Automation Notebook

Cover Story

2005 NEC® Changes

Article 409
Article 430

New Product Focus
Rhino Power Supplies

Technology Brief
EN418 Directive

Feature Story
2005 DARPA Grand Challenge
Automation Direct is committed to bringing you the best service, fast shipping, and superior service backed by experience. Our team consists of some of the best veterans from the industry giants with field-tested knowledge in a wide variety of applications.

Automation Notebook focuses on the release of the 2005 NEC. We invited Phil Simmons of Simmons Electrical Services to discuss some of the changes. I hope you find the articles informative and as always, we'll appreciate any feedback you send our way.

Editor's Note
Summer is winding down, the kids are back in school, and if you've been distracted by vacations and sunny weekends, you're probably thinking it's time to get your mind back on work.

At AutomationDirect, we've had our minds focused on lots of work. Early summer saw some of us moving, at last, into the building next door. It took longer than anticipated to get the facility ready, but thanks to great planning and teamwork, we've settled in and managed the move without any major issues. I was hoping we'd have stories to tell about an incident or two, but the whole process went off without a hitch. One of the more exciting elements was the purchase of a golf cart that we use as a taxi between the buildings.

While waiting on our office renovations, we concentrated on putting out our 2005 catalog (Vol. 10). It's amazing how much team effort goes into producing it. This one is over 1,750 pages filled with more than 5,500 parts, including many new ones. If you haven't received it yet, please fill out the request form on page 7 of this publication, and we'll send one out right away. This issue of Automation Notebook focuses on the release of the 2005 NEC. We invited Phil Simmons of Simmons Electrical Services to discuss some of the changes. I hope you find the articles informative and as always, we'll appreciate any feedback you send our way.

Jeff Payne
Contributing Writer

Your guide to practical products, technologies and applications
**New Product Focus**

**what's New**

**Rugged Power Supplies at Incredible Prices**

**New RHINO PSM series switching power supplies**

**Rugged and Versatile**

- **New RHINO PSM series**
- **Switching power supplies**
- **RHINO™ series offers variable DC output**
- **NEW!**
- **New RHINO PSP series power supplies**
- **Plastic-housed switching supplies available in 12 or 24 VDC adjustable output models.**

**Industrial Metal features:**

- Seven models offer power ratings from 78W to 600W, and up to 25A output current.
- Over current protection, short-circuit, overvoltage and overtemperature protection.
- Universal inputs for 115 VAC or 230 VAC.
- International agency approvals suitable for worldwide use.
- Low output ripple along with overload and overtemperature protection.

**Slimline Plastic features:**

- 14 models available with power ratings of 20W to 120W and up to 8A output current.
- DIN rail or panel mountable.
- Low output ripple along with short circuit, overvoltage and overtemperature protection.
- Featuring 85-240VAC/DC universal input voltage ratings.

**PSM Specialty Modules:**

- Redundancy module
- Battery Controller module
- Buffer module

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<table>
<thead>
<tr>
<th><strong>24 VDC Output, Plastic Case</strong></th>
<th><strong>24 VDC Output, Metal Case</strong></th>
<th><strong>24 VDC Buffer Module, Metal Case</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>24 VDC Output</td>
<td>110.88</td>
<td>780.12</td>
</tr>
<tr>
<td>100W</td>
<td>$111.68</td>
<td>$110.88</td>
</tr>
<tr>
<td>220W</td>
<td>$227.00</td>
<td>$220.00</td>
</tr>
<tr>
<td>50W/2.5A Output</td>
<td>$115.00</td>
<td>$115.00</td>
</tr>
<tr>
<td>60W/2.5A Output</td>
<td>$227.00</td>
<td>$227.00</td>
</tr>
<tr>
<td>160W/7A Output</td>
<td>$115.00</td>
<td>$115.00</td>
</tr>
<tr>
<td>200W/8A Output</td>
<td>$227.00</td>
<td>$227.00</td>
</tr>
<tr>
<td>240W/10A Output</td>
<td>$115.00</td>
<td>$115.00</td>
</tr>
<tr>
<td>320W/12A Output</td>
<td>$227.00</td>
<td>$227.00</td>
</tr>
</tbody>
</table>

**AutomationDirect now offers the RHINO line of power supplies, which includes several new metal and plastic-housed switching supply models.**

The new RHINO PSM series power supplies are industrial grade switching DC output supplies with a sturdy steel case to withstand harsh environments. Autoselect inputs for 115 VAC or 230 VAC and international agency approvals make the RHINO PSM series suitable for worldwide use. RHINO PSM power supplies are available in 12 or 24 VDC output, with adjustable output voltages, and feature low output ripple along with overload and overtemperature protection. The seven models offer power ratings from 78W to 600W, and up to 25A output current. Each power supply includes two diagnostic discrete outputs for monitoring low output voltage levels, allowing for remote notification to a PLC, SCADA or maintenance management system. One output is a relay output that can be directly connected to the logic input of an I/O device, such as a PLC, for remote monitoring and annunciating of low voltage levels. The other output is a relay output that can be connected to any dry contact capable device and will open its contact when the output voltage drops. Additionally, each PSM unit can be configured for Remote ON/OFF activation by wiring the RemoteON/OFF terminal in series with a relay or I/O device and the Vout terminal. This allows any logic device, PLC or remote I/O node to activate or deactivate the power supply output power for easy system startup/shutdown or maintenance purposes. RHINO PSM power supplies also include multiple output terminals to facilitate wiring in parallel load configurations, dual status indicator LEDs, and a pluggable screw terminal block for quick installation and removal. Prices for PSM models start at $56 for the 24V/1.75A model.

The PSM power supplies comply with the latest EMC immunity and emissions standards for industrial environments. There is also a model in this series that complies with NEC Class 2 safety requirements. The Mean Time Between Failure (MTBF) reliability is greater than 350,000 hours, in accordance with the IEC 61760 standard. Innovative add-on modules for the RHINO PSM line include a Redundancy Module for configuring a true redundant power system with power sharing, a Battery Controller Module suitable for creating a DC-UPS using a power supply (UPS) system by charging and monitoring an external battery, and a Buffer Module for maintaining output voltages of a 24 VDC power supply after brownouts or voltage dips. The Redundancy Module can connect two RHINO PSM power supplies to provide fully redundant output power and includes an alarm output signal when one of the power supplies has failed or has been disconnected. The Redundancy Module inputs are hot swappable for uninterrupted maintenance and can be loaded up to 15A each. For configuring a D C-UPS, the Battery Controller Module provides a battery management system for charging and monitoring a lead-acid battery. The Battery Controller module also has an option for connecting an external temperature sensor that adjusts the battery charging voltage automatically to avoid overcharging and increase battery life. The Buffer Module uses a capacitor bank to store energy and is therefore maintenance free. The hold-up time of the Buffer Module is typically 200ms at 25A, and up to 4 seconds at 1.2A. Accessories for panel mounting are also available for the PSM power supplies.

