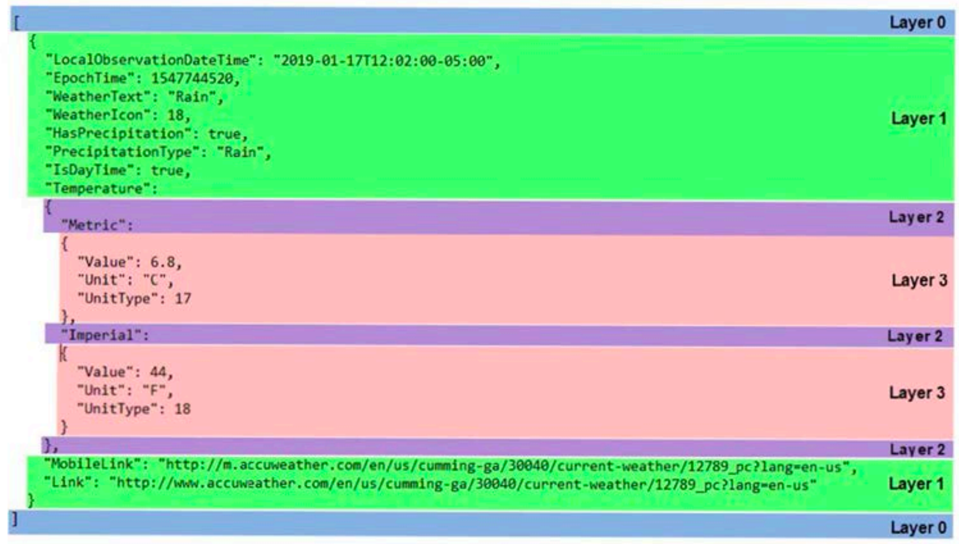

Figure 2: This color-highlighted JSON sample shows the layered nature of information, which contains human-readable data ready for parsing by software.

Research performed on the internet by searching for "website APIs" and similar terms will identify various websites and the APIs they offer. Some APIs offer free access, or at least a limited number of free connections per day. Other websites, often with more valuable information, may require registration and charge a usage or subscription fee.

Programmers should have a few software tools available as they begin their first project to connect a PLC with an internet website, including the open-source Wireshark packet monitoring software and a JSON-aware text editor.

Unpacking JSON

HTTP requests to website APIs will return responses in JSON format, which is not easily human-readable in raw format (Figure 1). However, JSON has a well-defined system of layers and nesting, and those information objects are readily viewed with a compatible text editor (Figure 2).

Figure 1: A typical JSON data payload requires some parsing to extract the desired data.

The information a user would want is often nested several layers deep within the JSON file, which must be progressively parsed so it can be retrieved. In the Figure 2 example, the temperature of 44 degrees Fahrenheit resides in Layer 3, underneath Layer 2 "Imperial" and Layer 1 "Temperature".

AutomationDirect BRX PLCs incorporate four key features to make communication with internet websites possible:

- An Ethernet port configured on the plant network, with proper privileges allowing the PLC to connect to the internet
- The ability to be configured as a transmission control protocol (TCP) client, so the PLC can open a logical channel to initiate HTTP instructions
- An HTTP command instruction, so request strings can be sent to the API of a target URL
- A JSON parsing instruction, so that the response data payload can be processed

For AutomationDirect, the specific program instructions are HTTPCMD and JSONPARSE. Following is an application example demonstrating the necessary steps.

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A PLC Asks, "What is Tomorrow's Temperature?"

Perhaps the most common example of using a PLC to obtain internet data is when a PLC contacts a weather website to determine the forecast local temperature for the next day. The current local temperature could also be obtained this way, or via an outdoor temperature sensor connected to the PLC.

The AccuWeather website, for example, offers an API with many details under the "API reference" tab. Users should always consult the target website regarding registration, creating an application, cost and other technical details or restrictions.

In this case, a private user API key is necessary for initiating HTTP communications. This user API key authorizes communications and is similar to a password.

This API offers many methods of obtaining data. If the PLC, for example, is in a major city, then the temperature can be obtained on that basis in one step. For better accuracy, the user can choose latitude/longitude or even the postal ZIP code to look up a location key, which is used to call additional API methods.

This example uses the latter approach. First, an HTTPCMD instruction is issued to the target website, to "get" results for a "postal code search" (Figure 3).

Following the API rules, the JSON response will be a data payload containing a "key" value, which in this case is a lookup index for the desired

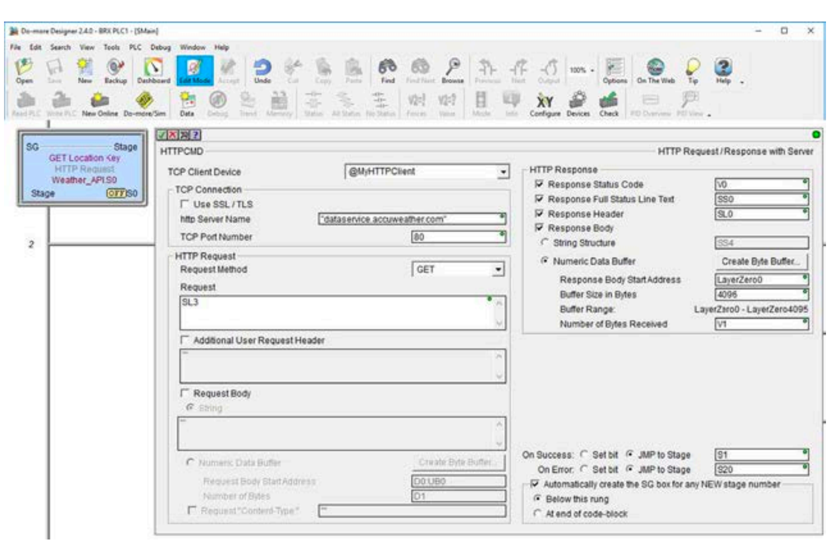

Figure 3: This HTTPCMD block in an AutomationDirect BRX PLC enables a PLC to initiate a request to an internet website API to obtain data. AutomationDirect Do-more Designer Software has the necessary instructions.

