The Other 5 Wires Of EtherNet/IP In-Cabinet Solution

Yutao (Tony) Wang
Sr. Project Engineering EtherNet/IP In-cabinet Architecture Lead
Rockwell Automation, Inc.

Chirag Malkan
Senior Manager, Advanced Engineering
Rockwell Automation, Inc.

Kelly Passineau
Product Manager
Rockwell Automation, Inc.

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Abstract

The rapid evolution of Single-Pair Ethernet (SPE) technology is revolutionizing the industrial panel building sector by introducing groundbreaking advancements in control wire reduction and, in certain cases, even eliminating the need for control wiring altogether. This paper highlights the transformative impact of the SPE/T1S implementation, as defined by ODVA's released specification in April 2021, which introduces a flat ribbon solution consisting of seven conductors. Five of the conductors are specifically designed to streamline panel wirings, significantly simplifying the complex network of connections by providing switch power for in-panel devices, thereby reducing the dependency on traditional control wiring methods. The remaining two conductors are responsible for enabling seamless SPE/T1S connectivity, ensuring optimal communication between devices. By leveraging SPE technology and the SPE/T1S implementation, industrial panel builders can benefit from improved efficiency, reduced complexity, and enhanced performance in their control systems. This paper sheds light on the significant potential of SPE technology to reshape the landscape of industrial panel building, empowering businesses to optimize their operations and embrace the future of streamlined and efficient control wire solutions.

Keywords

EtherNet/IP, Constrained-Node Networks, APL, In-cabinet, Ethernet, IEEE 802.3, IEEE 802.3cg, IEEE 802.3da, Single-pair, SPE, Industrial Automation, Process Automation, Fieldbus, ODVA, Reference Geography, Network Power, Select Line, Select Line Protocol, IDC - Insulation Displacement Connector, Device Commissioning, Network Commissioning, 5 wires.

Definition of terms

Industrial Automation	Discrete, Process, and Hybrid (Batch) Automation
IP	Internet Protocol
IEEE Std 802.3cg-2019	Ethernet standard, including 10BASE-T1L and 10BASE-T1S PHYs
PHY	PHYsical layer connecting a link layer to a physical medium
MAC	Medium Access Control layer (IEEE)
SPE	Single Pair Ethernet
PoDL	Power over Data Line (IEEE single pair power)
Fieldbus	Industrial network protocol for real-time control
Industrial Ethernet	Fieldbus protocol operable over Ethernet
Edge	Leaf nodes attached to a network core, i.e., sensor and actuators
Gateway	Network protocol converter spanning ISO model layers
Switch	IEEE 802.3 bridge, forwarding based on MAC addresses
IT	Information Technology
OT	Operational Technology
MES	Manufacturing Execution Systems
Purdue Model	Layered functional automation model
IIoT	Industrial Internet of Things
Point-to-point	Communication link with a single device at each end
Multi-drop	Communication link with multiple devices sharing the same link
Program Logic Controller (PLC)A	PHY-level Collision Avoidance, multidrop determinism protocol
Full duplex	Simultaneous communication in both direction on a link
Half-duplex	Communication in a single direction at a time on a link
MCU	Micro Controller Unit
ASIC	Application-Specific Integrated Circuit
Network Commissioning	Process of commissioning all devices on a network
Device Commissioning	For Constrained Devices on EtherNet/IP network is the setting the IP Address to a minimum.
NP	Network Power
SP	Switched Power
SP Tap	Supplemental Power Tap, also referenced as Power Tap
MAC	Media Access Control
PLC	Program Logix Controller, Programmable Logic Controller
I/O	Input/Output modules, provides discrete logical inputs and logical outputs for machine logic control
SELV	SELV is an electric system in which the voltage cannot exceed the value of extra-low voltage: – under normal conditions and – under single fault conditions, including earth faults in other electric circuits. SELV is the abbreviation for safety extra-low voltage.
PELV	PELV is an electric system in which the voltage cannot exceed the value of extra-low voltage: – under normal conditions and – under single fault conditions, except earth faults in other electric circuits. PELV is the abbreviation for protective extra-low voltage.

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Purpose of Paper

This paper explains the key technology that enables the use of Single Pair Ethernet (SPE) inside industrial cabinets. We go into detail about the SPE setup inside the cabinet and discuss how it solves familiar challenges found in industrial cabinets.

(The “NOW”) Conventional Control Panel Control Wiring Methods

For over a century, the methodology of in-cabinet wiring within industrial automation has remained constant. Such longstanding procedures are now on the cusp of transformation. By delving into the intricacies of control system design, installation, and testing/troubleshooting, we can shed light on the inherent challenges posed by traditional discrete wiring techniques. For the purposes of this discussion, it's important to note that terms like "industrial panels," "industrial control panels," "in-cabinets," and "in-panels" are all synonymous and will be used interchangeably throughout this paper.

In-Cabinet I/O Control Wiring: Design, Installation, and Challenges in Industrial Automation

The control wiring for in-cabinet I/O devices, such as push buttons and motor starters, is an essential area in industrial automation. The interface between physical components and their logical control is critical for the smooth operation of any system and is traditionally hardwired in various point-to-point configurations. These types of in-cabinet devices have long been used in electrical control systems providing machine control as they serve as inputs and outputs for traditional Program Logic Controller (PLC) control.

Figure 1 Conventional Panel

During the **design phase**, the Bill of Materials (BOMs) is the primary reference, detailing components, their specifications, and required quantities. Once the BOM is established, the wire up phase follows, components are connected according to the design. It's worth noting that the complexity inherent in this process increases the chances of errors, making meticulous attention to detail a necessity.

The type of control logic interfacing is also determined within this phase. There are two main approaches:

PLC system with I/O modules	Hardwired logic method
I/O modules interpret device inputs and produce the necessary outputs.	Referred to as 'wire-logic' and some applications do not require PLC I/O wiring.
PLC inputs and outputs are hard-wired directly to the device.	The PLC inputs and outputs are hard-wired directly to the device.
	Typical application would utilize a Hand/Off/Auto selector switch, whereas the Hand position provides local control and Auto position provides PLC control.

Here is a typical example of PLC I/O (hard wiring) where the PLC does all the "Soft" logic:

