PUB00361R0

In-Cabinet Media Planning and Installation Manual

Version history

Version	Date	Description
PUB00361R0	2026-05-25	Initial release.

Contents

About this manual

I Scope

This manual covers the planning and installation of EtherNet/IP In-Cabinet industrial control networks supporting 10 Mb/s. It describes systematic planning approaches and troubleshooting the In-Cabinet network. This is intended to be a companion document to the existing ODVA EtherNet/IP Planning and Installation manual (PUB00148R0).

Media types supported for EtherNet/IP networks are:

- Cabling components (components and designators described in section 1.5)
  - Cable C1
  - Plug Connectors P1 and P2
  - Jack Connectors J1 and J2
  - Terminator T1
  - Splicer S1
  - Dust Cover D1

Other data rates, media types, and the planning and installation of generic cabling systems are beyond the scope of this document.

This manual provides:

- A QuickStart
- Planning the Cabling
- EtherNet/IP In-Cabinet Network Verification
- EtherNet/IP In-Cabinet Network Troubleshooting

II Who Should Use This Manual

This manual is intended for use by control engineers, planners, installers, verifiers, acceptance test personnel, administration, maintenance personnel, and plant electricians. These people are responsible for designing, implementing, installing, and maintaining industrial control systems using EtherNet/IP In-Cabinet networks. It describes the required media components and how to plan, install, verify, troubleshoot, and certify the network. The manual assumes the readers have some minimum background knowledge on EtherNet/IP and/or EtherNet/IP In-Cabinet solutions.

III References

ANSI/TIA-1005-A – Telecommunications Infrastructure Standard for Industrial Premises

ANSI/TIA-5017 – Telecommunications Physical Network Security Standard

ANSI/TIA-568.0-E – Generic Telecommunications Cabling for Customer Premises

ANSI/TIA-568.2-D – Balanced Twisted-Pair Telecommunications Cabling and Components Standard

ANSI/TIA-568.3-D – Optical Fiber Cabling Components Standard

ANSI/TIA-607-D – Bonding and Grounding

BICSI TDMM – Telecommunication Distribution Methods Manual

IEEE 1100-2005 – IEEE Recommended Practice for Powering and Grounding Electronic Equipment

IEEE 518 - Guide for the Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources

IEEE Std 802.3™-2021 – IEEE Standard for Ethernet

IEC 60529 – Degrees of protection provided by enclosures (IP code)

CIP Networks Library, Volume 2, EtherNet/IP Adaptation of CIP

ODVA Pub 148R0 – EtherNet/IP Media Planning and Installation Manual

ODVA Pub 269 – Securing EtherNet/IP networks

NFPA 79 – Electrical Standard for Industrial Machinery

TIA / TSB 185 - Environmental Classification (MICE) Tutorial

IEC 61918 - Digital data communication for measurement and control. Profiles covering installation practice for Fieldbus communications media within and between the Automation Islands

Note: The reader is cautioned to ensure that the latest versions of the standards listed here are referenced.

IV Definitions

Active Devices – An active network element with a single Active Interface. These devices are generally dedicated to an automation application function such as a PLC, IO module, or a Sensor. These devices require a connection to an Active Connectivity Device or may be end-connected to an Active Two Port Device.

Active Network Element – Network element containing electrically and/or optically active components that allows extension of the network.

Active Two Port Devices – An active network element with two Active Interfaces. These devices are generally dedicated to an automation application function and used for connectivity in linear or ring topologies. These devices can form a network without Active Connectivity Devices.

Automation Island (AI) – The premises where combination of all systems that control, monitor, and protect the process of a plant is installed.

Bonding – Act of connecting exposed conductive parts and extraneous conductive parts of apparatus, systems, or installation that are essentially the same potential.

Cable – An assembly of one or more conductors with a protective covering and possibly filling, insulation and protective material.

Cabling – A system of communication cables, cords, and connecting hardware that can support the connection of automation equipment.

Channel – A transmission path connecting any two pieces of application specific equipment.

Note 1: Equipment cords are included in the channel, but not the connecting hardware into the application specific equipment.

Note 2: Channel specified in this standard may only be comprised of passive components.

Connection (of conductors) – An intentional electrical contact between conductors.