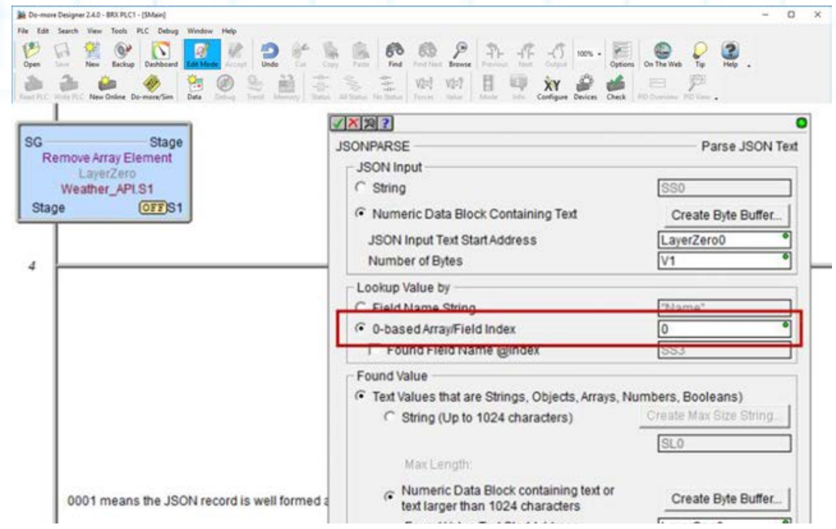

Figure 4: This JSONPARSE block in an AutomationDirect BRX PLC is used so the PLC can drill into the layers of objects within a JSON data payload and extract the desired information.

location. The JSONPARSE instruction allows the PLC to delve into the payload and extract the necessary key (Figure 4).

Once the key is known, it can be used to configure another set of HTTPCMD and JSONPARSE instructions, and then repeated as often as is necessary for the temperature value.

In this case, to obtain the temperature forecast for the next day, the user would configure the HTTPCMD to "get" the "forecasts/1day", and then use the JSONPARSE to extract the temperature in degrees. Note that JSON responses are handled as string variables and may require several successive JSONPARSE instructions to drill down through the layers to find the desired data.

Although initial programming requires a few steps, subsequent requests can be generated automatically.

Keeping Control

The ability for a PLC to interrogate the internet for useful data is powerful, but users must provide careful security for any industrial devices or networks capable of contacting the internet. Also, the PLC program must be robustly arranged so that it can withstand any type of internet outage.

The internet offers lots of information, much of which can't be easily obtained with local sensors and instruments. With the right PLC, some planning, and a little programming, users can enhance their applications by letting their PLCs directly gather information from internet websites.

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Practical Guide to Discrete Sensors for Industrial Applications

This eBook is for users who wish to advance their sensors knowledge. It covers a wide range of topics such as limit switches, proximity sensors, photoelectric sensors and more.

What's Inside:

- Introduction to Different Types of Sensors
- Common Terms Used for Discrete Sensors
- What Type of Sensors Do I Need?
- Limit Switches
- Inductive Proximity Sensors
- Magnetic Proximity Sensors
- Capacitive Proximity Sensors
- Ultrasonic Proximity Sensors
- Photoelectric Sensors
- Specialty Sensors
- Sensors with Analog Output
- Conclusion

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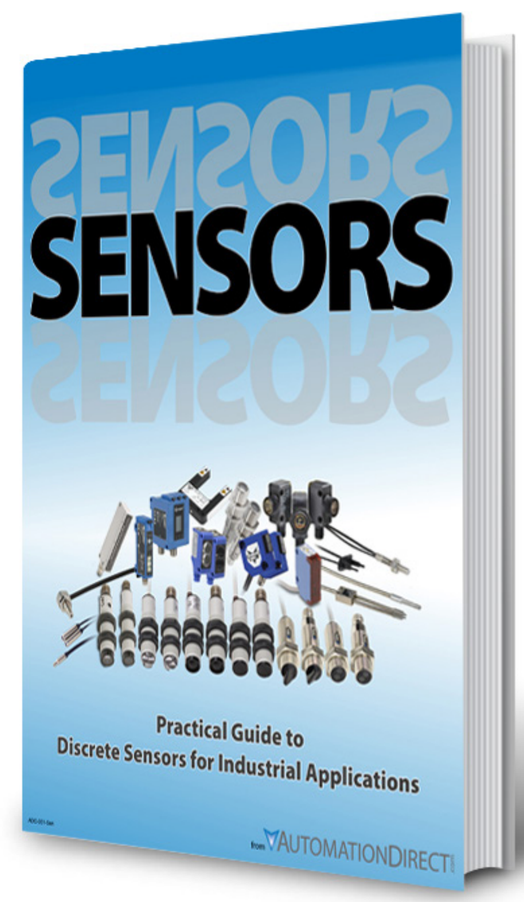
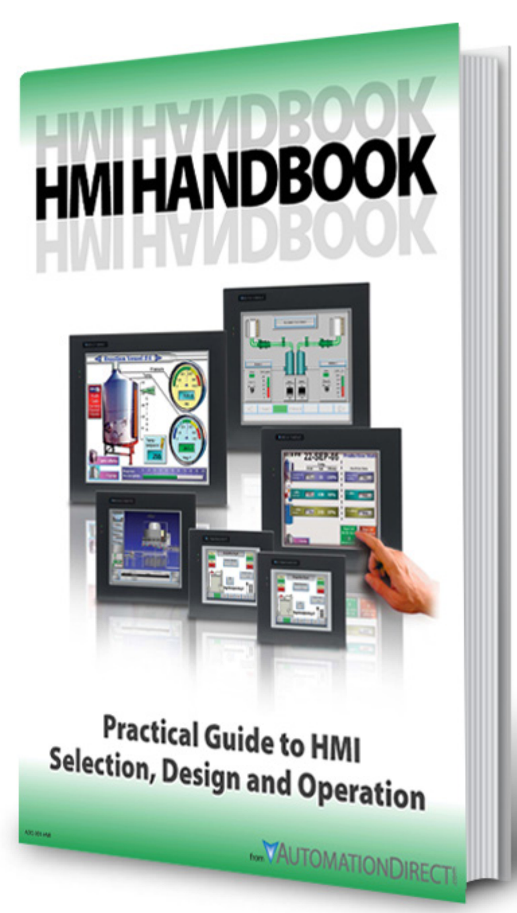