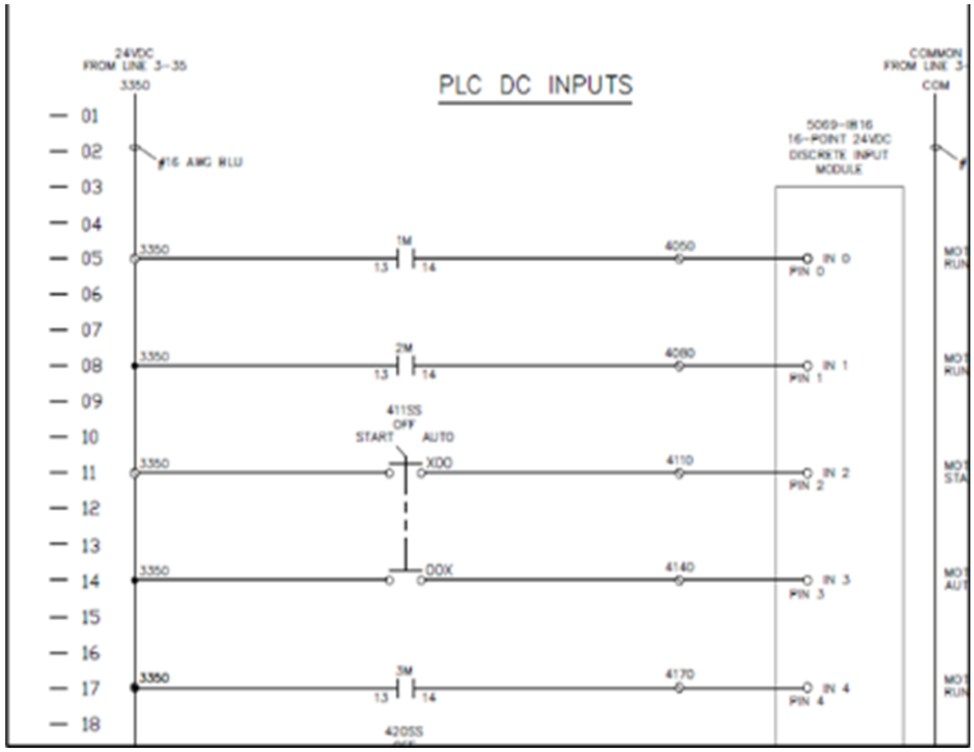


Figure 2 Example of PLC Logical **Input** Wiring

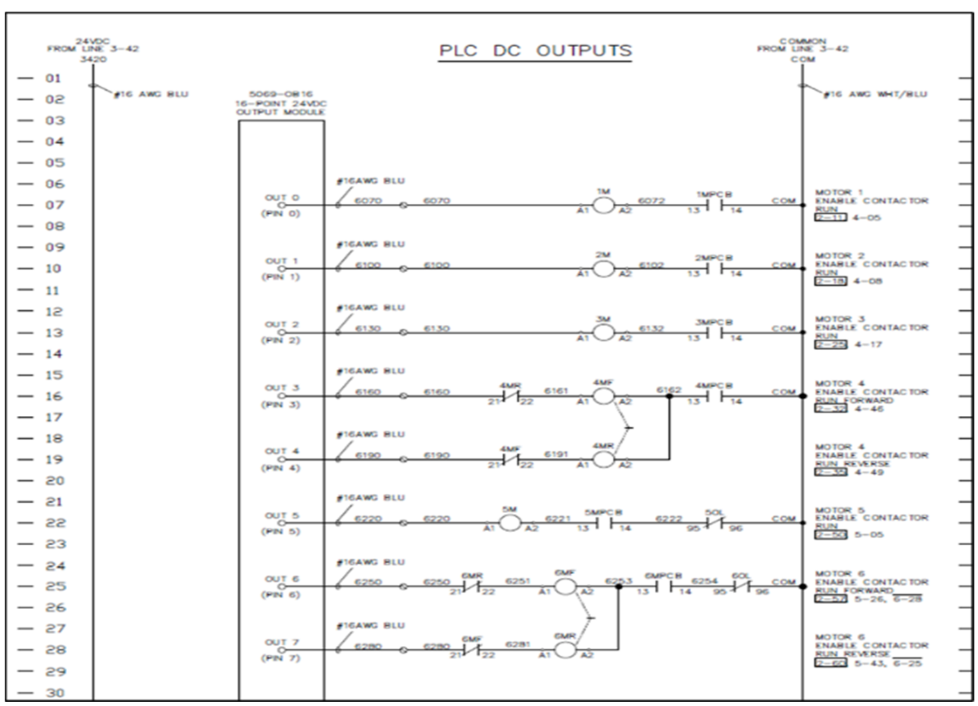


Figure 3 Example of PLC Logical **Output** wiring

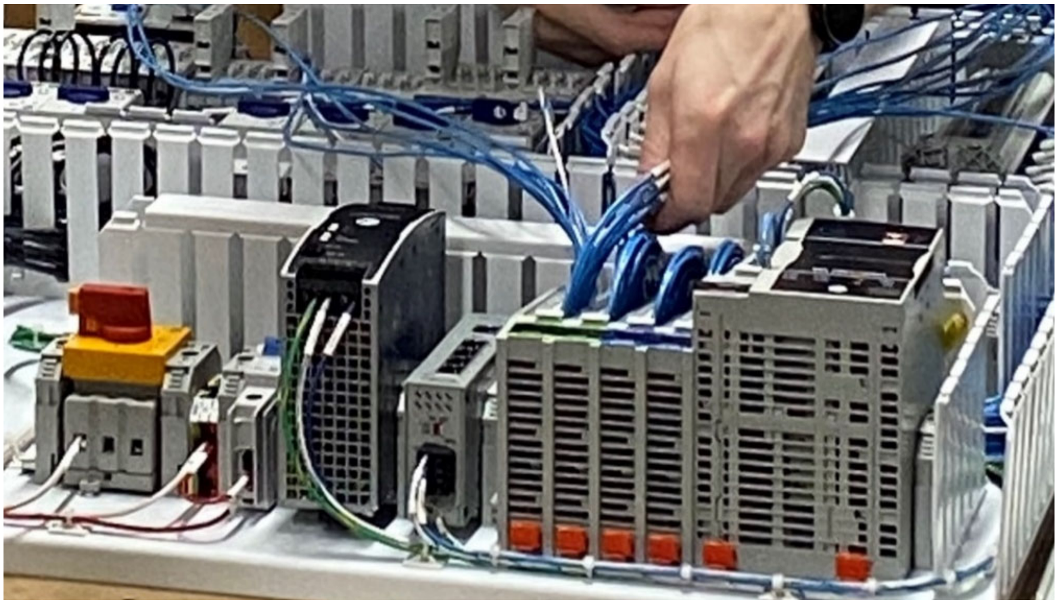


Figure 4 Wiring Conventional Panel

Here are two examples of “wire logic” without a PLC. Whereas components are hard-wired into logic.

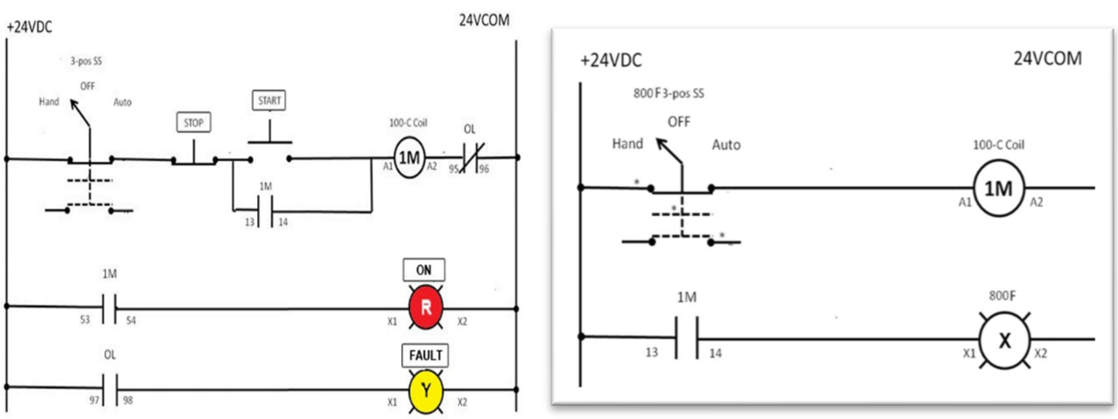


Figure 5 Wire logic without Program Logic Controller (PLC)

Figure 6 Wiring without Program Logic Controller (PLC)

While the PLC approach does use more I/O points, it does provide more adaptability and can be more straightforward to modify or reconfigure.

Wiring Method	Pro	Con
Program Logic Controller (PLC) I/O	• Easy to wire • Easy to control & configure • Easy to troubleshoot • Easy to accommodate system changes/additions	• Consumes more I/O points
Wire Logic	• Consumes less I/O points	• More difficult to wire • Increased risk for wiring mistakes • Difficult to troubleshoot • Difficult to add/change system design

Table 1 Wiring Methods Pros/Cons seen by Industrial Automation Customers

Control Wiring in Industrial Automation: Installation, Estimation, and Troubleshooting

In the ***installation phase*** the physical components are properly mounted and wired and depending on the control system's complexity hundreds of individual control wires will need to be installed.