Connector (for conductors) – A device providing connection and disconnection to a suitable mating component.

Cord – A cable unit, or cable element with a minimum of one termination.

Device – See Active Device.

Earth (noun) – Conductive mass of earth, who's electric potential at any point is conventionally taken as zero.

Note: This installation manual uses "Earth" with recognition of "Ground" as an equivalent term.

Earth (verb) – Make an electric connection between a given point in a system or an installation or in equipment and a local earth.

Enclosure – Housing affording the type and degree of protection suitable for the intended application.

Functional Earthing – Earthing a point or points in a system or in an installation or equipment for purposes other than electrical safety.

Note: functional earthing is preferred in this document for communications systems or networks.

Industrial – Is used to describe the set of attributes that make up the hardened elements of the physical layer and media components including Active Interfaces. These areas are typically MICE 2 and MICE 3 environmental areas.

Maintenance – Combination of all technical and corresponding administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function.

Note 1: See "preventive maintenance", and "corrective maintenance", for a more detailed definition of maintenance.

Note 2: The required function may be defined as a stated condition.

Network – All the media, connectors, repeaters, routers, gateways, and associated node communication elements by which a given set of communicating devices are interconnected.

Node – An EtherNet/IP In-Cabinet node is any addressable device connected to the EtherNet/IP In-Cabinet multidrop network that participates in cyclic or acyclic EtherNet/IP communication.

Physical Layer Collision Avoidance – An optional reconciliation sublayer mechanism defined in IEEE 802.3 (Clause 148) that enables deterministic, collision-free communication on half duplex, shared medium Ethernet networks.

Plug – connector attached to a cable.

Repeater – Two-port active physical layer device that receives and retransmits all signals to increase the distance and number of devices for which signals can be correctly transferred for a given medium.

Scheduled Maintenance – Preventive activity (time or number-of-actions directed) performed either on predefined schedule or on units of use (e.g., number of start-ups).

Troubleshooting – Locating the fault(s).

Verification – Action to assess that an installation is in accordance with its specification.

Note 1: The installer usually performs this action.

Note 2: This action usually covers verification of component correct selection, physical layout, communication earthing, isolation, and continuity of network components.

V Abbreviated Terms

For the purposes of this document, the following abbreviated terms apply.

AC – Alternating current

AI – Automation Island

BER – Bit Error Rate

CIP – Common Industrial Protocol

DC – Direct current

EMC – Electromagnetic Compatibility

IDC – Insulation displacement contact

IP – International protection (IEC 60529)

LV – Low voltage

Max. – Maximum

MICE – Mechanical, Ingress, Climatic/Chemical, Electromagnetic (See ANSI/TIA-1005-A, TIA TSB-185, ISO/IEC TR 29106, and/or ISO/IEC 11801-1)

Min. – Minimum

MNS – Module Network Status

NP – Network Power

PE – Protective Earth

PELV – Protective Extra Low Voltage

PLCA – Physical Layer Collision Avoidance

SELV – Safety Extra Low Voltage

SP – Switched Power

VI Units of Measure

This installation manual uses standard SI units in addition to those listed below.

Celsius (°C)

Pounds (lbs.)

Megabit (Mb)

Megabits per second (Mb/s)