AutomationDirect's HMI Handbook delves into the world of human machine interfacing with informative chapters on selecting, designing and installing HMIs. But that's just the first half, the back half of the book focuses specifically on C-more HMIs with chapters covering how to use screen objects, how to configure events, simulation basics, recipe functions and so much more. Plus, we included a step-by-step tutorial on designing a functional AC drive control interface. This HMI Handbook is a great resource for those new to HMIs, those new to C-more HMIs, or those looking for some helpful tips and tricks for designing HMI screens.

http://bit.ly/2Jxp8Mf



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https://www.automationdirect.com/videos/home

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Roller Coaster Overhaul

Automated Integration replaced many relays, an old PLC and what seemed like miles of wire when it upgraded the control and safety system on the Hurricane roller coaster in New Mexico.

By Manny Salazar, Manager, Automated Integration, LLC.

The Hurricane roller coaster was purchased from the Santa Cruz Boardwalk in California, where it was originally installed in 1992. From there, it was disassembled, placed on 12 semi-trucks, and transported to Western Playland Amusement Park in Sunland Park, New Mexico. It took about a month to sand, paint and reassemble the roller coaster at the amusement park, where it was re-commissioned in late spring of 2015 (Figure 1).

Figure 1: Hurricane
The relocated Hurricane roller coaster was a thrill to ride, but it was very difficult to troubleshoot and maintain.

The steel track, Windstorm and Twister type coaster is quite a thrill to ride. It is approximately 55 feet tall, and the original specifications indicate the cars can reach 50 to 60 mph on the track and exceed 4 G around turns. The ride consists of two 12-passenger trains with three 4-person cars each. With nearly 1500 feet of track length, the ride time is approximately 50 seconds.

After it's recommissioning in 2015 at its new location, the ride was very unreliable and difficult to maintain with intermittent problems. It was constantly breaking down, and the control system was very difficult to troubleshoot and repair, with many parts obsolete. Automated Integration (**www.automatedintegration.net**), a local system integrator, was contracted for this retrofit project to replace the coasters failing control system. There were many relays and much related wiring, along with a very old Siemens S5-100U PLC that needed to be replaced.

Automated Integration provides a variety of automation design, maintenance, repair and programming services. It has a broad customer base in oil refineries, water utilities, food processing, HVAC building control, manufacturing and communication systems. It provides controls integration and programming services to many companies. If a project has any level of automation using controllers, relays or similar equipment, Automated Integration can likely service and support it.

Failing Relays Cause Intermittent Faults

The entire control system was failing. It was a mess and the ride would not run reliably. Sometimes the chain drive used to pull the coaster to the top of the first hill would shut down. Sometimes the safety interlocks for the cars would fail, stopping car movement. The sensors used to determine speed and car position around the track were failing as well. For example, the sensors would fail to indicate a car was in the correct position to begin the ride, inhibiting the control system from starting the ride. The failures were numerous and were occurring more frequently.

The original control system was based on relay control, not a surprise considering is was designed, built and installed in 1992. There was a small Siemens S5-100U PLC used for braking functions, but this PLC was not fully operational because it had been bypassed in places by the previous owners.

One of main problems with the design was too

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many relays interconnected to other relays for operation (Figure 2). There were many complex, hardwired circuits. One relay in a chain would fail, sometimes intermittently, and a fault would occur, but it would be difficult to find the cause of the fault. It was a frustrating control system to support, with the intermittent faults the worst of many problems.

Figure 2: Relays
There were several control panels full of hardwired relays and accompanying wiring, causing intermittent problems which were difficult to diagnose.

Sequence of Operation

The ride sequence requires two sets of cars (trains) to alternate. When in automatic mode, the system is run with one start button and one forward button on the last zone of the ride. The ride can be started with a loaded train in the start (loading) area and an empty train in the unload area, immediately upstream of the start.

The start button is pressed and the 3-car train is released. The chain drive drags the train to the top of the hill where it runs free and coasts until the last zone is reached. The last zone is the unloading area. Once the loaded train clears the start area, the empty car can be sent forward and is ready for new riders to board.

The braking system was previously an all pneumatic system operating friction brake pad mechanisms at appropriate points in the ride. The new design still uses pneumatic brakes in several locations, but a few were replaced with magnetic brakes which require no external control, just adjustment to slow down the train at key points of the ride. The starting and endpoints still have pneumatic brakes, as well as electromagnetic brakes within the motors themselves.