New RHINO PSP series power supplies are plastic-housed ultracompact switching supplies available in 5V, 12V and 24V adjustable output models. There are 14 models available with power ratings of 20W to 120W and up to 8A output current. They are DIN rail or panel-mountable and feature low output ripple along with short circuit, overvoltage and overtemperature protection. The Buffer Module is typically 200ms at 25A, and up to 4 seconds at 1.2A. Accessories for panel mounting are also available for the PSP power supplies. New RHINO PSP series power supplies are plastic-housed ultracompact switching supplies available in 5V, 12V and 24V adjustable output models. There are 14 models available with power ratings of 20W to 120W and up to 8A output current. They are DIN rail or panel-mountable and feature low output ripple along with short circuit, overvoltage and overtemperature protection. The Buffer Module is typically 200ms at 25A, and up to 4 seconds at 1.2A. Accessories for panel mounting are also available for the PSP power supplies. New RHINO PSP series power supplies are plastic-housed ultracompact switching supplies available in 5V, 12V and 24V adjustable output models. There are 14 models available with power ratings of 20W to 120W and up to 8A output current. They are DIN rail or panel-mountable and feature low output ripple along with short circuit, overvoltage and overtemperature protection. The Buffer Module is typically 200ms at 25A, and up to 4 seconds at 1.2A. Accessories for panel mounting are also available for the PSP power supplies. New RHINO PSP series power supplies are plastic-housed ultracompact switching supplies available in 5V, 12V and 24V adjustable output models. There are 14 models available with power ratings of 20W to 120W and up to 8A output current. They are DIN rail or panel-mountable and feature low output ripple along with short circuit, overvoltage and overtemperature protection. The Buffer Module is typically 200ms at 25A, and up to 4 seconds at 1.2A. Accessories for panel mounting are also available for the PSP power supplies. New RHINO PSP series power supplies are plastic-housed ultracompact switching supplies available in 5V, 12V and 24V adjustable output models. There are 14 models available with power ratings of 20W to 120W and up to 8A output current. They are DIN rail or panel-mountable and feature low output ripple along with short circuit, overvoltage and overtemperature protection. The Buffer Module is typically 200ms at 25A, and up to 4 seconds at 1.2A. Accessories for panel mounting are also available for the PSP power supplies.
DataNet OPC™ software is here

Cumming GA—May 4, 2005
---AutomationDirect now offers DataNet OPC by BizWareDirect. This new software product keeps people connected to plant operations, without binding them to the confines of their facility.

DataNet OPC uses Open Connectivity (OPC) technology to communicate live data from industrial devices to a Web page, with no HTML programming required. Data is then available for viewing, printing or archiving on any computer, anywhere the Internet or company intranet is accessible.

For plants that use multiple PLC brands, DataNet OPC is able to provide a more unified approach to data display and logging.

DataNet OPC offers many other useful features, designed to make industrial data more accessible and useful. Dynamic colors allow users to determine the status of their plant operations at a glance and can be used as an early warning system to alert personnel of abnormalities in operations. In addition, a math tool allows the user to request that calculations be performed on the raw data before it is displayed. Visitors to this year’s National Manufacturing Week were exposed to this feature firsthand when DataNet OPC was used, along with DataWorx, to compile and display test scores in the “Automation I.Q. Challenge.”

OPC technology allows easy and inexpensive data collection and display because it is supported by so many different devices. DataNet OPC is compatible with any industrial device that runs on an OPC 1.0 or OPC 2.0 compliant server.

Edison fuse line has multiple applications

Cumming GA—May 12, 2005
---AutomationDirect now carries products from the Edison line of fuse products. Edison Fuse is a subsidiary of Cooper Industries, the worldwide leader in circuit protection. All Edison fuses can be cross referenced and used as replacements for other name-brand fuses. AutomationDirect offers the most popular 1/32” x 1 1/2” models of the Current Limiting Class CC and the Class M Midget general purpose fuses. The CC line is recognized for NEC branch circuit protection and Type 2 coordinated applications for IEC or NEMA starters/contactor. Where adherence to extensive current limiting codes is not required, the Class M general purpose midget fuses provide an effective solution for both time-delay and fast-acting protection. Primary among the applications for the Midget class are supplemental protection of end-user equipment as well as small motors, transformers, solenoids, and other high-inrush power circuits. All fuses are compact in size and offered in boxes of 10 at prices ranging from $7 to $50 per box. Also available are companion DIN rail-mount fuse holders and panel-mount fuse blocks.

Ethernet Communication Module

HO-ECOM100

Cumming GA—June 1, 2005
---Recently added to AutomationDirect’s line of Ethernet communication products is the HO-ECOM100 module. Ethernet communication modules represent a price breakthrough for high-speed, peer-to-peer networking of PLCs. No longer are you forced to designate a single PLC to be the network master. Any PLC can initiate communications with any other PLC.

The HO-ECOM100 supports the industry standard MODBUS TCP/IP protocol connected through standard cables, hubs, and repeaters. Or, use our KEPDO Direct I/O Server to link to your favorite HMI/SCADA, data historian, MES or ERP software to DirectLOGIC PLCs. Our Lookout Direct HMI and DataWorx data collection software include ECOM drivers. DirectSOFT32 Programming Software can be used to monitor or update the program in any DirectLOGIC PLC on the network.

Free NetEdit3 Software ships with the ECOM Module. User Manuals to be used for setting up the ECOM modules for your network.

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"You see, telegraph is a kind of a very, very long cat. You pull his tail in New York and his head is meowing in Los Angeles. Do you understand this? And radio operates exactly the same way: you send signals here, they receive them there. The only difference is that there is no cat."

- Albert Einstein, when asked to describe radio

US (German-born) physicist (1879 - 1955)

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Laboratories (UL) 508A as the safety

Cover Story

2005 NEC® Code Changes

by Phil Simoncic
Guest Writer

T
he purpose of the National Electrical Code® (NEC®) is the practical safeguarding of persons and property from hazards caused by using electricity.

The NEC is prepared by a committee made up of a Technical Correlating Committee and 19 code-making panels.

The committee’s responsibility is to create documents specifying code, which when adhered to, minimizes the risks of electricity as a source of electric shock and as a potential ignition source for fires and explosions.

Published by the National Fire Protection Association, the NEC is updated every three years. Significant changes in the 2005 edition that we will be discussing are the new Article 409 and changes made to existing Article 430.

It should be noted that UL and other electrical testing laboratories have a procedure whereby a “panel shop” can produce control panels that comply with the UL Industrial Control Panel safety standard. As such, the control panels are eligible to bear the listing mark of the testing laboratory. The internal wiring of these listed control panels is not usually inspected by the local electrical inspector at the time of installation, as provided in Section 90.7 of the NEC. On the other hand, the internal wiring of industrial control panels that are built in accordance with new NEC Article 409 is usually subject to inspection by the local Authority Having Jurisdiction (AHJ).

This is due to the field-assembled control panels not being listed by a qualified electrical testing laboratory, but being assembled in accordance with NEC rules.

If the AHJ determines the control equipment being field-assembled is an Industrial Control Panel, compliance with all conditions of Article 409 is required, including the extensive marking specification in 409.110. The NEC offers no explanation for the term “systematic and standard arrangement of two or more components” as included in the definition in 409.2. The question is raised since industrial control panels are often one-of-a-kind, designed to control a specific operation rather than being mass-produced.

Requirements for grounding industrial control panels must generally comply with Article 250. Specific requirements are provided in 409.60.

Construction requirements for industrial control panels are found in Part III of Article 409. Rules are provided for enclosures, installing busbars and conductors, wiring space, and for where the control panel can be used as service-entrance equipment. Extensive marking requirements are contained in 409.110, including the short-circuit current rating of the assembly. A fine-print note refers to UL 508A-2001, where an approved method for determining the short-circuit current rating can be found.

Rules in other standards might apply to specific control panels such as NFPA 79 for industrial machinery. Article 430

Several changes to Article 430 were made for the 2005 NEC. This includes some reorganization, renumbering, and inclusion of a new Part X on adjustable speed drives.

Disconnection means for industrial control panels that supply motor loads must be distinct from disconnecting motor controllers in Article 430, Part IX. This generally requires a disconnection means on the supply side of the controller and within sight of the controller (defined in Article 100 as visible from and not more than 50 feet away).