Figure 7 Conventional Panel

 In estimating the cost of installation, ***6 minutes per wire*** (3 minutes per termination) is an appropriate guide. Six minutes to measure, cut, strip the ends, label, and terminate. A single motor starter (non-reversing) wired with a Hand/Off/Auto (HOA) selector and 3-wire start/stop requires 13 physical wire terminations.

Troubleshooting is an inevitable part of any industrial automation project. This process often starts by tracing the control wiring, especially when guided by error messages from the Program Logic Controller (PLC). Essential tools in this phase include continuity checks, voltage measurements, and isolating parts of the system to identify the problem source. Common issues often encountered include loosened connections, failed contacts, and problems caused by environmental wear and tear.

In summary, control-wiring for I/O devices is a complex but vital area in industrial automation. Proper design, installation, and troubleshooting practices are key to ensuring system reliability.

Trends and Advancements in Control Wiring for In-cabinet I/O Devices

The industrial automation sector is undergoing significant transformations, necessitating a re-evaluation of traditional methodologies associated with control wiring for in-cabinet I/O devices.

In the Commissioning Workflow, **precision is paramount**. The establishment of a system's foundation requires meticulous configuration of components, ensuring alignment with both design specifications and operational parameters. This step serves as a precursor to the broader system implementation and is pivotal in avoiding downstream complications.

The Design Workflow is where we observe a noticeable shift towards **efficiency**. Modern practices advocate for a systematic allocation of wiring numbers and I/O points. Coupled with comprehensive physical configuration drawings and schematics, this method champions clarity and reduces the room for error. For visual clarity, a comparative illustration drawing a clear demarcation between traditional and current wiring approaches.

Figure 8 Traditional hardwire control *Figure 9 EtherNet/IP in-cabinet solution*

As we delve into the Characteristics of Modern Control Wiring, the significance of innovations like EtherNet/IP in-cabinet solution becomes evident. When integrated with terminal nodes in devices such as push buttons and motor starters, it offers an alternative to the ubiquitous PLC controllers. This strategy eliminates the dependency on the “PLC Soft Logic" wiring. The tangible benefit? A marked reduction in traditional I/O wiring, promoting system streamlining and reliability enhancement. To elucidate this transition, before-and-after visuals shown in Figures 8-10 can serve as compelling evidence of the efficiency gains and system optimization.

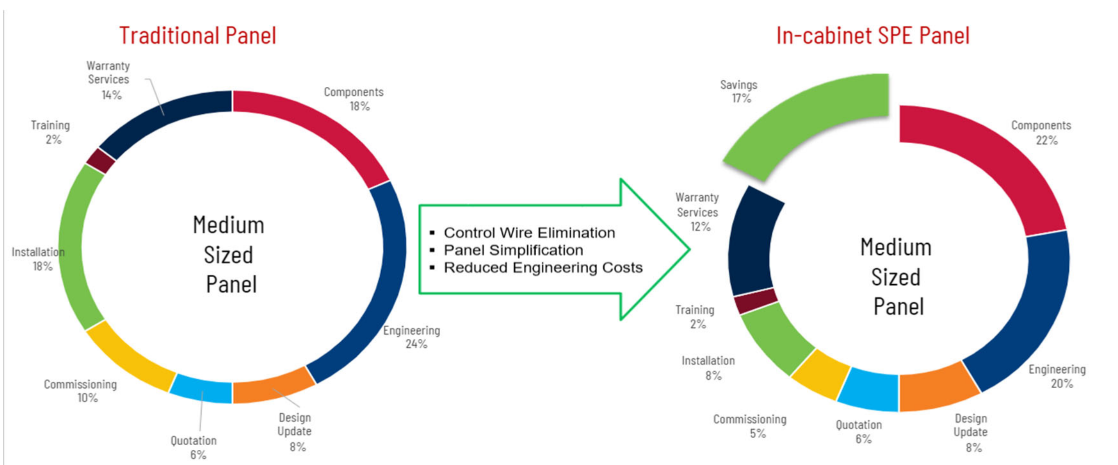


Figure 10 EtherNet/IP in-cabinet solution cost savings

Lastly, an evaluation of the PLC approach is necessary. While this methodology does intensify the consumption of I/O points, its strength resides in configurational simplicity. In an industry characterized by rapid technological shifts, the ability to swiftly adapt and modify systems becomes invaluable.
To encapsulate, as industrial automation strides forward, the embrace of these progressive advancements methodologies in control wiring is not just advantageous—it's imperative. Ensuring adaptability and efficiency in in-cabinet devices will undeniably influence the future trajectory of the industry.

Future view: Control Panel Control Wiring Method Benefits

As we look towards the future of industrial automation, it's imperative to consider the evolving needs and challenges faced by panel builders and machine manufacturers. Their role is central to the implementation and success of any automated system, and as such, the tools, and methodologies they employ can impact the efficiency and reliability of the entire operation.

A paramount concern is **Efficiency and Accuracy,** introduced in the previous section. With the rapid advancements in control wiring techniques, there is an opportunity to drastically improve the speed and precision of panel building. Streamlined wiring techniques and intuitive device interfaces can significantly reduce the margin for error. The result? *Faster* panel construction without compromising quality. By introducing systems that are straightforward to assemble and connect, panel builders can expedite their processes and ensure the reliability of their work.

The industry is also grappling with **Labor Challenges**. There is a palpable shortage of workers, making it increasingly challenging to onboard individuals for panel building tasks. This scarcity is further compounded when seeking individuals with specialized skills, such as the ability to read ladder logic or interpret electrical line diagrams.

Moreover, the deficit is not limited to numbers alone. **Expertise Shortages** are a pressing concern. Finding personnel skilled enough to not only assemble but also trace and troubleshoot potential issues is becoming a rare commodity. As systems grow more complex, the value of these skilled professionals cannot be understated.

Looking even further ahead, the **Future Workforce** presents unique challenges and opportunities. As newer generations enter the field, their interaction with these systems will differ significantly from their predecessors. For them, many of these system components will be networked and simply understood as “just another node” on the network. This shift in perception will necessitate changes in training methodologies, ensuring that foundational knowledge is transferred amidst the rapid technological evolution.

These real benefits of “modernizing” the work on industrial in-cabinet builders and machine manufacturers are foundational to the value and enable other Single Pair Ethernet (SPE) benefits such as cyber security, data mining, etc. to solve industrial automation trends as carbon footprint reduction and cybersecurity resiliency.

In summary, the future of panel building in industrial automation is poised for transformative changes. By proactively addressing challenges and leveraging advancements the potential to not only enhance efficiency and accuracy but also to prepare for the inevitable shifts in the workforce landscape.

EtherNet/IP In-Cabinet Solution

The In-Cabinet Solution is intended to replace hardwiring between devices with composite network cabling. This brings potential benefits in rapid assembly, programmable functionality, and enabling intelligence to provide greater information for maintenance and process optimization. The system achieves a reduction in device complexity by utilizing a multi-drop bus to reduce the device interface complexity and to reduce the average number of interfaces per device.