1 EtherNet/IP In-Cabinet System QuickStart

1.1 Introduction

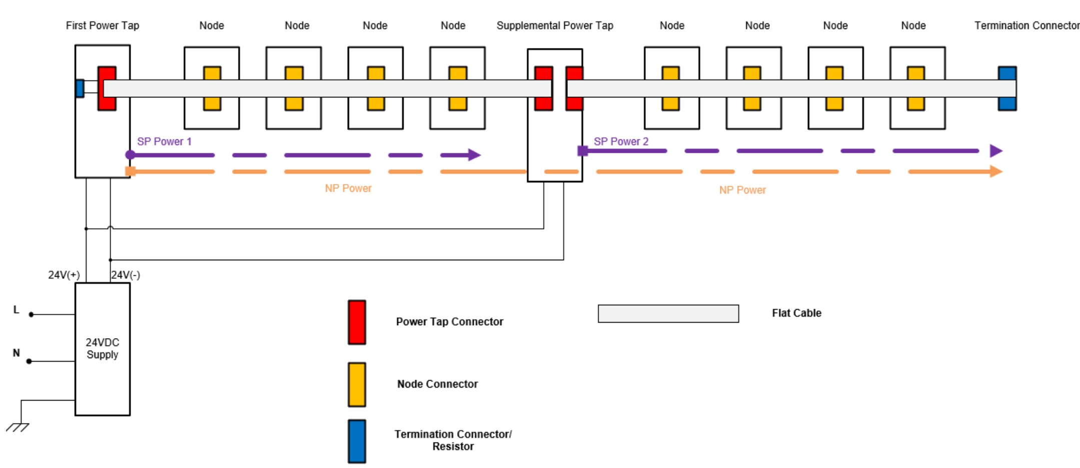
This chapter describes the commonalities and differences of installation of an EtherNet/IP In-Cabinet network to installation of a traditional EtherNet/IP network. It specifically highlights considerations that should be taken when provisioning the network planning and installation. Traditional EtherNet/IP systems use a point to point switched based topology. This topology effectively conserves bandwidth and can support a higher performance network but can be prohibitive to constrained devices facing limitations of size, power consumption, and cost. EtherNet/IP In-Cabinet system is designed to address these limitations.

1.2 About the EtherNet/IP In-Cabinet network

The EtherNet/IP In-Cabinet bus network is an augmentation of traditional EtherNet/IP systems. It consists of a First Power Tap (which typically acts as a gateway) to connect into a multidrop network and to aggregate edge devices into a linear bus with up to 40 devices within a 25 meter range. The EtherNet/IP In-Cabinet network incorporates an integrated device power bus and an integrated auxiliary power bus for powering device auxiliary circuits such that all devices only need a single media connection. The EtherNet/IP In-Cabinet network is an IEEE 802.3 10BASE-T1S implementation requiring use of the physical layer collision avoidance (PLCA) feature.

EtherNet/IP In-Cabinet operates as a 10 Mbps, half duplex- network and provides scheduled, time division- bandwidth allocation among connected devices. Due to the scheduled access mechanism, EtherNet/IP In-Cabinet is not suitable for high throughput- data transport and is intended for edge-of-network deployment. Use outside this context may introduce a bottleneck on the shared bus.

Figure 1-1 EtherNet/IP In-Cabinet Architecture



The EtherNet/IP In-Cabinet bus network typically operates with Gateway as a PLCA coordinator to facilitate scheduling. The Gateway supports all traditional EtherNet/IP network topologies feeding into the subnet network including DLR, PRP, or star type configurations. Because bandwidth is shared among all devices on the same bus, the

EtherNet/IP In-Cabinet network does not have a dedicated implementation for high availability.

1.3 Considerations for security

EtherNet/IP In-Cabinet system follows the same device level handling of security as traditional EtherNet/IP but has limitations in end node performance for hardware acceleration of security. EtherNet/IP In-Cabinet device is allowed to support Resource-Constrained CIP Security Profile. To implement a fully secure system, CIP security connections are proxied through the local network gateway. Details of network security are beyond the scope of this manual, and the planner is advised to consult appropriate standards.

1.4 Roles and Responsibilities

Planner – responsibility is to create the system design, and the following tasks listed below. The tasks are listed in sequential order of execution based on the overall control system functional specification.

1. Network topology(s) required to accomplish the required functioning of the control system
2. Data rates within the topology(s)
3. Evaluate environmental considerations within the topology(s)
4. Evaluation or specification of facility and installation earthing and bonding strategy in line with ODVA EtherNet/IP Media Planning and Installation Manual, PUB000148R0
5. Selection of components to satisfy the requirements put forth in steps 1 through 3
6. Selection of additional mitigation techniques if components do not directly satisfy requirements from steps 3 through 4
7. Create detailed network design
8. Create wiring diagrams and installation documents
9. Create Bill of Materials
10. Update wiring diagram and installation documents per the installer's feedback
11. Define the acceptance criteria to be given to the person carrying out the network acceptance test. The acceptance criteria shall include testing coverage, for example percentage of channels/links tested
12. Provide guidelines for maintenance of the network

Installer – responsibility is to carry out installation of the cabling defined above, meeting the requirements of the planner.