Upgraded Control System

An AutomationDirect (www.automationdirect.com) Click PLC was chosen to replace the old PLC and many of the relays. The PLC is used in a "dual-rack" configuration and controls all ride operations. It also controls the air compressor system and braking systems, and monitors the position of the trains in the ride.

The PLC monitors positions of the train cars, and determines whether to allow them to proceed to the next station (blockzone) in the ride.

All the compressed air system monitoring was replaced with new pressure switches, and programming in the new PLC was added to monitor and verify all pneumatic and electromagnetic brakes are operating when and where required. The new control system monitors for air pressure problems, and for brakes failing to operate when required. Should the braking systems fail to register as activated, the control system will create an alarm and shut down the ride.

All E-stops and related safety relays are also monitored by the PLC, and can shut down the ride any time they are activated. Safety relays are used in the power systems, as well as during the release of the cars at the starting point. The safety relays operate power contactors to energize the five motors used throughout the ride. These contactors also energize the variable frequency drive used to control the chain drive motor pulling the train up the hill at the start of the ride. The unloading station also includes safety relays monitoring the lap bar release system.

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The PLC is capable of remote access via the internet, but the Park is not currently using this functionality.

A Need for Speed Control

One of the main control requirements was to limit the speed the cars could travel during the ride. The original ride specifications specified the cars could reach 60 mph. There was concern that the existing proximity sensors would be able to detect the car traveling at that speed, register it in the PLC and calculate train speed—all within a very short window of time.

The ride is set up in six different zones (stations), and cars are monitored when they enter and exit each zone using proximity sensors. The original proximity sensors were very old and failing, so they were replaced. Capacitive sensors were initially specified to detect cars on the track in the new control system, but they didn't work consistently. New inductive proximity sensors were added to the system to monitor the cars movements throughout the ride. The new inductive proximity sensors now detect cars reliably.

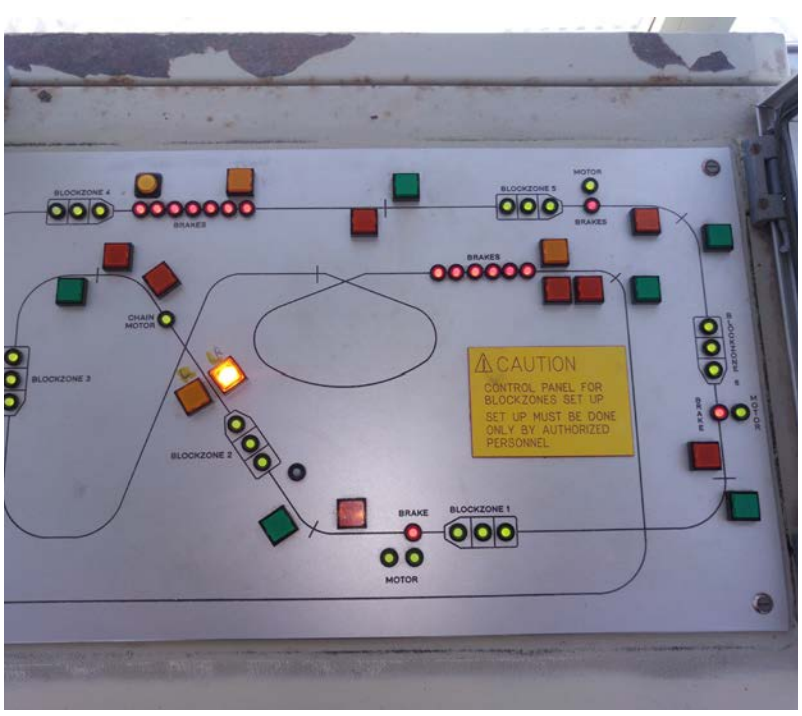

Figure 3: Status Display
The AutomationDirect Click PLC interfaces to and controls this operator interface panel, providing system status information, along with manual functions based on PLC- monitored sensors and control interlocks.

The original control system sometimes permitted cars to collide with one another if the operator was not careful. With the new control system, even if operations are done manually, program interlocks prevent collisions. Operators are warned if they try to push a train into a zone that already has a train (Figure 3).

Control System Details

The design uses two full racks of PLC components. Each rack has a controller and a power supply (Figure 4). The main rack has eight 16-point, 24 VAC/VDC discrete input modules. The second rack has eight 6-point, 5-27 VDC, discrete output modules. AutomationDirect ZIPLink pre-wired connection cables and modules were used to simplify wiring of the many I/O points. The Click PLC was selected due to the low cost of the controller and related hardware, and for its ability to handle all control functions reliably.

AutomationDirect 24 Vdc power supplies and terminal blocks were also used. A graphics panel was not needed for this project because hardwired pushbuttons and lights were sufficient to provide the required level of operator interface.

Figure 4: CLICK PLC racks
Two racks of AutomationDirect Click PLC hardware are used to monitor safety systems and control train sequencing, brake systems and the air compressor.

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Let's Ride

The installation of the new control system was very difficult at the beginning. What seemed like miles of wire were removed from the original control panels. Once the relay-logic wiring was removed, the PLC controlled I/O was terminated to field devices.

One of the complexities in programming the ride was the design requirement for a safe and reliable control system under all conditions, even operator error. These difficulties were overcome by working with the operators and the owner during development of the new control system's function and operation procedures.

How was it tested? To start, many basic tests were performed without riders, just sand bags in the train cars. After initial testing, willing volunteers were used. We did a lot of testing, but this automation project startup was much more fun than many others because we got to ride a roller coaster!