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Motor Controller

Section 430.32(A) covers marking on motor controllers. M motor controllers are now required to be marked with the “short-circuit current rating.” Exceptions are provided for certain motor controller applications. The short-circuit current rating is the current the controller is rated to open under short-circuit conditions. A controller must be selected that has a short-circuit rating that equals or exceeds the short-circuit current available at its line or supply terminals. M motor controllers are provided to start and stop the motor. Branch-circuit, short-circuit and ground-fault protection is provided on the line side of the motor controller by a circuit breaker or fuse. The newly required short-circuit marking can be thought of as a withstand rating. The concept is that the motor controller will remain intact while carrying short-circuit current until the circuit breaker or fuse on the line side opens the circuit. The product safety standard for industrial control equipment, UL 508A-2001, Supplement SB, provides an example of an approved method for determining the short-circuit current rating.

Other markings required on the controller include the manufacturer’s name or identification, the voltage the controller is rated as general or horse power, and other necessary data to properly indicate the applications for which the controller is suitable.

Four exceptions were added to exempt the short-circuit current rating marking. Exception No. 1 exempts certain controllers for small motors as allowed in Part VII, such as clock motors, attachment plugs and receptacles, and snap switches. The second sentence permits controller short-circuit current ratings to be marked elsewhere on the assembly. The third exception covers applications where the short-circuit current rating is marked on the assembly in which the controller is installed. Exception No. 4 exempts controllers rated less than 2 hp at 300V that are listed exclusively for general-purpose branch circuits.

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Combination motor controller Section 430.102(B) provides the location requirements for the disconnection means for motors. This section has been the subject of much discussion over recent NEC editions. Changes were made to the rule on disconnecting means being located within sight of the motor and driven machinery. The second sentence of (B) in the 2002 NEC requirement is deleted, and a phrase in the exception has also been deleted.

The NEC Code Panel made organizational and substantive changes to the main test and exception. The second sentence of the opening paragraph is moved to follow the fine-print notes, so the exception does not now modify the previous second sentence. Now, clearly, the disconnecting means on the supply side of the motor controller is permitted to be the only disconnecting means for the controller and motor if it is within sight of both.

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The Code Panel stated the word “permanently” in the exception, as related to the method for locking the disconnecting means. It was deleted because it was considered confusing. The intent of this change in the 2002 NEC was to require the provisions for locking always to be in place and not to be removed when the lock is removed. “Permanently” was used to convey this concept but some interpretations have been that “permanently” means it shall not be possible to remove the locking means. As stated in the NFPA documents, “That was not the intent and there are few, if any, locking means that are permanent to the point they cannot be removed.” The original purpose of adding “permanently” to the Code was to require that a locking means be available at all times, i.e., to prohibit a portable locking means that is removed when the lock is removed.

Section 430.10(A)(6) covers manual motor controllers. Manual motor controllers are often a switch that includes a heater element to provide motor overload protection. Manual motor controllers are permitted as the motor disconnecting means where marked by the manufacturer as being suitable for that purpose. Rules were added on locating the manual motor starter on the line side of the fuse used for running overload protection as permitted in 430.52(C)(5).

Semi-conductor fuses are permitted to be used as branch-circuit fuses under 430.52(C)(5). However, they are often used as supplementary fuses to protect electronic equipment, and may be located on the load side of listed manual motor controllers marked as “Suitable for Motor Disconnect.” Since, as branch-circuit fuses, they are technically the final motor branch-circuit protective device, their use downstream from the manual motor controllers violates the Code. The change permits the use of these fuses in this location, as supplementary protective devices. The manual motor controllers additionally marked “Suitable as Motor Disconnect” will be suitably protected by the branch-circuit protective devices located on their line side.

Section 430.10(A)(7) lists rules for installing system isolation equipment. “System isolation equipment” is defined in Section 430.2 as “a redundantly monitored, remotely operated contactor isolating system, packaged to provide the disconnection/isolation function, capable of verifiable operation from multiple remote locations by means of lockout switches, each having the capability of being padlocked in the OFF (open) position.” The concept of system isolation equipment provides lockout capabilities in the motor control circuit rather than in the power circuit.

This change to Article 430 was intended to align with the latest edition of NFPA 79, the Standard for Industrial Machinery. Specifically, it refers to Section 5.5, Devices for Disconnecting (Isolating) Electrical Equipment, paragraph 5.5.4(3). This type of equipment is principally intended for industrial machines covered by NFPA 79, where, because of multiple entry points or high-frequency usage, the use of other isolation devices becomes impracticable.

Because of size, manufacturing machines often have several entry points used by operators and maintenance personnel who cannot always see one another. With a monitored safety lockout system, each point of entry has a lockout capable disconnecting means, and a method to verify to the user that the disconnection function has succeeded. Each of the several point-of-entry “disconnecting means” is monitored and opens a magnetic contactor that prevents the machine from being energized.

The “redundantly monitored, remotely operated contactor isolating system” is always located within the machine’s electrical system on the load side of a circuit breaker or fuse. A typical redundantly monitored, remotely operated contactor isolating system that incorporates control lockout provisions has been reviewed with OSHA; the resultant interpretation is that it can be part of an energy control program and therein a suitable disconnecting means for such purposes.

Underwriters Laboratories is expected to develop one or more product safety standards for a redundantly monitored, remotely operated contactor isolating system that incorporates control lockout provisions.

The new Part X of Article 430 covers adjustable-speed drives. New definitions have been added to 430.2 for “adjustable-speed drive” and “adjustable-speed drive system.” This recommended change places requirements for these drives in a central location in Article 430 that begins at 430.120.

The following list provides an indication of the subjects covered in the new part of Article 430.

A - Adjustable Speed Drive Systems

430.126 Motor Overtemperature Protection

430.128 D Inconecting Means

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430.122 Conductors - Minimum Size and Ampacity

430.122 Conductors - Minimum Size and Ampacity

430.120 G General

430.122 C Conductors - Minimum Size and Ampacity

(A) Branch / Feeder Circuit Conductors

(B) Bypass Devices

430.124 O Inverter Protection

(A) Included in Power Conversion Equipment

(B) Bypass Circuits

(C) M Multile Motor Applications

430.126 M Motor Overtemperature Protection

Written in accordance with the 2005 NEC®, this new book provides readers with a comprehensive introduction to the essential elements of electrical grounding and bonding. Using straightforward, easy-to-understand explanations it examines the critical concepts of calculating conductor sizes, reading and interpreting NEC® tables, the use of grounded conductor connections in DC and AC systems, as well as various installations and sizing.

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Use of Ethernet communications on the plant floor has basically doubled in the past five years. While serial communications remain popular and reliable, Ethernet is fast becoming the communications media of choice with advantages that simply can’t be ignored:

- Speed of the network
- Ease-of-use, i.e., setup and wiring
- Availability of off-the-shelf networking components
- Convenient “built-in-communications” setup

It’s not every day you can say you picked up a component for your industrial application at Wal-Mart or from a Web site that makes buying a snap. Ethernet communications modules are readily available with high-speed performance (10/100Mb) and flexible protocols. For example, AutomationDirect now offers Ethernet option modules for the DL05/06, DL205 and DL405 PLCs. These modules install easily in an option slot and allow peer networking among PLCs and PCs, for as little as $175 per node (10Mb H-B ECOM module for DL05/06).

The 100Mb models provide support for TCP/IP, UDP/IP, IPX and MODBUS TCP/IP protocols.

Additionally, wireless communications is also gaining popularity, particularly in applications where distance and wiring expense make it a cost-effective alternative to wired systems. (For detailed articles on wireless communications, see the Winter 2005 issue of Automation Notebook or visit www.automationnotebook.com.) AutomationDirect’s Ethernet modules and serial port modules work well with the Common Protocol Lantronix products.

Availability of off-the-shelf networking components and the ease-of-use of Ethernet communications adds up to a networking solution that is easy to implement and support. The result: a more efficient process with improved performance.