1. Perform the installation according to the planner installation documents
2. The installer shall report any inconsistencies back to the planner
3. The installer shall follow the component manufacturer's installation recommendations
4. The installer shall label the cabling according to the information provided by the planner. If there is no guidance, the installer shall provide adequate labeling.
5. Provide the labeling details back to the planner
6. If there is no verification entity, the installer shall perform verification of the network and provide a report back to the planner

Network Verifier – responsibility is to show that the network has been installed correctly:

1. In accordance with the planner documentation
2. Connector termination has been carried out correctly
3. Verify the earthing and bonding in accordance with local codes and ODVA EtherNet/IP Media Planning and Installation Manual, PUB000148R0
4. Provides any inconsistencies to the installer for correction
5. Provide a report containing verification findings back to the planner

Acceptance Testing – the responsibility is to determine that the cabling can provide the quality of service to meet the application needs. Acceptance testing is defined by the planner and is a planner's measure of successful installation. Network certification testing is defined by an appropriate standard as a measure of successful installation. Acceptance testing and certification testing can be but are not required to be the same.

1. Testing per the planner documentation
2. Provides inconsistencies back to the installer for correction
3. Generates a final report for the planner

Maintainer– the responsibility is to carry out maintenance through its lifecycle:

1. Monitor network performance
2. Execute moves, adds, and changes to the network
3. Document changes in network wiring diagram and administration files
4. Maintenance

a. Scheduled maintenance

b. Condition based maintenance

c. Corrective Maintenance

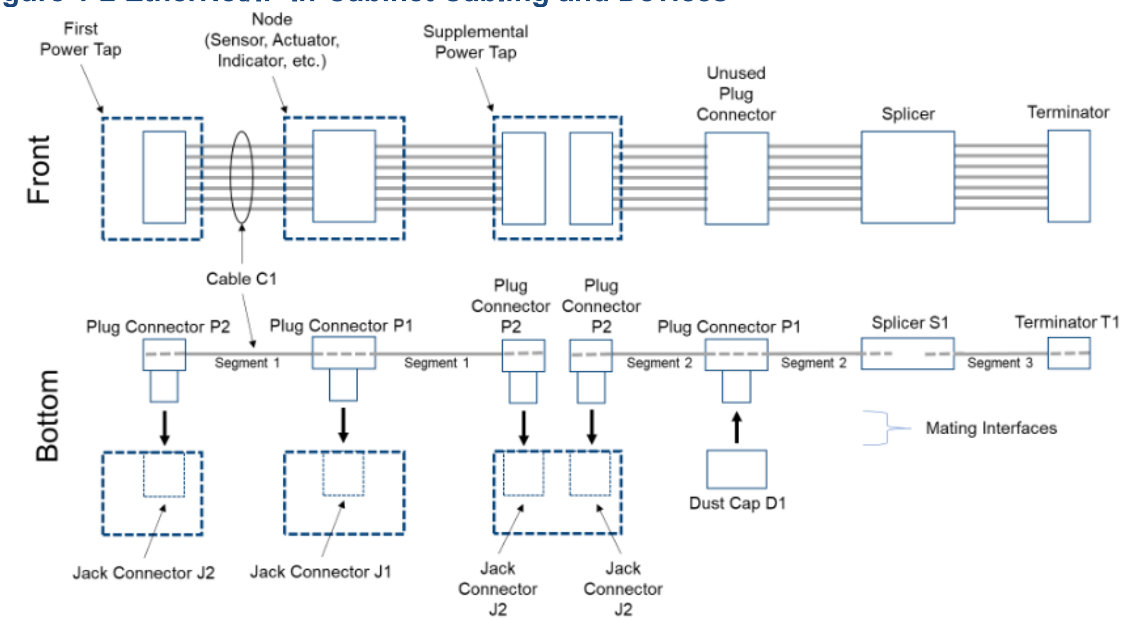
5. Generates maintenance reports throughout the network lifecycle

1.5 EtherNet/IP In-Cabinet Components

CIP Networks Library, Volume 2, EtherNet/IP Adaptation of CIP defines the set of In-Cabinet components: cable, connectors, terminator, splicer, and dust cap. Each type of component has a designator to identify different versions of the component type. For example, connectors are designated as J1 and J2 for node connection and power supply connection respectively.