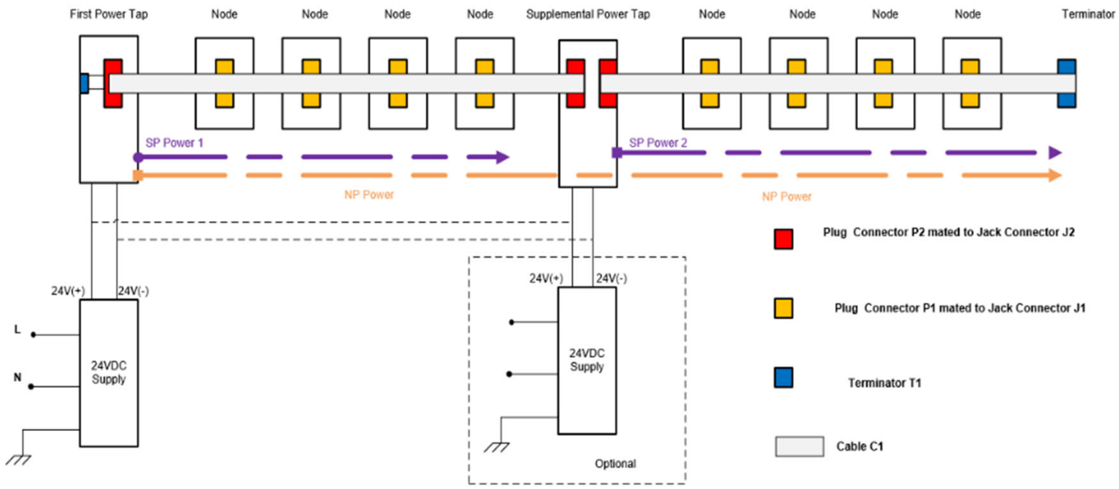


Figure 11 Power System Architecture

The First Power Tap, shown in Figure 11 supplies both NP (Network Power) and SP (Switched Power) to a multidrop bus system. Network Power supplies communication electronics with a 4 amps capacity whereas Switched Power is used for switching larger loads such as contactor coils with 4 amps capacity with boosted ampacity to 8 amps up to 100 millisecond duration. This is to account for the initial inrush current when the loads are switched on.

NP is provided to all nodes on the bus. The First Power Tap supplies SP to the first segment, to which it is directly attached. SP can be segmented for groups of nodes on the bus. A Supplemental Power Tap passes NP from an upstream segment to the next downstream segment. The Supplemental Power Tap does not pass SP from the upstream segment (SP Power 1); it supplies a separate SP to the downstream segment (SP Power 2).

The First power tap and supplemental power taps can be powered by the same 24V supply source. The total network length is 25 meters with a maximum node count of 40. The 10BASE-T1S transceiver within each node is compliant with the IEEE 802.3cg-2019 standard.

10BASE-T1S physical layer specification was published as IEEE 802.3cg-2019 amendment.

The following are key technical characteristics of the IEEE 802.3cg-2019 10BASE-T1S:

- Half-duplex multidrop (8 nodes, 25m)
- Half-duplex or full-duplex point-to-point
- 10 Mb/s, 1Vpp

ODVA specifications require the PHY to support the following:

IEEE PHY Option and Setting	Description	IEEE Reference	ODVA Support
*MULT	Multidrop mode	Clause 147.8	Required
*INS-MIX	Installation / Mixing segment	Clause 147.8	Required
aPLCATransmitOpportunityTimer	This value is assigned to define the time between PLCA transmit opportunities for the node.	Clause 30.16	Required Value = 32

Figure 11 IEEE PHY Options and Settings

The ODVA EtherNet/IP In-cabinet bus media and physical layer specification increased the node count from 8 to 40 and still meets the mixing segment specifications from IEEE 147.8 section.

EtherNet/IP In-cabinet Flat Cable

The 7-conductor flat cable interconnects communication, power, and discrete signals between devices in a bus.

NP and SP conductors are 20 AWG (19 strands). The SPE+, SPE-, and Select line conductors are 24 AWG (7 strands).

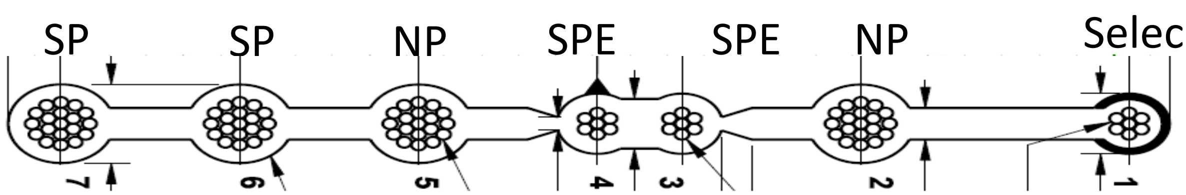


Figure 12 EtherNet/IP In-cabinet cable

NP, SP lines are rated at 4 amps. To prevent incorrect connector orientation, the cable design unique feature is the asymmetrical design of conductors, preventing wrong connector orientation.

EtherNet/IP In-Cabinet Connectors

Plug Connectors interconnect signals between a bus cable and a device Jack Connector. The connectors are applied to a flat cable by a tool that closes the connector housing, causing insulation displacement/piercing connections to penetrate the cable insulation, providing electrical connection to all the cable signals. Cable connectors are easily installed using standard pilers with no special installation tool required. Connector, when installed will sever the SPE and Select line and inline inductors compensate for node capacitance as shown in Fig. 13.