The Greatest Change

Possibly the most significant change in the PLC market in recent years lies in the communications arena. Think about it. What single development has literally revolutionized the way PLCs are programmed, the way they talk to each other, and how they interface with PCs for HMI, SCADA or DCS applications? Not a tough question - in a word, the answer is Ethernet.
User Solutions

Time Saver System

Downtime Monitoring With PLC Technology

by Steven Noto, Guest Writer

When our company set out to design a basic system for monitoring downtime on customers' factory machines, we were new to using PLCs and related technology. Four years later, by incorporating products from AutomationDirect, we are now able to offer our customers a comprehensive system for tracking uptime, downtime, production, efficiency, and more.

Our initial goal was to develop a system to report machine downtime for customers in the fastener-making industry who were concerned with the productivity of their headers and thread rollers. Some of these machines were monitored by our existing IMPAX process monitors, some were monitored by competitors' monitors, and some were not monitored at all. We needed a system that could track production and uptime/downtime for each machine.

We built a basic system using an EZTouch 6-inch touch screen and a DL05 PLC. We programmed the PLC to count pulses from a magnetic proximity sensor positioned to detect parts as they leave the machine. The program tracks production counts and determines downtime by calculating occurrences of 5-minute periods during which there was no signal. PLC timers and registers store the times and counts, and the touch screen provides access to this data. When a downtime incident occurred, the touch screen prompts the operator to select a downtime reason from a list. This information is logged in the PLC and used for analyzing downtime causes. To ensure that the data is accurate, a PLC-controlled relay is used as an interlock to prevent the machine from restarting until the operator responds. A D0-01MC card is used to provide the PLC with the data that it needs, including operator actions.

Using one of the new IMPAX TimeSaver System (TSS) monitors on each machine produced a basic downtime recording system that worked very well. For data access, we developed a data collection program using LookoutD Direct, a PC-based HIMI and acquisition package, to collect the numbers from the PLC's across a serial network and display them in real-time.

As the system grew and features were added, it evolved from a simple recording system to a comprehensive solution. For example, we developed a custom system that allows users to track machine efficiencies, and allowing the user to enter up to 64 custom downtime reasons.

After upgrading the machine monitors, we decided to switch from LookoutD Direct to Microsoft Excel on the PCs when used with a DS0 AL datserver. Excel can access the PLC data. Excel was chosen to provide more flexibility for future customizations. We have a complete system, built in Excel, with screens for viewing live data from the shop floor and for reporting historical data. This data is automatically gathered by Excel periodically and saved to files. Another advantage of using Excel is access to all of its charting and graphing features. In addition, we can perform automatic calculations and display relevant data via Excel macros.

The overall configuration is depicted below.

![IMPAK TSS System Block Diagram](image)

In developing the system, problems were encountered that required extensive programing and debugging efforts, along with resolution of hardware configuration issues. Each hurdle was overcome with determined troubleshooting and the aid of AutomationDirect's responsive technical support staff, who helped us solve some quirky networking glitches. Consequently, today we have a very solid system.

The TSS production monitoring system is ready-to-install for most applications, but can also be customized for a particular application. Using AutomationDirect's interconnect parts, software, and tools provides lots of options. With the IMPAX TSS system, ECOM PLC software on a laptop, we can make modifications for a customer on their shop floor. For example, one of our customer's machines consists of three parts. Using the DirectSoft software and EZTouch editor, we were able to update our program to properly record sorted-good and sorted-bad counts, on the fly, DirectSoft and NetEdit (a networking configuration) are excellent tools used by our technicians to trouble-shoot installations and other problems. We are also using the DNLoader program to distribute software updates to our customers online, and are investigating using AutomationDirect's KEFDirect software as an upgrade from our offline system.

The end result of our work is, the IMPAX TSS system is a complete production and downtime monitoring system, with stand-alone monitors and networked, real-time data collection and display. The system is built from a variety of products that are affordable, readily available, and reliable. In 3 years, we've not had a single hardware failure. Our customers are very happy with the TSS and are equipping many of their shop floor machines with TSS monitors. Because we were able to develop the system out of quality building blocks that can be easily procured from a single program, at an affordable price, we were better able to focus on the end result. Delivering a product that effectively assists our customers with downtime management needs was a satisfying achievement, to say the least.

Company Profile

Process Technologies Group, Inc. (PTG) designs and manufactures process monitors, efficiency monitors, and data collection software. The IMPAX TimeSaver System is the company's machine efficiency and downtime monitoring system. PTG can be reached at 1-800-272-4784 or at www.impaxptg.com.

Feature Story

DAR PA

2005 DARPA Grand Challenge

by Chip McDaniel

"A" the preliminary telling of our team's story and the subsequent breaking of a couple of toilets, we've come to a few conclusions. First, our steering algorithm has a lot more pondering than we really need. Second, we never should have attempted to steer the steering system without the use of the encoder feedback. And third, we really need to add a couple over-travel limits which is the steering system.

This excerpt is just one sample of various e-mails exchanged by AutomationDirect and Team Buffalo over the last several months. Team Buffalo is a pair of engineers from Buffalo, N.Y., who constructed and entered for the 2005 DARPA Grand Challenge.

The Challenge

DARPA Grand Challenge 2005 is a field test of robotic ground vehicles for the purpose of advancing autonomous vehicle technology. The vehicles must travel approximately 150 miles over rugged desert roads using only onboard sensors and navigation equipment to find and follow a designated route while avoiding obstacles. After the October 8, 2005 event, DARPA will award $2 million to the team whose autonomous vehicle successfully completes the route the fastest, within a 10-hour period. All vehicles must be developed without government funding.

The Defense Advanced Research Projects Agency (DARPA) is the central research and development organization for the United States Department of Defense (DOD). DARPA's mission is to "manage and direct selected basic and applied research and development projects for the DoD, and pursue research and technology wherein risk and payoff are both very high, and where success may provide dramatic advances for traditional military roles and missions." DARPA was founded in response to the surprise Sputnik launch in 1958, and it's been Uncle Sam's hope that DARPA would help the U.S. avoid technological "surprises" created by other countries since then. Among other notable achievements, DARPA even helped to fatten the Internet along the way.

This is the second time DARPA has held the Grand Challenge. In 2004, none of the 15 teams entered was able to complete the course successfully. Some entries failed spectacularly, and others failed on the starting line, making no progress whatsoever. The two most successful teams managed to travel just 7 of the 142 prescribed miles.

The stated purpose of the Grand Challenge is "to accelerate development of autonomous vehicle technologies that will save lives on the battlefield." Although there was no winner at the Grand Challenge 2004, DARPA obtained a number of important ideas that may lead to continued. p. 18 >>
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A sample of parts and prices:

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC-E01-110VAC</td>
<td>Breakfast</td>
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<tr>
<td>SC-E02-110VAC</td>
<td>Lunch</td>
<td>$22</td>
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<tr>
<td>SC-E03-110VAC</td>
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<td>$25</td>
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<td>SC-E04-110VAC</td>
<td>Dessert</td>
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**Manual Motor Starters**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>BM3RHB-004</td>
<td>10 Amp Starter</td>
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<tr>
<td>BM3RHB-010</td>
<td>15 Amp Starter</td>
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<td>BM3RHB-015</td>
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**Motor Controls Head-to-Head**

<table>
<thead>
<tr>
<th>Feature</th>
<th>AutomationDirect</th>
<th>Manual Motor Starter</th>
<th>FEM-N</th>
<th>Advance Realty</th>
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<tr>
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<td>40 Amp Contactor</td>
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<td>10 Amp Manual Motor Starter</td>
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**Molded Case Circuit Breakers: Technical Specifications**

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<tr>
<th>Circuit Breaker Type</th>
<th>Amperes Rating</th>
<th>No. of Poles</th>
<th>Federal Specification</th>
<th>UL Listed Interrupting Ratings (rms Symmetrical Amperes)</th>
<th>Starting Price</th>
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<tbody>
<tr>
<td>E-Frame</td>
<td>10-120</td>
<td>3</td>
<td>25</td>
<td>UL 1077</td>
<td>100 (AC) 75 (DC)</td>
</tr>
<tr>
<td>M-Frame</td>
<td>100-600</td>
<td>2</td>
<td>75</td>
<td>UL 2077</td>
<td>750 (AC) 500 (DC)</td>
</tr>
<tr>
<td>L-Frame</td>
<td>100-600</td>
<td>1</td>
<td>25</td>
<td>UL 2077</td>
<td>225 (AC) 150 (DC)</td>
</tr>
</tbody>
</table>

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Feature Story

promising developments and is certain that important research progress will also be made leading up to the 2005 event, regardless of the outcome.