In addition to improved reliability, there will also be cost savings if part failures occur. Most of the parts used in the original control system are no longer available new, and had to be purchased from eBay or other unconventional sources.

For example, the new PLC I/O modules are priced at $45 each and relays at $4 each. With the old control system, relay replacements were anywhere from $50-$150 each. The new proximity sensors do not need the interface hardware the old system required, which cost roughly $450 each when purchased used on eBay.

The end result is a safe, stable and easy-to-operate roller coaster. The new control system has been operational and working since May 2017. With the flexibility and expandability of the control system, additional functions, such as remote monitoring and advanced diagnostics, will be added to the design in the coming months.

Park patrons now enjoy riding a vintage roller coaster with decades of history, but with the safety and security of a modern control system.

Industrial Automation with a Mission

A student design team developed a PLC-based control system to safely automate a test stand and prove out an engine prior to rocket launch.

By Simon Bambey and Griffin Peirce, UBC Rocket Student Team

At the University of British Columbia (UBC) in Vancouver, Canada, a group of determined students faced a technical task more challenging and with greater real-world implications than presented by typical homework or exams. They needed to safely test-fire an actual rocket engine to verify correct operation prior to launch.

The UBC Rocket student team consists of over 100 students working on multiple rocket projects. About one third of this group are engaged in the UBC Rocket Spaceshot project, working to build a sizable 25-foot-tall rocket powered by a liquid propellant engine. The rocket alone would weigh about 450 pounds empty and 1800 pounds when loaded with propellants. As part of designing and building the rocket, the project required in-house creation of a custom propulsion system, the most complex part of the rocket.

About a dozen students focused entirely on designing and manufacturing evolving generations of the rocket engine, machined and assembled out of steel and aluminum parts. Once each propulsion system was developed, the team needed to test the engine control, functionality, and performance on the ground so they could verify the overall rocket design before flight. This meant developing and qualifying some form of test stand and associated automation to control and monitor test runs.

After some initial research, the team realized that controlling and monitoring a rocket engine on the ground was much like operating an industrial machine. This led them to conclude that a programmable logic controller (PLC) platform would be ideal for the task. This article shows how they created a PLC-controlled rocket engine test stand, improving and adapting it as requirements evolved.

On the Job Learning

The student team is made up of dedicated and motivated individuals who embrace the challenge even though it is over and above their normal school and work commitments. For many, it is one of the few opportunities for Canadian citizens to engage in this type of aerospace and rocketry program.

The UBC Aerospace and Engineering Experience

Actually launching the rocket is the ultimate goal for the team, but like any large project, this one is organized from smaller projects. The rocket engine test stand is one essential piece of the larger rocketry project, with every element of the program critical to overall success. Much of the math and science behind rocketry is covered in the classroom, but for real-world implementation the students would need to learn a lot on the job.

A few team members were assigned to find out the requirements for controlling the rocket engine, and to then specify and design control hardware and software to create the necessary test stand system.

It Is Rocket Science

For the team's rocket, the engine size was specified early in the design. The liquid propellant engine combines liquid oxygen with kerosene and a source of ignition, with the resulting combustion developing about 3400 pounds of nominal thrust. At full power,

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the engine consumes about 15 pounds per second of the fuel and oxidizer propellants combined, with the combustion chamber operating at about 200 pounds per square inch of pressure.

The test stand would need to remotely, reliably, and safely control the engine for a test run (Figure 1), while monitoring and storing results of each firing for later analysis.

Controlled by Real-World Science

After some initial investigation, the team targeted AutomationDirect products for the PLC platform, with the AutomationDirect website's features assisting in this decision. Online product selection guides quickly helped the team focus on the Productivity2000 micro-modular PLC platform as it had plenty of computing power, I/O options, and configuration flexibility.

Figure 1: Picture of rocket test stand venting tanks after a hot fire.
The rocket engine, shown here attached to the test stand, must be controlled to carefully combine and ignite liquid oxygen and kerosene while monitoring results.

Test stand automation operates valves and actuators, monitors sensors, initiates ignition, and provides various safety shutdown functions. The last item is critical because a properly designed control system can recognize instrumented problems within milliseconds and act to drive the system to a safe state. No personnel were ever expected to be anywhere near the engine in operation, but the team also needed to protect the equipment from damage.

Because the team was learning so many disciplines at once, there was a great desire to avoid re-inventing the wheel. They already knew that PLCs and other industrial devices like control valves and sensors could do the job if they selected the right parts and programmed them properly. Here's how the team specified the required hardware and software.

Selection of the Productivity2000 was reinforced by the wealth of online product documents, support information, and training videos. Even though none of the team members had ever programmed or even heard of a PLC prior to this project, many members were familiar with other contemporary languages such as C++ and Python.

Using the free software and online tutorials, the team quickly discovered how to configure and scale inputs and outputs, and create the ladder logic necessary to achieve control. This gave them plenty of confidence they could meet their goals. The team was very excited for the hands-on opportunity to work with real-world products and systems, which isn't always possible at university. However, they needed to be mindful about incorporating the "minimum viable product", engineering-speak for keeping it simple and economical.

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Mission Control

The test stand design and development process evolved in several ways. Initially the design team tried using stepper motors to control valves, but they found this approach to be difficult and unable to provide the necessary feedback. They moved to using pneumatically actuated valves and electric solenoid valves, both easily interfaced with the PLC via relays. As development continued, more valves were progressively automated, eventually reaching a total of 12.