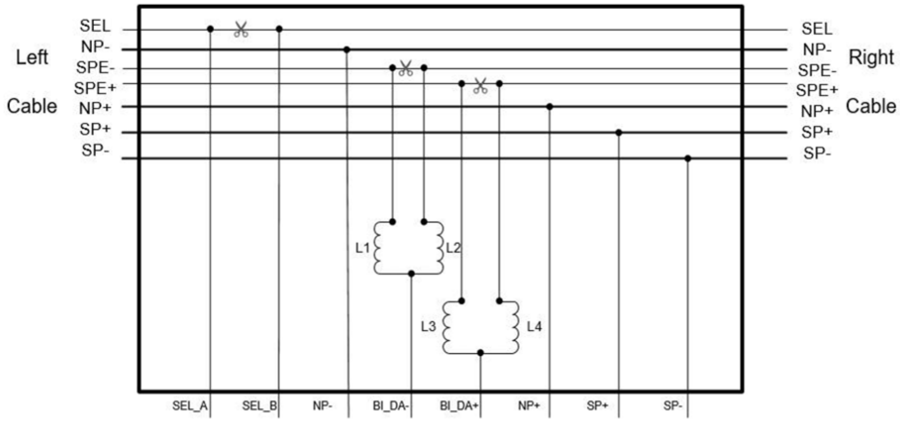


Figure 14 Plug Connector P1 Circuit

NP Power for Communication Electronics

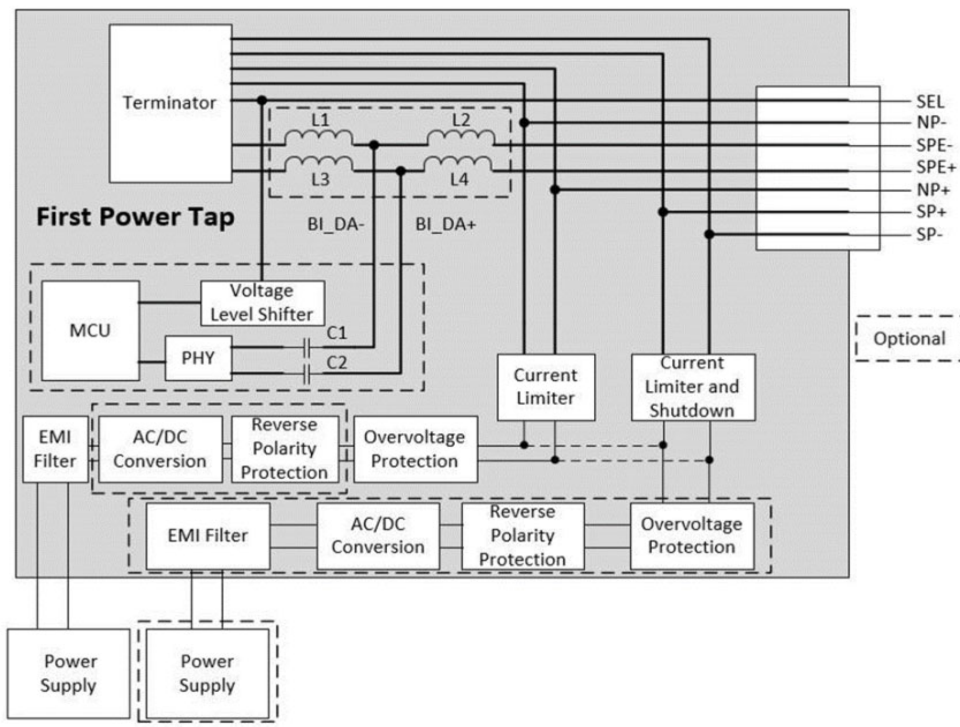


Figure 15 First Power Tap block diagram and NP Power

A First Power Tap is illustrated in Figure 15 and connects to flat cable media via Jack Connector shown in the Figure 14 diagram. The Jack Connector attaches to the entire set of signals on the cable, and supplies NP and SP. External power (24VDC, SELV or PELV compliant) is conditioned and used to generate NP and SP. The conditioning may include EMI filtering, reverse polarity protection, and overvoltage protection. NP and SP are each protected by current limitations. SP includes a shutdown circuit for sequenced control of the loads. Because the First Power Tap is placed at the end of the bus, it must provide the termination circuit for all the signals on the cable. The First Power Tap may optionally embed bus communication functionality. If communication is not implemented, the SEL, SPE+, and SPE- signals route only from the Jack Connector to the matching termination circuit. If communication is implemented, additional inductors are added to compensate for the media dependent interface (MDI) capacitance. If the First Power Tap implements a bus communication circuit; it shall also implement one, Select Line transceiver circuit and the circuit is only required to drive the SEL line.

100 milliamps are allowed for each end node device, so one power tap has enough current for all 40 nodes on the network. This allows all end node devices to tap on the same power bus for their network power.

Network output power is maxed at 100 VA, compliant to NEC class 2. This allows the end node device circuit to be simplified as it requires no further protection for shock or fire hazards.

Network Power	
NP Output Voltage	21.1 Vdc min., 26.4 Vdc max.
NP Output Current	4 A max.
NP Output Power	100 VA_{max}, NEC Class 2

Table 16 Network Power Specification

The table below enumerates the advantages and disadvantages of a continuous bus source.

Advantages	Disadvantages
One continuous bus connection	Required terminator at end of the bus
Reduction in wiring (just tap off the bus)	Excessive current draw from a single device could impact the overall supply quality
Disconnecting a device without impact to other connections	
Integrated diagnostics / fault handling like overvoltage, undervoltage	
Right sized DC supply – based on system needs. System detects if additional power is required for connected network	
Consistent power quality with a regulated, SELV (Safety Extra Low Voltage), Class 2 rated supply	

SP Power for Coil Control

No additional or separate control power wiring is required for energizing the contactor coil. Additional ampacity (8 amps max for up to 100 milliseconds) provides for multiple devices to be energized at the same time providing the capability of controlling different zones of control. If primary switched power ampacity is exceeded the use of an in-line supplemental power tap is required, consider this simply an in-line power boost to renew the SP power to 4 amps. The same 24V DC supply can be used for multiple power taps.

Switched Power	
SP Output Voltage	21.1 Vdc min., 26.4 Vdc max.
SP Output Current	4 A max. continuous 8 A max. for up to 100 ms
SP Output Power	100 VA, NEC Class 2 Compliance

Table17: Switched Power Specification

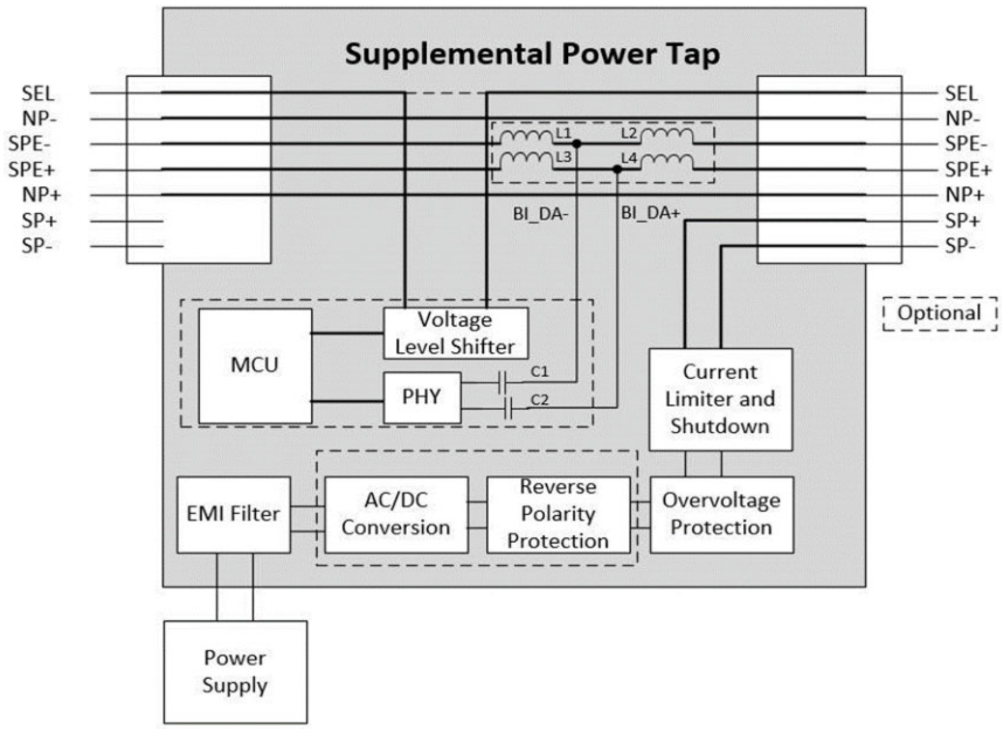


Figure 18: Supplemental Power Tap block diagram

A Supplemental Power Tap is illustrated in the block diagram shown in Figure 18. It connects to two segments of SPE Cable via Plug Connectors. The upstream segment connection is shown on the upper left, and the downstream segment connection is shown on the upper right. NP is passed through the Supplemental Power Tap. SP is supplied from the Supplemental Power Tap to the downstream segment. External power is conditioned and used to generate SP. The conditioning includes EMI filtering and overvoltage protection with optional reverse polarity protection. SP is protected by current limitation. SP includes a shutdown circuit for sequenced control of the attached load set. The Supplemental Power Tap may optionally embed bus communication functionality. If communication is not implemented, the SEL, SPE+, and SPE- signals route only from one Jack Connector to the other Jack Connector.

Key Benefits for using separate SP Power

- No additional control power wires for coil control.
- Current boost capabilities allow more loads to be turned on at the same time.
- Additional switch power can be made available by supplemental power tap.
- The same 24V DC supply can be used for multiple power taps.
- Bank of loads can be powered by the same power tap, allows zone control.

- Planning and installation tools can help users identify how much switch power is needed based on the number of loads.

SP Power for Zone Control

Implementation of supplemental power taps can provide segmented control to one or more banks (i.e., zones) of motor controllers within a larger control system. An example of establishing zone control can be seen in the illustration below Figure 19.

The system illustration reflects the in-cabinet solution with 40 end node devices.