The Team

Team Buffalo is a two-man partnership lead by Mark Schwartz, a software engineer and a licensed master electrician specializing in systems integration, process controls and automation. He has over 20 years of experience designing and developing automated systems. Past projects include an emergency shutdown system designed for a multi-national chemical producer, and a satellite-based automatic dispatch system implemented for a national utility company. Schwartz has extensive software experience at both the embedded and applications levels, and enjoys developing practical solutions to real-world problems.

Joining Mark is Team Manager and Senior Engineer Brad Burzynski. Brad is a PLC programmer, systems integrator, and electrical engineer with over 10 years of field experience. Brad’s repertoire includes designing controls for an automated assembly line at one of the big three automotive manufacturers, and designing quality-control vision systems for a pharmaceutical giant.

Team Buffalo was formed in late 2004, and immediately began to design its vehicle and search for sponsors. While talking to AutomationDirect about a sponsorship, Team Buffalo lined up a number of other sponsors, according to their Web site. By the middle of January 2005, Team Buffalo had confirmed sponsorships from an engineering software company, a local plastics thermoforming outfit, and most importantly, a catering service!

According to Schwartz, Team Buffalo had been in discussions with several other international PLC manufacturers however, AutomationDirect was the only PLC manufacturer willing to make a firm commitment and provide a concrete ship date. “They had everything we needed right in stock and were ready to ship overnight. Quality, service, and availability. What more could we ask for?” Schwartz said. On February 9, all requested PLC components were in-hand and Team Buffalo began to assemble its control system.

The Vehicle

Team Buffalo decided early on to use an All-Terrain Vehicle (ATV) as its “motion” platform. The combination of low-cost and go-anywhere design were compelling attributes. Modifications to enable autonomous control and the guidance system were begun only after an extensive test driving and break-in period. Burzynski was eager to gain in-depth knowledge of the vehicle’s capabilities. He said, “I need to know the vehicle’s limitations and handling characteristics so I can program the PLC to those limitations.” The vehicle was dubbed the ANT: Autonomous Non-Manned Transport.

Team Buffalo’s approach to the navigation and control system was fairly straightforward: a pair of commercially available GPS systems that acquire position data, and a “heading” (direction of travel) from geo-synchronous satellites. This navigational information is transferred to a Pentium-class single-board computer via an RS-232 serial link. The PC is used to preprocess and filter the navigational information before sending it to an AutomationDirect DL205 PLC. The PLC controls servos for steering and throttle control, and a linear actuator for “shifting” the transmission. The PLC also accepts inputs from seven ultrasonic “obstacle avoidance” sensors, and plots the actual course of the ANT. To quote Schwartz, “In essence, the single-board computer tells the PLC where we are now, where we want to go, and our current heading.” The PLC then uses that information, along with the obstacle and collision avoidance information, to steer the vehicle toward our designated destination.

Qualifiying

With a vehicle procured, sponsorships lined up, and a control system design in hand, Team Buffalo worked day and night—seven days a week—to modify the ATV, fabricate the control system, and program the PLC and PC. As part of the formal application process to DARPA, the team was required to submit a 5-minute video, detailing and demonstrating the vehicle. By March 11.

There were some hurdles, as Schwartz explains: “At first, we had some minor difficulty programming the analog inputs and outputs on the DL205 PLC. However, one quick call to AutomationDirect’s support line and we were back on track in no time at all. In fact, I was truly amazed at how fast we were able to get through to a knowledgeable support engineer. We had the answers and information needed to configure the analog inputs and outputs in less time than we typically spend on hold with some of the other PLC manufacturers.”

As detailed in the opening e-mail excerpt, Team Buffalo also learned a hard lesson about encoder feedback and limit switches for servos and actuators. The team was unable to cross-wire some of the actuators, thus making troubleshooting almost impossible. In the end they were unable to successfully navigate the course, but the DARPA officials were still encouraging and very interested in the vehicle and design approach. The Team was left to wait until June for a final decision from DARPA.

On June 6, DARPA released the names of the 40 teams that made the final cut, and Team Buffalo was not among them. The Team is disappointed, but hasn’t given up. They plan to continue work on the ANT, and unless one of the other teams wins the prize at this year’s contest in October, Team Buffalo will re-enter the contest in 2006.

You can follow the Team’s hard work and efforts at www.TeamBuffalo.org. Find out more about the DARPA Grand Challenge 2005 at www.darpa.mil/grandchallenge. And finally, check out more pictures and a video of the ANT at the Automation Notebook website www.AutomationNotebook.com. (Search for “Team Buffalo” to see the latest entries.)
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*30 mm metal*

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- Selector switches in knob or lever versions
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*22 mm non-metal*

- Stroke, extended, illuminated or non-illuminated, and mushroom pushbuttons, many available in three colors
- Pilot lights and push-to-test models
- Two or three position selector and keyed switches
- Space-saving non-metal devices useful in hazardous environments

---

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<table>
<thead>
<tr>
<th>Pushbuttons</th>
<th>Allen-Bradley</th>
<th>Eaton/Cutler-Hammer</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 mm pushbutton, flush black (operator, L.N.O. contact)</td>
<td>$7.75</td>
<td>$6.60</td>
</tr>
<tr>
<td>24V indicator light (red)</td>
<td>$10.25</td>
<td>$13.80</td>
</tr>
<tr>
<td>30 mm pushbutton, flush green (operator, L.N.O. contact)</td>
<td>$16.00</td>
<td>$19.90</td>
</tr>
</tbody>
</table>

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**Technology Brief**

**Emergency Requirements**

The EN418 Directive must meet the requirements of the European Machinery Directive including EN418. If you ship equipment to Europe, the equipment must be in compliance with the machinery directive. If not, you must perform a risk assessment. You must then identify hazards and evaluate them. Then you must provide protective devices from those hazards. Finally, you must document your performance. Eaton/Cutler-Hammer has a complete line of self-monitoring circuit contact blocks that meet EN418 requirements. Part numbers and styles include: E22LTA2QB E-Stop trigger action maintained 40mm red mushroom pushbutton; and E230, PB30, E230LB28, BB, and E230PLB28 with 40mm and 50mm push-pull maintained mushroom operators to ensure acceptance by machinery inspectors. These products are tested by DEMKO, a third party European Standards company.

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**EN418 Directive**

With compliance to code and safety regulations continually taking on a more influential role across the industry, we will focus on European Machinery Safety Directive EN418. Eaton/Cutler-Hammer supplied source information that has been compiled for the benefit of our readers.

EN 418 - What is it?

EN 418 is the European Standard for the Safety of Machinery Emergency Stop Equipment. It defines specific requirements for emergency stop devices and actuators. These requirements are summarized as follows:

- All Emergency OFF devices must be “self-monitoring” (maintained) devices. With regard to an E-Stop, this means it must be either a “push-pull” or “twist-to-release” device.
- The actuating mechanism must be engaged prior to the electrical contact change-of-state to avoid an arbitrary OFF signal.
- All devices must have a “mushroom” head that is red in color.
- The background immediately surrounding the E-Off OFF device must be yellow in color.
- All Emergency OFF devices must have positive opening (direct opening) operation. This means there must be a direct mechanical link between the operation of the mushroom head and the contacts to drive the electrical contacts open. This protects against a potentially unsafe condition should contacts weld. A spring action contact does not comply with this requirement.
- The devices must not be reset automatically, manual reset is a requirement.
- Why should AutomationDirect customers care about EN 418?