For instrumenting the test stand and rocket engine, temperature and pressure sensors sourced from AutomationDirect were specified for the necessary ranges and service. Industry-standard 4 to 20 mA signals ensured straightforward connection to the PLC and provided reliable signals.

Core automation elements were assembled into a control panel mounted on-board the test stand (Figure 2). The team designed and fabricated the control panel, using AutomationDirect ZIPLink pre-wired connection cables and modules to facilitate field wiring of the devices. The use of a modular PLC and ZIPLink cables provided flexibility for design updates. Other complementary panel fabrication hardware and devices were also obtained from AutomationDirect.

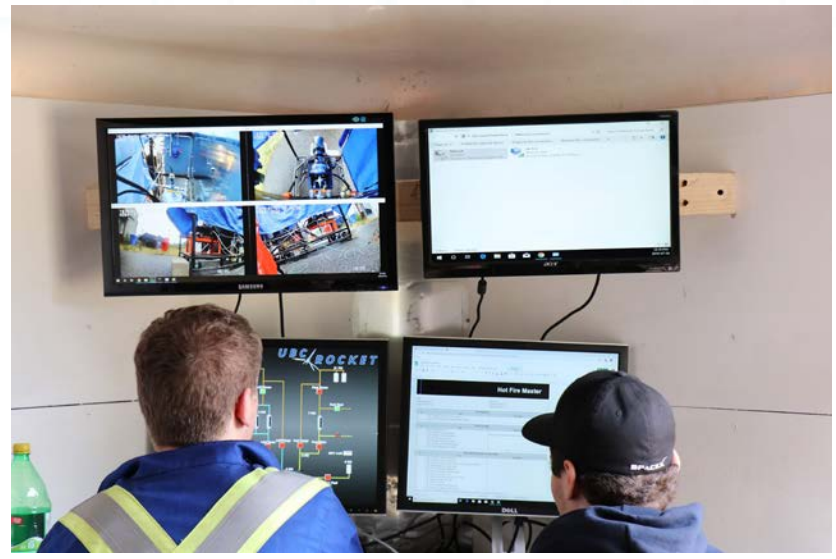

Figure 3: Picture of team remotely operating the test stand. The test stand is remotely monitored by team members.

Test stand operation encompassed several types of functionality including:

- Valve control
- Ignition
- Auto-abort
- Status and data logging

The team developed a human-machine interface for monitoring and control of test operations from a remote operating location, and also used video recording (Figure 3). Complete valve control is generally achieved through timing sequences programmed into the PLC so all actions can be performed repeatably and precisely once triggered by the operator. For a typical test session, an operator remotely actuates valves while a technician performs the propellant filling. Once propellant tanks are filled, the technician joins the operator in the control bunker where they set the test parameters.

Before a test can begin, the PLC enforces that all valves are in the correct state. The operator initiates a test and the PLC takes over

continued >>

Figure 2: Picture of control panel.
The team designed, fabricated, and wired a control panel mounted on-board the test stand, featuring an AutomationDirect Productivity2000 PLC, with ZIPLink connector cables installed at the top.

automatic control of valves where timings are scheduled with millisecond precision. To begin, valves sequentially open to mix fuel and oxygen in the igniter, a small chamber which shoots a flame into the main rocket engine. Following this, the PLC outputs a 4-20mA signal to precisely command positions of the main propellant valves with better than 1° of precision as they follow a pre-programmed profile to ensure smooth engine startup. Once the propellants enter the engine's combustion chamber they mix and are ignited by the igniter, which is then shut off.

As the test reaches completion the main propellant valves close and are followed by a sequence of valves automated to inject inert gas into the engine and surrounding area to clear any residual propellants and suppress any small fires. Closely tied with the normal valve and ignition functionality is the complementary auto-abort logic. The program is configured so any sensed anomaly will abort operation, driving all valves closed and other devices to their safe state. The team has experienced engine startup sequences that were abnormal and the test was reliably shutdown each time by the PLC.

For each test run, all device status and instrument data are data logged to the PLC's built in webserver. This allows quick, remote access of data for export in CSV format after the run so the team can perform more detailed analytics using other PC-based software. Being able to remotely access the data from within the safety of a control bunker enables the team to efficiently run back to back engine tests.

Figure 4: Picture of live fire.
The testing regimen progressed from dry cycling, to water tests, to ignition tests, to the final live fire operation. The automation system worked flawlessly throughout.

3-2-1 Ignition

In 1961 as the Mercury Freedom 7 launch experienced delays, an exasperated Alan Shepard is said to have barked "light this candle" to mission control. However, any rocket program has extensive tests leading up to the proverbial candle lighting moment (Figure 4).

The UBC team members extensively and progressively tested their rocket engine test stand to ensure proper operation. Hundreds of test runs were performed, first operating dry to just exercise the controls and the equipment. Later the systems were operated with water so certain control and monitoring could be safely achieved without introducing propellants. Because reliable ignition is a must, the team next performed over 60 igniter tests before ever filling the system's supply tanks with propellants. Finally, the team conducted a series of cryogenic checks where the liquid oxygen plumbing was tested with liquid nitrogen to ensure that all sensors and valves operated nominally when exposed to cryogenic temperatures.

Eventually the team performed actual and complete live fire tests. As of this writing, there have been multiple fully operational test sessions, with five total firings. All systems and automation elements have operated consistently and as expected.

A Platform for the Future

Choosing and implementing commercially available AutomationDirect PLC controls and instrumentation enabled the UBC Rocket team to rapidly develop a reliable automation platform. It also gave them the ability to readily adapt the system to new and changing requirements.