- Zone 1 - Switch power from first power tap/gateway 0
- Zone 2 - Switch power from supplemental power tap node 14
- Zone 3 - Switch power from supplemental power tap node 3

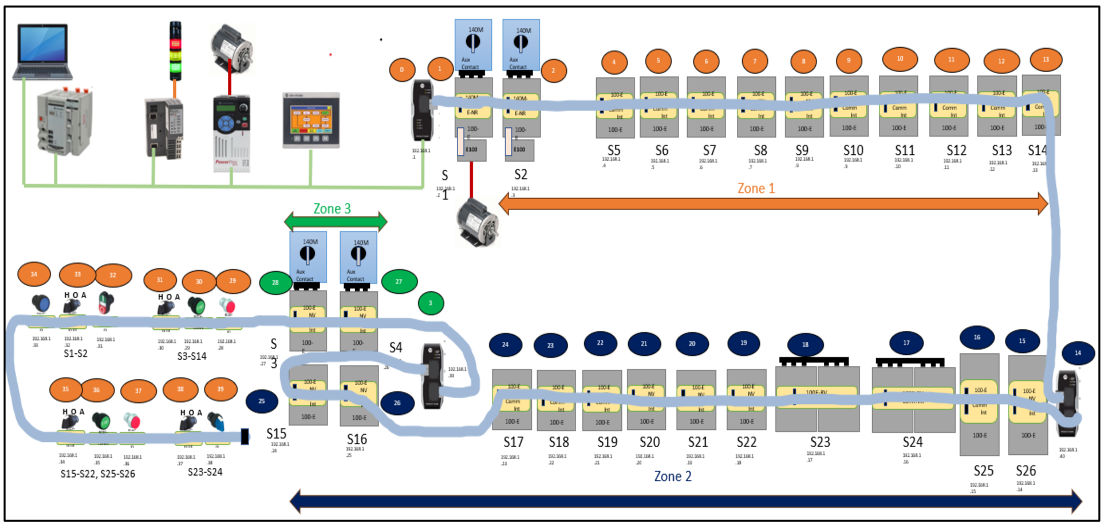


Figure 19: Supplemental power taps for zone control

Select Line

A single conductor that runs through In-cabinet media facilitates sequential command delivery. Application of Plug Connectors to the bus cable, severs the select line into separate segments. The two segments adjacent to each node are brought into the node on Jack Connector pins. SEL_A and SEL_B as shown in Figure 20. A signal chain is formed by the segments, the attached Select Line Circuits, and the MCUs. On initial power up, the “Select A” and “Select B” pins on all nodes are configured to be input pins. After a first message is detected on one of the Select pins, the other Select pin is configured to be an output pin. System wide sequential commands are delivered for actual topology discovery, system commissioning and device replacement operations.

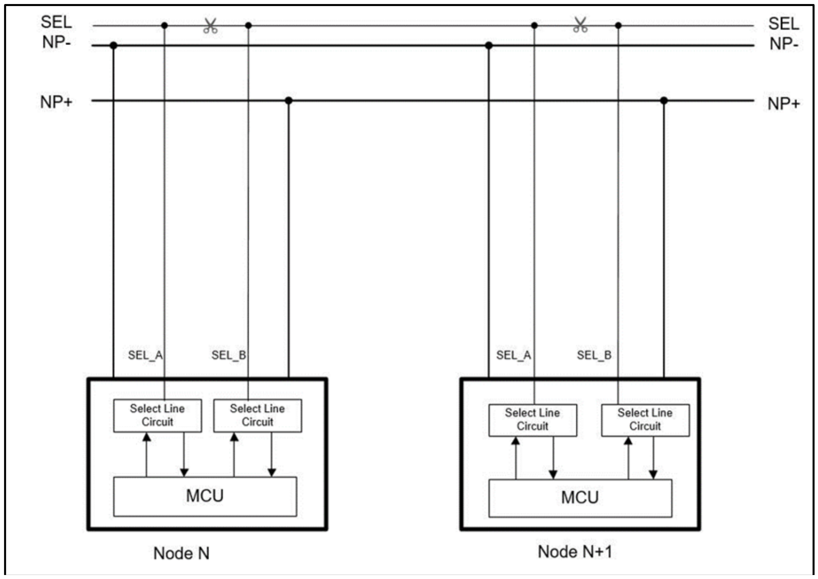


Figure 20: Interconnection diagram for Select Line

Select Line Enables Discovery of Actual Topology

A "Nodal Topology" is a complete ordered set for all devices on a network. The In-cabinet Actual Topology Object works together with the Select Line Link Object and the LLDP Data Table Object to capture the nodal topology for an In-cabinet network segment. The node that implements the In-cabinet Actual Topology Object must be the first (leftmost or rightmost) node on the network segment.

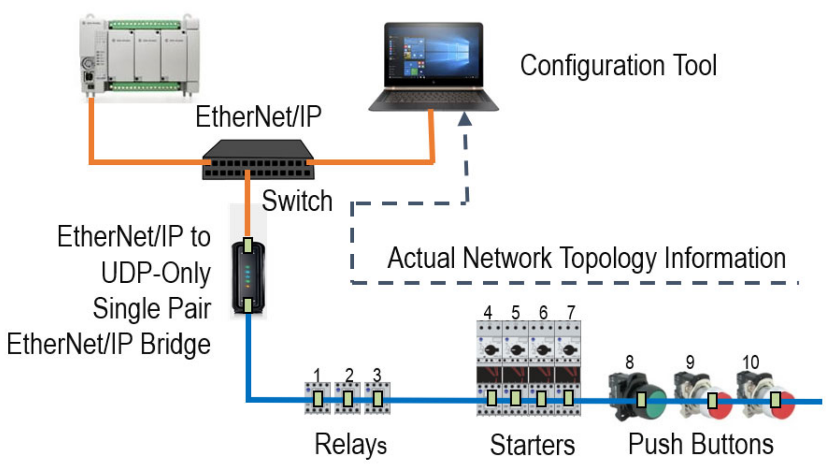


Figure 21: Actual Topology information enabled by the Select Line

Select Line is Agnostic of Cable Routing Direction

The Select line is bi-directional and flat media can be routed left to right or right to the left. The advantage to panel builders will minimize excess cable length to make cable routing neat, clean and easy to track down devices by visually following the flat cable.

A significant advantage is the ability to change the panel component layout and routing of the cable without impact to the PLC ladder logic program.

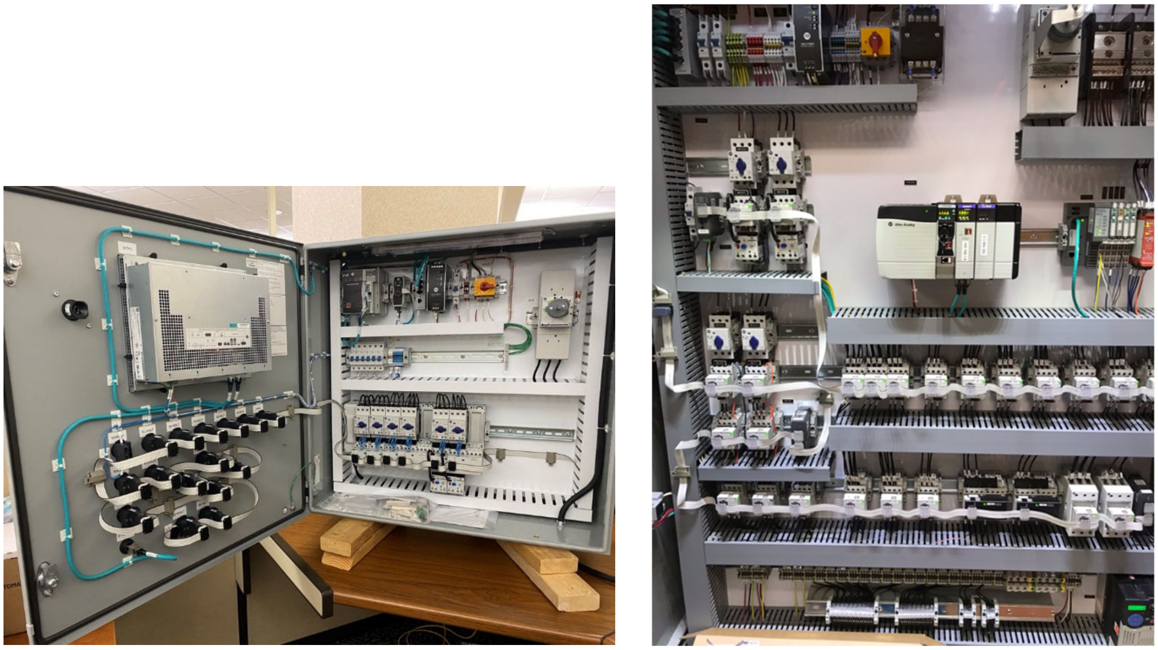


Figure 22: Agnostic cable routing

Select Line Enables In-Cabinet Commissioning

The In-Cabinet Commissioning Object works with the Select Line Link Object and the In-Cabinet Actual Topology Object to facilitate node commissioning (configuration of T1S PHY settings, and TCP/IP Interface Object) for EtherNet/IP In-cabinet network.