The EtherNet/IP In-Cabinet cabling consists of one or more segments of bus Cable C1, used to distribute power, provide a communication channel, and to enable relative location services based on node-to-node select line signaling. Devices are connected to the In-Cabinet system via embedded Jack Connectors J1 (Nodes) and J2 (Power Taps), then attached to the bus cable through intermediate matching Plug Connectors P1 and P2. The Terminator T1 is used to terminate the bus cable end, providing differential and common-mode termination to preserve communication quality and minimize interference. The First Power Tap can optionally terminate the second end of the cable. A Splicer S1 is optionally used to join two cable segments for repair or bus length extension. An optional Dust Cap D1 is used to terminate and protect unused Plug Connectors.

Figure 1-2 EtherNet/IP In-Cabinet Cabling and Devices



The following sections describe the basic media components of an EtherNet/IP In-Cabinet system.

1.5.1 Plug Connector P2

P2 is a one-time use IDC style connector that interfaces the C1 cable to gateway and power type devices. It connects directly into each line and passes it along to the device side connection for utilization. This connector covers and protects the cable end and is installed on the beginning (input) side of the network typically at the left, or the ending (output) side typically at the right.

1.5.2 Plug Connector P1

P1 is a single-use IDC style connector that interfaces the C1 cable to network node devices. It splits the data and select lines, provides a signal conditioning filter for the data lines, and connects a node device to the bus.

1.5.3 Splicer S1

S1 is a connector component that joins input and output ends of two C1 flat cable media segments, interfacing them together. Each side of the Splicer is constructed of a one-time use IDC style connector.

1.5.4 Cable C1

C1 is a flat media cable component that implements a system bus with communication, power, and relative location determination. It is composed of seven conductors and has a marked polarity for mating with In-Cabinet IDC cabling components.

1.5.5 Dust Cover D1 (Node Termination)

D1 is a component that mates with a P1 connector. It provides filtering of the system in the absence of a node device and helps to preserve network performance. This component also provides repair of the broken select line to allow topology discovery of the adjacent nodes.

1.5.6 Terminator T1 (Bus Termination)

T1 is a single-use IDC style connector that attaches to an end of a C1 cable and incorporates line termination and noise filtering. A bus may not operate unless properly terminated with this termination cap applied at the end of the network.

1.5.7 Node

Nodes are EtherNet/IP devices that integrate with industrial controls such as sensors, actuators, and indicators. The C1 cable transmits power and signals into node devices, allowing all devices along the cable upstream and downstream to communicate together.

1.5.8 Gateway

This is an active network device that acts as a bus master and allows connection of the bus to the larger EtherNet/IP network. This component is often integrated with a Power Tap/Primary Power Conditioner.

1.5.9 First Power Tap

The First Power Tap is an Active Device used to inject and condition power at the first P2 connector in the system. This power source supplies both the entire network power and the first segment supplemental power along the C1 cable. This component is often integrated with the network Gateway.

1.5.10 Supplemental Power Tap

The Supplemental Power Tap is an active device used to inject and condition power into the bus for increasing total switched load capacity. This device accepts the first segment of C1 cable affixed to a P2 connector in and starts a new switched power segment and continues the bus using another P2 connector out with another C1 cable segment.

2 Planning the Cabling

2.1 Selecting the network size and length

The EtherNet/IP In-Cabinet network is pre-engineered to support up to 40 devices. There are steps that can be taken to improve the network performance.

- Each end of the network cable must be terminated with a compliant termination connector, which on one side is built into the main power tap.
- The minimum separation between connectors is 50 mm, however ease of assembly may be impacted by this dimension and a 100 mm or larger separation is recommended. 100 mm minimum spacing ensures that some additional length is kept allowing adjustment of connector spacing to support fixed spacing DIN rail mounted devices. If the recommended minimum spacing is not followed additional mechanical stress may be put on devices and connectors which could have adverse effects on network or device reliability.
- Ample margin should be given to cut cable lengths to allow installation of the necessary number of nodes on each length. The number of connections on the network may place limitations on the system tolerance to electromagnetic noise and can also reduce the maximum system response time.