For instance, the team was able to progressively transition manual valves over to automatic valve control. They also upgraded the propellant valves to pneumatic valve positioners, enabling them to throttle flowrates during key startup sequences. Currently the test stand is trailer-borne, but upcoming construction phases are adapting the design to fit in a shipping container, with more automation for fire suppression and propellant filling.

UBC Rocket team members began the project with plenty of passion, but perhaps somewhat less hands-on experience. They were enthused to find how AutomationDirect systems and support

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Break Room
Brain Teasers

helped them build skills and produce a reliable automation solution. The team repeatedly found that AutomationDirect offered the wide portfolio of products they needed, suitable for the difficult field operating conditions, at a good price point.

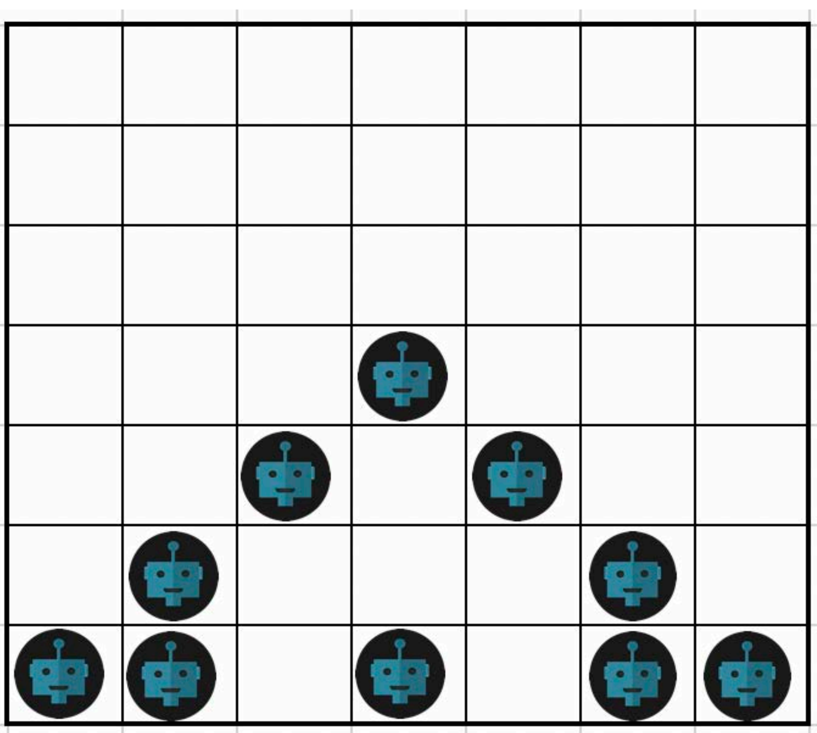
Author Bio

The UBC Rocket team includes over 100 students, with more than a dozen on the Spaceshot project forming the propulsion testing group and tasked with developing the rocket engine test stand. This case study was authored by Simon Bambey, team lead, and Griffin Peirce, propulsion testing lead.

Brain Teasers

By Chip McDaniel, AutomationDirect

1.) Robotic Shuffle

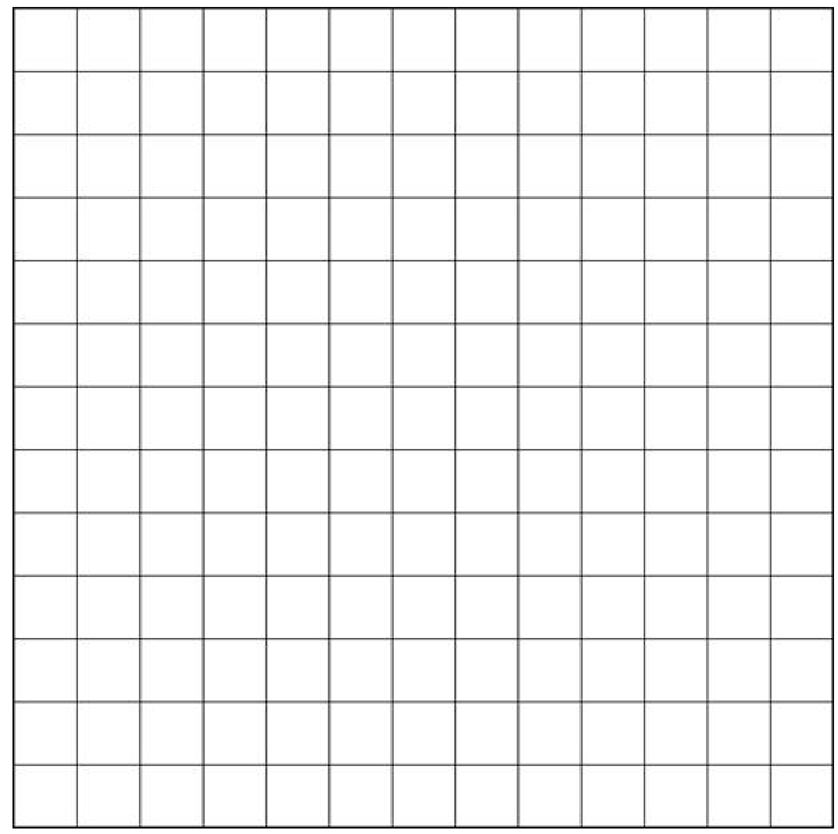


The puzzle factory has a grid of 49 robotic work cells, but only 10 robots are currently installed as shown in the illustration below. One morning the eccentric factory owner declares that three (and only 3) of the robots should be moved to new work cells, such that the robots will be aligned into five rows, with four robots in each row. *Can you find a way to achieve her whimsical placement request?*

2.) Thirteenth Squaring

Cutting only along the grid lines, what is the smallest number of square pieces into which you can dissect this image?