The node containing the In-Cabinet Commissioning Object must be the first (leftmost or rightmost) node on the SPE network as shown in Figure 23.

Various addressing schemes (using the last octet of the IP address) can be implemented.

- Sequential IP addressing based on topology location of the devices on the cable.
- Next Available IP addressing based on “next available node address” for each newly added device.
- Manual IP addressing to match the address in the Reference Topology.

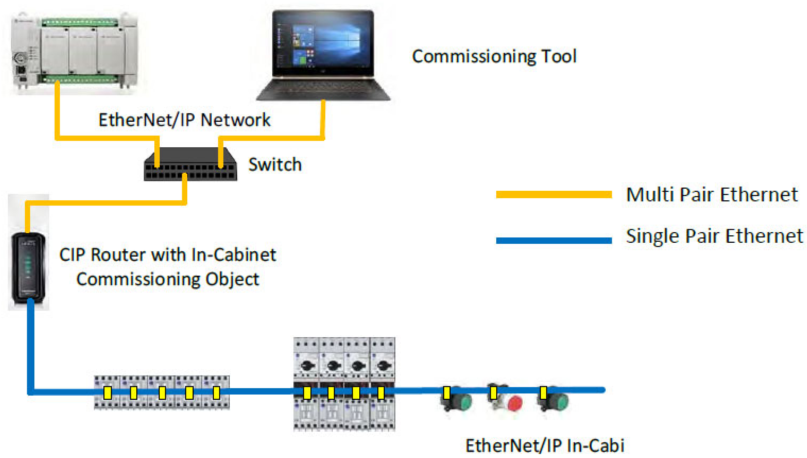


Figure 23: In-Cabinet Commissioning Object in CIP Router

Select Line Enables Auto Device Replacement

In the event of an end-node failure, the Gateway (CIP Router) will detect a new end-node, deploy a Discovery service, and determine the topology.

This process would be initiated when the 24V DC control power to the system is switched off, the failed device is removed and a new device is installed, re-connected to media, and re-applying 24VDC control power. This triggers the Gateway (CIP Router) to initiate the Discover Topology Service to determine the actual topology. When the reference topology and new actual topology match, the Gateway configures the end node with the IP address of the replaced node. The connected system PLC will respond and download the configuration parameters to the new devices and re-establish all IO connections.

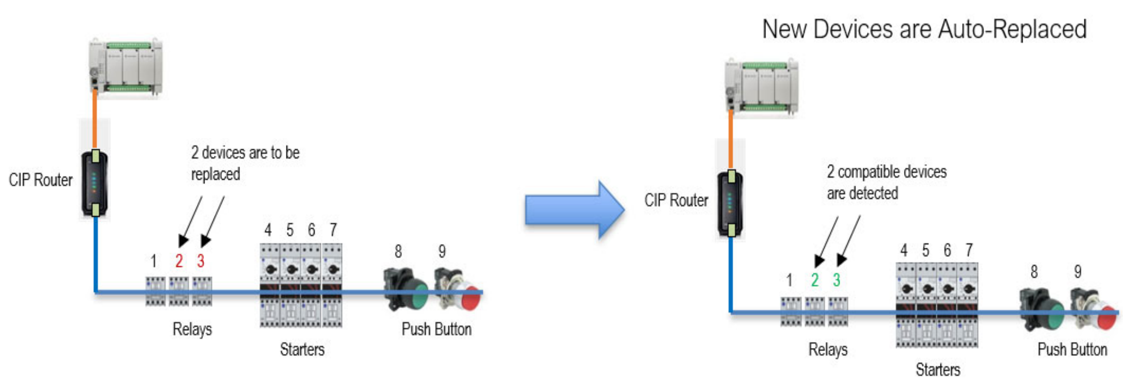


Figure 24: Select Line provides device location to initiate Automatic Device Replacement

Cable Conformance

The minimum specification and requirements for 7-Conductor flat media cable are shown in Figure 25.

Minimum Specifications and Requirements	
Electrical	
Conductors	SPE+, SPE-, SEL: 24 AWG, 7/32 stranded tin-coated copper (0.23 mm^2 (strand 0.203 mm DIA. / bundle 0.61 mm DIA.)) Lay length of outer layer is from 12 min. to 16 max. times outer diameter NP+, NP-, SP+, SP-: 20 AWG, 19/32 stranded tin-coated copper (0.61 mm^2 (strand 0.203 mm DIA. / bundle 0.95 mm DIA.)) Lay length of all layers is from 12 min. to 16 max. times outer diameter
Impedance (Ω)	Reference impedance of 100 Ω for SPE pair
Insertion Loss, IL (dB)	Measured per section 8-10.4.4, for SPE pair, at 25 m length 0.25 * (2.73 * sqrt(f) + 0.026 * f + 0.375 / sqrt(f)) $0.3 \leq f \leq 40$ where f is the frequency in MHz
Return Loss, RL (dB)	Measured per section 8-10.4.4, for SPE pair, at 25 m length $24 + 5 * \log_{10}(f/10)$, 24 max. $0.3 \leq f \leq 40$ where f is the frequency in MHz
Mode Conversion, MC (dB)	Measured per section 8-10.4.4, for SPE pair, at 25 m length TCL and TCTL: $46 – 10 * \log_{10}(f)$, 40 max. $0.3 \leq f \leq 100$ where f is the frequency in MHz
Current	NP+, NP-, SP+, SP-: 4A minimum at +75 °C ambient SPE+, SPE-: 12 mA minimum at +75 °C ambient
DCR	Measured for each conductor, at 25 m length, at +20 °C NP and SP: 0.935 Ω max. SPE and SEL: 2.355 Ω max. (Ref: UL 1581)
DCR Unbalance	Measured per ASTM D4566 NP and SP: 3%
Dielectric Strength	2000 V AC (UL 758, Table 29.1, 600 V AC)

Figure 25: Flat cable media specifications and conformance

Actual cable sample measurements are shown below to show full compliance to the specifications.