Equipment shipped for use within the European Union must meet the requirements of the European Machinery Directive including EN418. If you ship equipment to Europe, the equipment must be in compliance with the machinery directive. If not, you must perform a risk assessment. You must then identify hazards and evaluate them. Then you must provide protective devices from those hazards. Finally, you must document your performance. Eaton/Cutler-Hammer has a complete line of self-monitoring circuit contact blocks that meet EN418 requirements. Part numbers and styles include: E22LTA2QB E-Stop trigger action maintained 40mm red mushroom pushbutton; and E230, PB30, E230LB28, BB, and E230PLB28 with 40mm and 50mm push-pull maintained mushroom operators to ensure acceptance by machinery inspectors. These products are tested by DEMKO, a third party European Standards company.

---

**What does AutomationDirect offer?**

AutomationDirect offers the Eaton/Cutler-Hammer E22 push-pull and twist-to-release E-Stop devices that meet EN418 requirements. Part numbers and styles include: E22LTA2QB E-Stop trigger action maintained 40mm red mushroom pushbutton; and E230, PB30, E230LB28, BB, and E230PLB28 with 40mm and 50mm push-pull maintained mushroom operators to ensure acceptance by machinery inspectors. These products are tested by DEMKO, a third party European Standards company.

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**What else should I know?**

Ensuring compliance with EN 418 is imperative to avoid problems associated with even minimal non-compliance. Most major suppliers of pilot devices have products that may meet the requirements of EN 418, but some do not carry a third party testing certificate. Others may have products such as momentary devices and maintained twist-to-release devices that do NOT meet the EN418 requirements for positive opening operation. To ensure EN 418 compliance, OEMs should thoroughly research and specify with their customer, the type of E-Stop device being used.

---

**Emergency Stop Integrity**

The E22 self-monitoring circuit contact block Eaton/Cutler-Hammer has an additional circuit to monitor its self-monitoring device. The Emergency OFF device must be “self-monitoring” (maintained) devices. Without the self-monitoring circuit contact block, the E-Stop becomes a weak link in the E-Stop safety relay circuit.

How it works: An extra circuit is wired in series with the normally closed (N.C.) contact. It monitors whether the contact block is removed from, or remains attached to the Emergency Stop operator. This provides an extra margin of safety and a higher level of integrity in the proper functioning of the Emergency Stop switch. Without the self-monitoring circuit contact block, there would be no detection of a fault if the contact block became disengaged. Without the self-monitoring circuit contact block, the E-Stop becomes a weak link in the E-Stop safety relay circuit.

---

**Circuit Contact Block**

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Tech Thread
Numbering Systems Explained

Numbering Systems
by Keri Schieber, AutomationDirect

There are several types of numbering systems typically used in automation equipment: Binary, Hexadecimal, Octal, BCD, and Floating Point (Real). If you are to use them, you can be confusing. This article, from our Technical Support web page, explains the different numbering systems.

Binary Numbers

Computers, including PLCs, use the Base 2 numbering system called Binary or Boolean. There are only two valid digits in Base 2: 0 and 1 (OFF and ON). You would think it would be hard to have a numbering system built on Base 2 with only two possible values, but it can be done by encoding, using several digits.

Each digit in the Base 2 system, when referenced by a computer, is called a bit. When four bits are grouped together, they form what is known as a nibble. Eight bits—or two nibbles—is a byte. Sixteen bits—or two bytes—is a word (Table 1). Thirty-two bits—or two words—is a double-word.

H exadecimal Numbers

As you have probably noticed, the Binary numbering system is not very easy to interpret. For a few bits, it is easy, but larger numbers tend to take up a lot of room when writing them down and it is difficult to keep track of the bit position while doing the conversion. That is where using an alternate numbering system can be an advantage. One of the first numbering systems used was Hexadecimal, or it is for short.

Hexadecimal Numbers

Here is a numbering system that uses Base 16. The numbers 0-9 are represented normally, but the numbers 10p through 15p are represented by the letters A through F, respectively (Table 3). This works well with the Binary system as each nibble (11112) is equal to 15p. Therefore, for a 16-bit word, you could have a possible Hex value of FFFp. See Table 4 for an example.

Hex-to-decimal conversions work much the same way as Binary. C216 would be equal to 19410 (12*161 + 2*160 or 19210 +13*161 +4*160 or 409610 +153610 +20810 +410). A6D4 16 would be equal to 42708 10 (10*163 +6*162 +4*161 +2*160 +9*16-1 +5*16-2 +4*16-3). The formula and layout of the number is as follows:

Number = 1.M*2(E-127)

M = Mantissa
E = Exponent

Calculating the Real number format is a very complex operation. If you are interested in the conversion process, there are numerous documents on the Internet that go into specific detail. You may have noticed that there is not a minimum or maximum value given for the Real number format. The range is from negative infinity to positive infinity. Having said this, and having noticed that there are only 32 bits possible to create every number, it is easy to surmise that not all numbers can be represented. This is in fact the case. There is an inherent extent of error with the Real format.

I’m sure you’re wondering how much error can exist and if there is a lot of error, why is this format used? It really depends on the application. For most PLC applications, unless you are aiming for 100% accuracy, the Real format will not pose many problems. Most of the time the inherent error can be ignored, but it is important to know it exists.

Data Type Mismatch

Data type mismatching is a common problem when using an operator interface. Mismatching is a bigger problem than you might think. It can be the difference between a PLC reading a real number correctly or not at all.

Here is a table showing some examples of what a data type mismatch can look like. BCD stands for Binary Coded Decimal and Real refers to Floating Point, the term used in PLCs to denote a floating-point number.

As you can see, there is a great deal of difference between BCD and Real numbers. It is important to understand the difference between these number types.

Let’s look at a larger number shown in Table 10.
Tech Thread

Numbering Systems Continued

As a BCD number, the value is 4096. If we interpret the converted BCD number as Binary, the Decimal value would be 16384. Similarly, if we interpret the Binary number as BCD, the Decimal value would be 1000.

Signed vs. Unsigned Integer

So far, we have dealt with unsigned data types only. Now let’s talk about signed data types (negative numbers). BCD representation cannot be used for signed data types.

In order to signify that a number is negative or positive, we must assign a bit to it. Usually, this is the Most Significant Bit (MSB) as shown in Table 11. For a 16-bit number, this is bit 15. This means that for 16-bit numbers we have a range of −32,767 to 32,767.

We have two ways of encoding a negative number: Two’s Complement and Magnitude Plus Sign. The two methods are not compatible.

As long as the value is positive (bit 15 is OFF), then the rules work similarly to binary. If bit 15 is ON, then we must know which encoding method was used.

The Magnitude Plus Sign is the easiest to decode. Basically, the negative number is in the same format as the positive number, except with bit 15 ON (Table 12).

Two’s Complement is slightly more difficult. The formula is to invert the binary value and add one (Table 13).

Table 11

<table>
<thead>
<tr>
<th>Magnitude Plus Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decimal</td>
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Table 12

<table>
<thead>
<tr>
<th>Two’s Complement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decimal</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>100</td>
</tr>
</tbody>
</table>

Table 13

Obviously, numbering systems vary and yet are similar. It is vital to know which system is being used in order to program the application properly. A methodical and logical approach to understanding a given number system being used makes interpreting the data less complex.