The largest number possible is 169 of course, where all the small squares are cut apart. But we are looking for the smallest number. Another approach might be to cut out a large 12x12 square, then cut the remainder into 25 little squares for a total of 26. That's certainly better than 169, but it can be done with far fewer. Give it a try!



3.) Cut the Cable

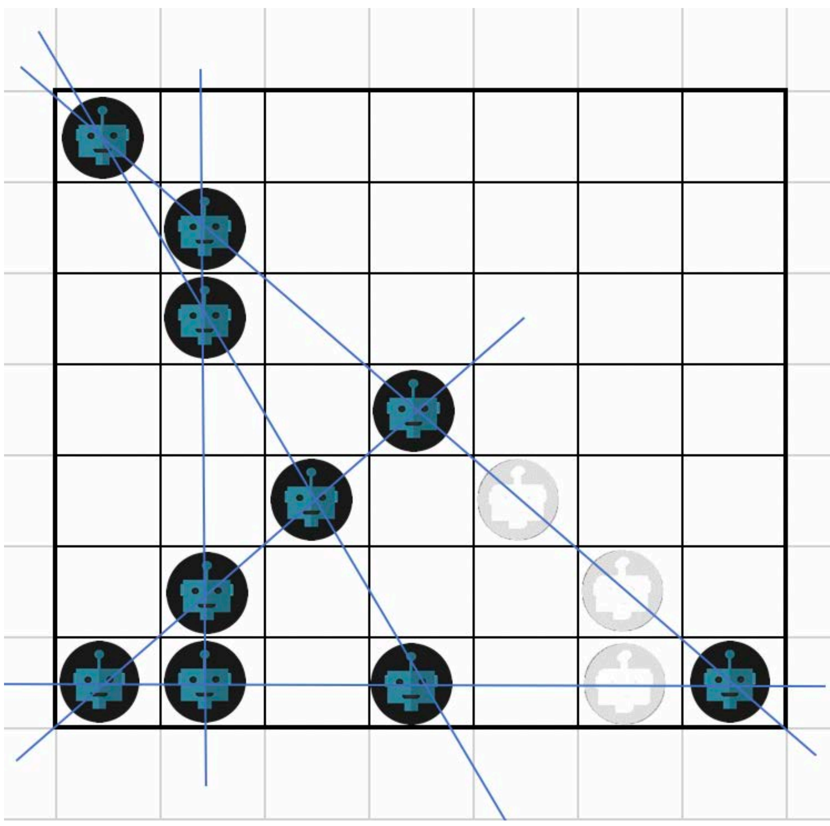
Four automation firms along with an engineer from each firm went shopping for cable. Each company bought twice as many sections of cable as their engineer, and each purchaser bought as many sections of cable as the number of dollars paid for each section. Acme spent $76 more than Globex; Dave bought three sections less than Standard; Alice bought two sections more than Fred, who spent $48 less than xCel. *What company does Jane work for?*

Solutions on next page

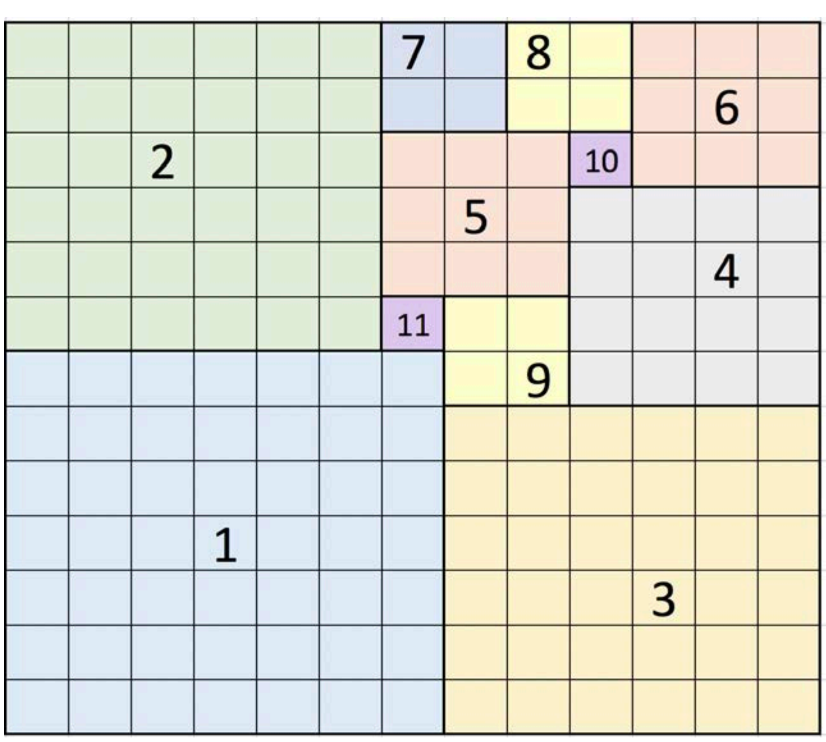
Brain Teaser Answers

By Chip McDaniel, AutomationDirect

1.) Robotic Shuffle Solution



2.) Thirteenth Squaring Solution



3.) Cut the Cable

	Sections	$/Section	Total Spent
Engineers			
Fred	4	$4.00	$16.00
Alice	6	$6.00	$36.00
Dave	9	$9.00	$81.00
Jane	10	$10.00	$100.00
Respective Companies			
xCel	8	$8.00	$64.00
Standard	12	$12.00	$144.00
Globex	18	$18.00	$324.00
Acme	20	$20.00	$400.00
Therefore Jane works for Acme			

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