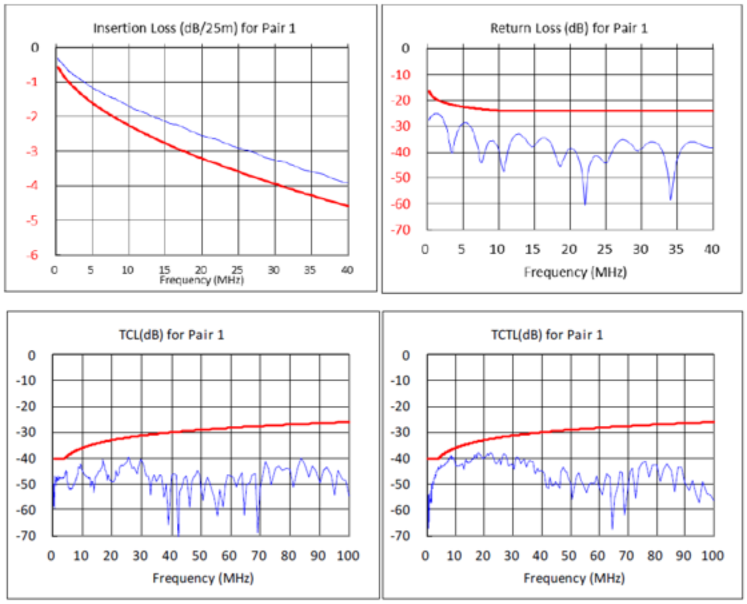


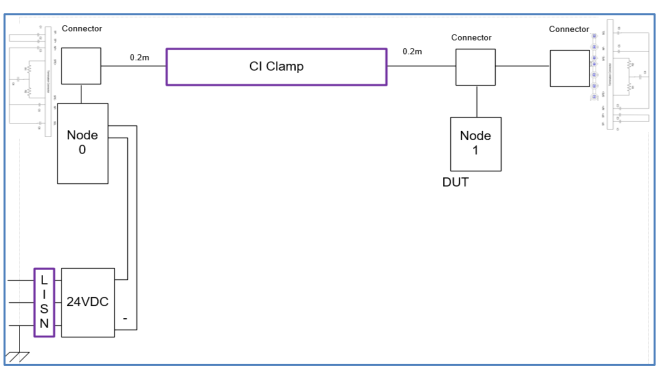
Figure 26: Data from Actual Cable Sample Measurement

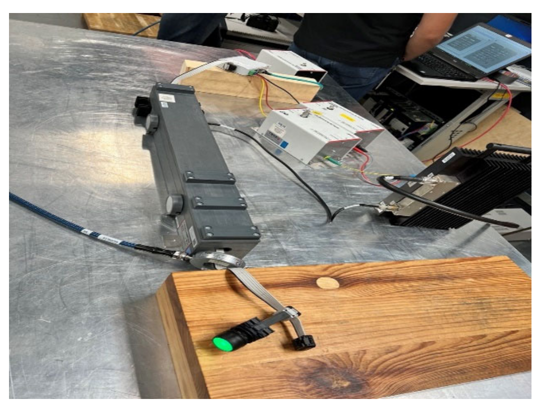
The EtherNet/IP in-cabinet solution is designed to be robust and able to fully meet EMC compliance requirements in an industrial electromagnetic environment. Conducted immunity and fast transient burst test results are shown below as two examples.

EMC-Conducted Immunity

Setup

- EtherNet/IP in-cabinet proto cable and connectors.
- EtherNet/IP Node 0 is the master node.
- EtherNet/IP Node 1 is the DUT.
- Conducted immunity test per IEC/EN 61000-4-6
- 10V is the test level required by products.





Acceptance criteria

Criteria A, Equipment should operate normally during and after EMC testing.

Configurations:

(1) 10V with AM on Master node 0: transmitting node
DUT Node 1: receiving node Passed BER
no loss of packet.

(2) 10V with AM on Master node 0: receiving node.
DUT Node 1: transmitting node Passed BER
no loss of packet.

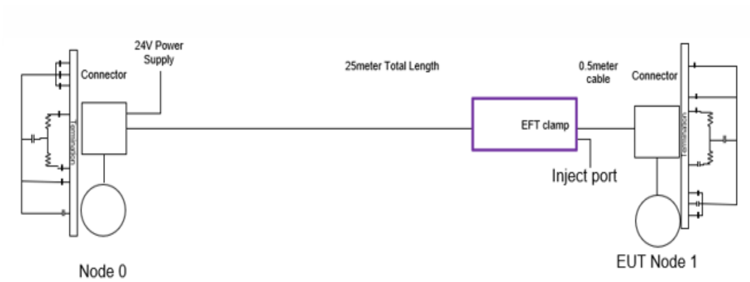
Test Conclusion:

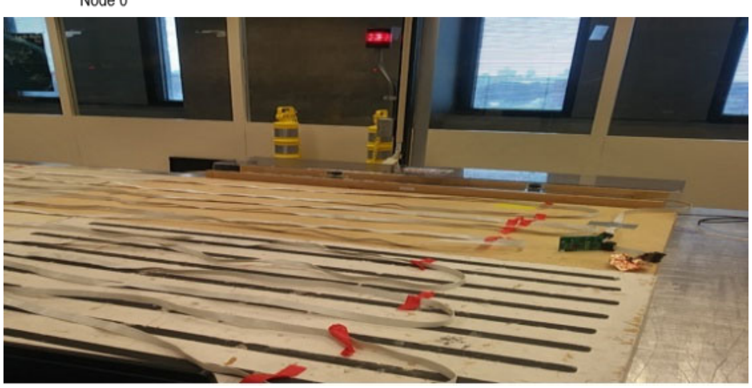
EtherNet/IP in-cabinet solution showed good performance during preliminary conducted immunity testing.

EMC-Fast Transient

Setup

- 25 meters EtherNet/IP in-cabinet cable and connector protos.
- EtherNet/IP in-cabinet Node 0 is the transmitting node.
- EtherNet/IP in-cabinet Node 1 is the DUT and the receiving node.
- Conducted test per IEC/EN 61000-4-4





Acceptance criteria

Criteria B, temporary degradation or loss of performance which is self-recoverable. **PASS**

EFT Test Levels	Frames sent by Node 0	Frames received by Node 1	Frames Lost
+500V	65000	64987	13
-500V	65000	64988	12
+1KV	65000	64989	11
-1KV	65000	64985	15
+2KV	65000	64994	6
-2KV	65000	64988	12
+3KV	65000	64998	2
-3KV	65000	64991	9
+4KV	65000	Node 1 LED flashes, unit self recovered back	

Test Conclusion:

The EtherNet/IP in-cabinet solution showed good performance during preliminary EFT testing.

Summary

The EtherNet/IP in-cabinet solution provides communication interface accessories to connect existing industrial control components to create a single multi-drop in-cabinet network. The communication interface provides all appropriate electrical connections to each component to operate without the need to connect additional control wiring.

A significant cost in electrical control cabinet design & build is labor, individual point-to-point control wiring for industrial control components such as contactors, push buttons, pilot lights, programmable logic controller input cards, programmable logic controller output cards, etc. System integrators and OEMs are continuously looking for more efficient ways to design, wire, test, and commission an electrical control panel to be more competitive in their market space.

In panel components such as direct-on-line motor control and panel operators account for a significant number of individual wires per circuit based on the control scheme. Eliminating this traditional hard wiring can dramatically reduce costs in the overall design and installation phase. Validated time study initiatives have shown that reductions of 30% in project engineering and 80% in installation time are achievable when compared to conventional hardwire control. Other areas of reduction include both capital equipment and panel sizing.

Beyond the installation advantages, the EtherNet/IP in-cabinet solution provides additional device-level insights for better diagnostics, troubleshooting and maintaining device-level assets.
Hardwired control circuits perform functional operation but lack the device-level diagnostics to evaluate the end device health. In-cabinet devices have assigned IP addresses for control, monitoring, and preventative maintenance data. Configuration and commissioning leverage the same programming tools used by standard EtherNet/IP devices. Further integration with the advanced industrial application software can help users manage and maintain installed assets to avoid disruption with unplanned downtimes.

Leveraging ODVA's open standard for EtherNet/IP constrained in-cabinet devices is significant and will transition in-cabinet industrial components to the next level!

Background Material

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5. IEEE 802.3 CFI, “10 Mb/s Extended Reach Single Twisted Pair Ethernet PHY”, http://www.ieee802.org/3/cfi/0716_1/CFI_01_0716.pdf
6. IEEE 802.3 SG, “10SPE” (10 Mb/s Single Pair Ethernet), http://www.ieee802.org/3/10SPE/index.htm
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8. Resource-constrained Industrial Things - Proposal for the Adaptation of CoAP to EtherNet/IP: 2017-ODVA-Conference_Green Otterdahl_CoAP_FINAL
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