2.2 Impact of connections to data loading

Increasing the number of devices will increase the average minimum RPI time that can be supported within the bus. There is a portion of the bus bandwidth reserved for network administration that does not vary with network size, and another portion allocated for node message scheduling that scales with the number of nodes. The scheduled traffic can be calculated using the simplified equation below and can be used to make determination of if the network is appropriately configured for the expected bandwidth consumption. Percent allocations are assigned to allow some network margin for asynchronous traffic such as pulling parameters or status information from a device or for minor network loss. Please note that devices with slower RPI may not have data to transmit or receive for some PLCA cycles.

D = Data payload size in bytes (for class one CIP connections this is 32 bytes)

N = The number of end nodes in the network

C = number of CIP IO connections per node

RPI = the average network RPI rate between all network nodes in ms

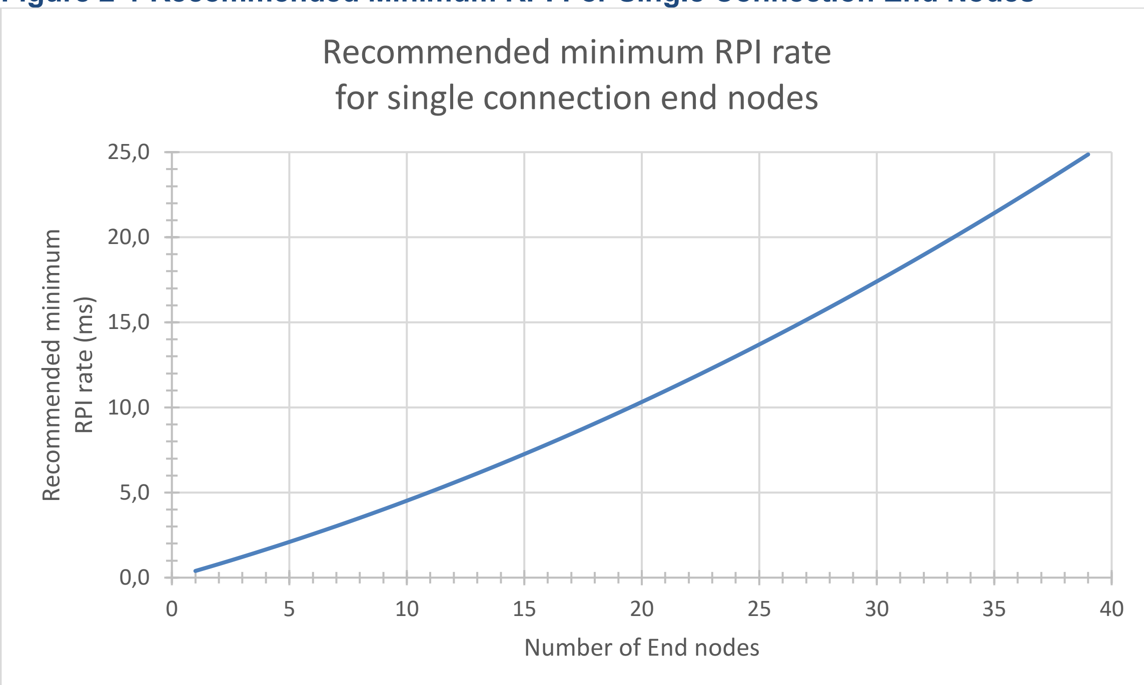
$$Percent\ Loading = N * C * \frac{8 * [(90 + D) * 2 + (N - 1) * 4] + 20}{RPI * 10^4} * 100\%$$

Given the need for the network to accommodate asynchronous traffic for support and maintenance, and to maintain sufficient margin to mitigate event-driven disruptions, the following guidance is recommended.

Where % loading is less than 50%	No action is needed
Where % loading is greater than 50% but less than 75%	Consider options to reduce network load
Where % loading is greater than 75%	Steps must be taken to reduce network load. This could include increasing node RPI or dividing the network into two individual networks

Using this equation and an expectation that most end nodes will use a single CIP class 1 IO connection, we can show the following relationship between the number of nodes and the recommended 50% scheduled loading average RPI rate.