Technical Review

Control System Design

A Condensed Guide to Automation Control System Specification, Design and Installation

Part 3: Design

by Tom Elskay, AutomationDirect

In Part 2 (Spring 2005 issue 4), we covered how to specify the various devices required for interfacing and controlling the electrical equipment in an automated control system.

In Part 3, we will cover the steps needed to design our automated control system. The design topics will include planning by defining our sequence of operation, creating a schematic with the devices shown in a high-voltage to low-voltage order, input to output design layout, panel layout, wiring diagrams, bill of materials, software tools to document our design, choices between using hard-wired relays versus a PLC with programming, etc.

As stated in the previous articles, special expertise is generally required to design, wire, install, and operate industrial automation control systems. Persons without such expertise or guidance should not attempt control systems, but should consider seeking the services of a qualified System Integrator. Control systems can fail and may result in situations that can cause serious injury to personnel or damage to equipment. The information provided in this series of articles is provided “as is” without guarantee.

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Magnitude Plus Sign

Table 11

<table>
<thead>
<tr>
<th>Decimal</th>
<th>Binary</th>
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<tr>
<td>100</td>
<td>0000 0000 1010 0100</td>
</tr>
<tr>
<td>100</td>
<td>0000 0000 1010 0100</td>
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</tbody>
</table>

Two’s Complement

Table 12

<table>
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<th>Decimal</th>
<th>Binary</th>
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<tbody>
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Two’s Complement

Table 13

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<th>Decimal</th>
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<tr>
<td>1111 1111 0101 1010</td>
<td></td>
</tr>
</tbody>
</table>

Design

The design for our control system will be in the form of a documenting task. The challenge will be to get our design specifications down on paper so that it can be easily understood. It is important that anyone can look at our documents in the future and be able to interpret the information. Useful to us at this step will be any notes and lists that were developed during the “Identifying” and “Specifying” steps and actions that need to take place. Figure 1 shows a partial example of a flowchart.

A flowchart can be developed with graph paper and-area chart, or an application software program such as Microsoft Visio®, Microsoft Word software program has a built-in drawing tool that contains flowchart symbols.

In some cases, the application may be better suited to using a timing chart, in which each condition and event is graphed in a time relationship to each other, as shown in Figure 2.

Once we have a sequence of operation developed and a list of our input and output devices, we can determine our automated control system is best suited for hard-wired relay logic or can benefit from a PLC. A PLC can be cost-effective when used in place of only a half dozen industrial relays and a couple electronic timers. It adds the flexibility of making future “logic” changes without the labor of making wiring changes.

Schematic

The next step in our design is to develop a schematic. Most electrical designers and engineers define a schematic as a drawing that shows the logical wiring of an automated control system. A control schematic is normally drawn in the form of a ladder, showing the various wiring conditions. This analogy of a ladder is what PLC ladder logic was based upon. It made the transition to PLC ladder logic easier for engineers and electricians because they were accustomed to troubleshooting hard-wired relay control systems shown in a ladder fashion.

It is normal practice, as shown in Figure 3, to show input type devices on the left-hand side of drawings and output devices on the right-hand side. For example, the symbols for protective devices (fuses), contacts and overload relay elements are shown to the left, while the symbol for the motor is shown to the right.

The schematic should start with the incoming power, including protective devices such as circuit breakers and/or fuses. Our design should show the distribution of the AC power and include all circuitry and required devices for conformance to the National Electrical Code (NEC)2 and any local codes that might apply in our area.

Electrical isolation provides safety, so that a fault in one area does not damage another. Using Figure 5 as reference, we see a transformer which provides magnetic isolation between its primary (high voltage) and secondary (control voltage) sides. A power-line filter provides isolation between the power source and the electronic devices.

Continued, p. 26 >>
Why is grounding important? Electronic instrumentation such as PLCs and field I/O are typically surrounded by various types of electronic devices and wires. These electronic devices may include power supplies, input/output signals from other instrumentation, and even devices that are near the instrumentation enclosure. All these may present a risk of Electromagnetic Interference (EMI) or transient interference. This type of interference may cause failure or erratic operation of the device.

Proper grounding is one of the most important things in good automated control system design. More details can be found at the schematic to reflect all points that need to be grounded. The better chance we have of properly grounded control system that provides both safety and functionality.

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Isolation transformers should be used near equipment that produces excessive electrical noise. If DC power is required in our control system, we need to calculate the worst case amperage draw (load) of all the devices that will be powered from the DC supply. We also need to look at the amount of ripple the devices being powered can tolerate and select a DC power supply that can meet the most stringent requirement. Ripple is the amplitude of the AC component that rides on the DC voltage signal. A typical rating for most applications involving DC powered sensors would be 100 mV peak-to-peak. It is also a good idea to double the calculated amperage capacity of the DC power supply. This is especially important if our control system needs to meet Underwriters Laboratories, Inc. (UL)® 508A.

The next section of our schematic will show the hard-wired devices that are powered from our control voltage (115 VAC). If our control logic is based on hard-wired relays, this is where we would show the hard-wired connections, along with the normal 115 VAC powered devices, such as DC power supplies, 115 VAC power to PLC power supplies, auxiliary devices, etc. Figure 6 is a partial example of the hard-wired section of our schematic.

Figure 5

Figure 5 also shows some general suggestions for device grounding and distributing the control power to various devices, along with individually fusing these devices.

The terminal blocks can be sized, organized and even color-coded to handle the different types of signals that enter and leave our control panel. We may choose to use black for high voltage, red for inputs, violet for outputs, etc. We should try to locate the terminal blocks so they provide the best wire routing from the components to the terminal blocks. The terminal blocks also make it convenient for the electrician to terminate wiring when the control enclosure is installed.

Our design should include the selection of the enclosure that will house our control system. We need to consider the environment, where the enclosure will be located. Outdoor? Indoor? Wash down required? Refer to the section on enclosures in Part 2 of this series of articles for references to NFPA’s National Electrical Code (NEC)®, the National Electrical Manufacturer’s Association (NEMA)® Type 1, 2, 3, 4, 5, 6, and a list of items to consider when selecting an enclosure.

Bill of Materials

The Bill Of Materials (BOM) should list each component in our automated control system, the quantity of each component, any designations or “marks” that allow us to easily identify the component on our schematic, a description of the component, and its part number. We also have comments or remarks about the component that will help the panel builder know what needs to be done when the control panel is being built. Figure 9 is a short example of a BOM of materials.

The higher voltage devices (those that operate at 240/480 VAC) should be mounted toward the top of the panel, keeping as much distance as possible between the high-voltage devices and any electronic devices, such as PLCs, DC power supplies, electronic timers, etc. Keeping the high-voltage devices toward the top allows us to cover all of the high-voltage devices with a non-conductive safety shield for personnel safety. It keeps the lower voltage devices grouped together, allowing access to wiring terminals that will aid in troubleshooting our control system. In some cases, a metal partition between the high-voltage section of our control panel and any sensitive electronic devices can act as a shield from any EMI generated by the high-voltage devices.

In our panel layout design, we need to include wire duct between the various components. The wire duct simplifies the wiring routing between components, keeps the wires in place, makes working with the wires easier, and gives the panel a well-organized look. We should also make use of terminal blocks in our design.

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**Technical Review**

**Control System Design Continued**

It should include all control enclosures or cabinets, any external devices that are wired into control enclosures, junction boxes, conduits, wireways, etc. The wiring diagram usually includes conduit sizes, distances, number of conductors between devices, wire sizes, colors, wire numbers, terminal blocks, etc. The wiring diagram is also useful for system startup and later for locating wiring routes and devices during troubleshooting.

**Design Tools**

Although all of the tasks related to documenting the design can be performed with nothing more than a pencil, a ruler, it is normally more efficient to use software drafting tools, such as AutoCAD® or AutoCAD LT®. The biggest advantage in using software drafting programs to create schematics, panel layouts, bill of materials and wiring diagrams is the ability to reuse the work for future electrical control system designs. The drafting software can also be used to create our sequence of operation, flowchart or timing diagram. Add-ins for the various drafting software packages are geared toward electrical control system design. These add-ins contain pre-constructed elements of different manufacturers' electrical devices. This may include schematics of PLC I/O modules, power supplies, communication devices, etc. These pre-constructed elements also include scaled outline of relays, motor starters, terminal blocks, etc. that can be dropped into your panel layout design. One such add-in package that works with AutoCAD and AutoCAD LT for electrical control design and includes some pre-constructed elements for various PLC manufacturers is ECT’s "promis e draw" software. More information on the promise draw can be found at: http://www.automationdirect.com/static/specs/pcdrawspecs.pdf. This software has the ability to act as a database for components that would be used in our control system design and can aid in coordinating the components between our schematic, panel layout and bill of materials.

Discussion of automation control systems will continue in our next issue with Part 4, Build, Install and Maintain.

**Footnotes:**

1. For “Considerations for Choosing a PLC,” refer to: http://support.automationdirect.com/docs/ worksheet_guide_lines.html
2. The National Fire Protection Association® (NFPA®) produces the National Electric Code® (NEC®), Publication NFPA 70. Further information can be found at: http://www.nfpa.org/ Another good reference is the NFPA 45, Electrical Standard Industrial Machinery, Publication NFPA 79.
3. Addional UL information can be found at: http://www.ul.com/controlequipment/devices.html
4. Information for the National Electrical Manufacturer’s Association (NEMA) can be found at: http://www.nema.org/. NEMA is also being harmonized with the International Electrotechnical Commission (IEC) and other European standards. Additional information can be found at the Global Engineering Documents’ Web site (www.gloabalhls.com). Global Engineering Documents is also the source for obtaining NEMA, IEC and CE documents.
5. Additional information can be found on OSHA’s Web site (http://www.osha.gov/SLTC/controlhazardso.html).

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**FYI**

**Wiring Combinations**

How to Wire a Motor Starter

by Ken Scheiber, AutomationDirect

The Technical Support page on the AutomationDirect web site is full of valuable information and is available 24/7. The following was referenced from the Technical and Application Notes section:

A motor starter is a combination of devices used to start, run, and stop an induction motor based on commands from an operator or a controller. In North America, an induction motor will typically operate at 230V or 460V; 3-phase, 60 Hz and has a control voltage of 115 VAC or 24 VDC. Several other combinations are possible in North America and other countries, and are easily derived from the methods shown in this document.

The motor starter must have at least two components to operate: a contactor to open or close the flow of energy to the motor, and an overload relay to protect the motor against thermal overload. Other devices for disconnecting and short-circuit protection may be needed, typically a circuit breaker or fuses. Short-circuit protection will not be shown in the examples that follow.

The contactor is a 3-pole electromechanical switch whose contacts are closed by applying voltage to a coil. When the coil is energized, the contacts are closed and remain closed, until the coil is de-energized. The contactor is specifically designed for motor control, but can be used for other purposes such as resistive and lighting loads. Since a motor has inductive reactance, the breaking of the current is more difficult so the contactor has both a horsepower and current rating that needs to be adhered to.

The overload relay is a device that has three current sensing elements and protects the motor from an overcurrent. Each phase going from the contactor to the motor passes through an overload relay current-sensing element. The overload relay has a selectable current setting based on the full load amp rating of the motor. If the overload current exceeds the setting of the relay for a sufficient length of time, a set of contacts open to protect the motor from damage.

This article shows how to wire various motors using the Fuji series of contactors sold by AutomationDirect. Other brands of contactors may be wired the same or similar. Consult the manufacturer’s wiring diagrams for other brands of contactors.

There are four basic wiring combinations:

- Full-voltage non-reversing
- Full-voltage reversing
- Single-phase motors
- Full-voltage non-reversing 3-phase motors
- Full-voltage reversing 3-phase motors
- Single-phase motors
- Full-voltage non-reversing 3-phase motors
- Single-phase motors

This diagram is for single-phase motor control. It uses a contactor, an overload relay, one auxiliary contact block, a normally open start pushbutton, a normally closed stop pushbutton, and a power supply with a fuse. The start, stop, and timing circuits can also be controlled using PLC inputs and outputs.

Full-voltage single-phase motors

**Wye-delta open transition 3-phase motors**

The following diagram is shown for 3-phase motor control of a delta-star connection. It uses three contactors, an overload relay, one auxiliary contact block, a normally open start pushbutton, a normally closed stop pushbutton, and a power supply with a fuse. The start, stop, and timing circuits can also be controlled using PLC inputs and outputs.

Full-voltage reversing 3-phase motors

The following diagram depicts 3-phase non-reversing motor control with 24 VDC control voltage and manual operation. We will use a contactor, an auxiliary contact block, an overload relay, a normally open start pushbutton, a normally closed stop pushbutton, and a power supply with a fuse. The start and stop circuits can also be controlled using PLC inputs and outputs.

Full-voltage non-reversing 3-phase motors

The following diagram depicts 3-phase non-reversing motor control with 24 VDC control voltage and manual operation. We will use a contactor, an auxiliary contact block, an overload relay, a normally open start pushbutton, a normally closed stop pushbutton, and a power supply with a fuse. The start and stop circuits can also be controlled using PLC inputs and outputs.
buried holiday seasons, is an annual celebration held the first week of May to celebrate Greenery Day, Constitution Memorial Day, and Children’s Day. Many companies close for several days, allowing people to travel, sightsee, and participate in the festivities.

We kicked off our event in late April by decorating our main lobby with colorful carp flags and streamers, which symbolize strength, power, and success in life. In Japan, this is a traditional practice of parents to commemorate the health and future success of their sons. (A Girl’s Festival is celebrated March 3.) Our flags were proudly placed in honor of our Japanese team members.

"A Taste of Japan"
Cultural Observance

A classic puzzle describes the hunter who walks a mile south, turns and walks a mile east, turns again and walks a mile north. He is surprised to find himself right back where he started. He then shoots a bear. What color is the bear? The answer is usually given as “white”, because the hunter must have started his 3-mile walk at the North Pole. Can you find some other places on the globe where you could follow those same directions and end up at your starting point?

Hints: No polar bears near any of those places!

2. Out of Sight
Fred has designed a new machine for the factory where he works. His design was followed perfectly, but he forgot to specify the order, and the labels, for four light switches on the control console. These four on-off switches are wired to four ordinary light bulbs on the far end of the machine—out of sight from the control room panel. He knows that each switch is correctly wired to one of the lights. He knows that all the bulbs are new and working, and he even knows the on and off position of the switches, but he doesn’t know which light is connected to each switch.

Fred's boss is on the way out to the factory floor to see a demonstration of the machine, but Fred must determine how the switches and lights are wired before he can give a successful demonstration. He only has time for one trip down to the far end of the machine where the lights are mounted. How can Fred determine which switch controls each light in a single trip without anyone to help him?

As we tasted authentic Japanese foods prepared by Mr. Ono, our guest sushi chef, volunteers from the Atlanta Japanese Cultural Center introduced us to culture, art, clothing and other traditions. Many thanks to our Japanese team members and their families for the success of "A Taste of Japan" at AutomationDirect.

Our flags were proudly placed in honor of our Japanese team members.

Golden Week, one of Japan’s three
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- 250, 500 and 600 VAC rated general purpose fuses, some up to 50 amps
- Available in time-delay and fast-acting models
- Fuse holders and fuse blocks available in 1, 2 and 3-pole models for convenient fuse installation and replacement.

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<th>Type</th>
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<td>$4.30</td>
<td>$11.09</td>
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