Figure 2-1 Recommended Minimum RPI For Single Connection End Nodes



2.3 Impact of node connections to signal loss and extended noise immunity

The EtherNet/IP In-Cabinet system simultaneously supports maximum cable length of 25 meters, and maximum node count of 40. All end nodes maintain adequate noise margin for reliable operation under typical industrial control noise conditions. Additional system noise tolerance can be gained by reducing the number of nodes on the bus or reducing the cable length.

EtherNet/IP In-Cabinet network uses an optimized connector technology to maximize the number of nodes that can be added to the bus. This connector optimization technology minimizes the impact of reflections that act to reduce the signal to noise ratio of the system but relies on the loading of the Active Device. Because of connection construction, attenuation becomes the network limiting parameter and each connection contributes to the total system signal loss.

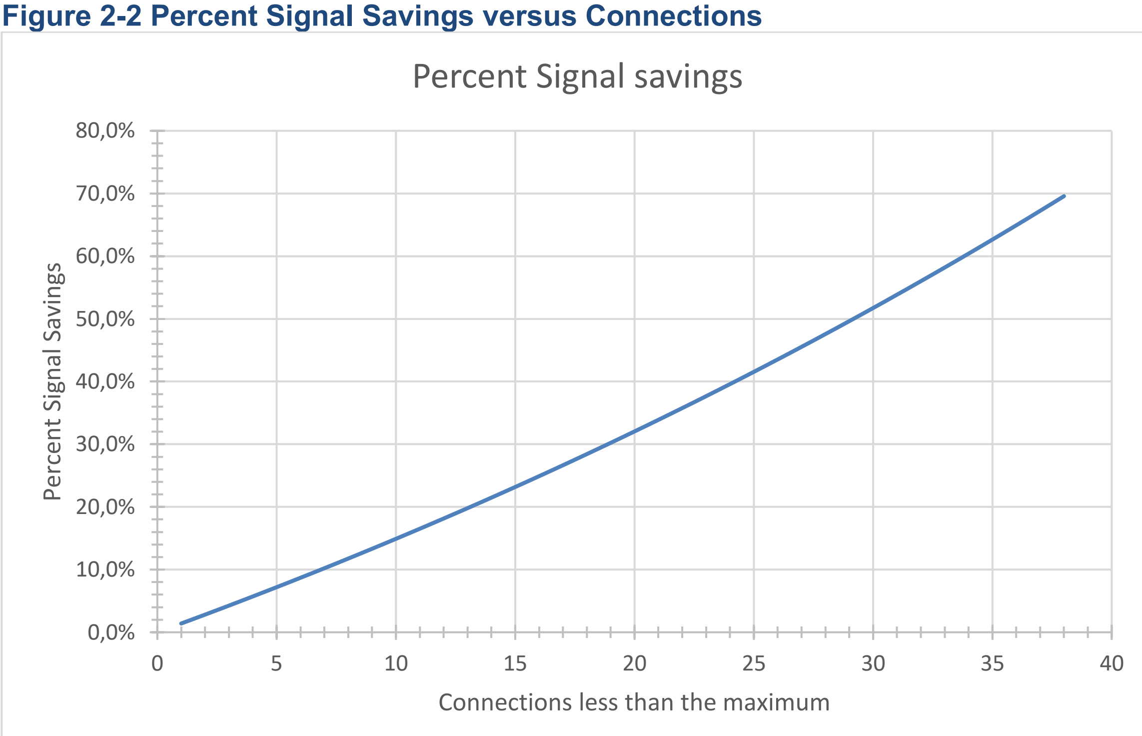
This specialized connector technology acts to compensate the bus for the expected loading effects of the attached end devices and because of this the bus will see worsened performance when devices are not populated on the network. Additionally, to apply compensation the connector must physically break and disrupt the bus during its installation. The network has been designed with consideration of worsened contribution of one node at a time in support of live maintenance. As a result of this, the following rules must be applied.

Resulting rules:

1. Node connectors cannot be added to or removed from an active system
2. Any unpopulated nodes shall be terminated with an approved node termination dust cover
3. Only one device can be removed at a time without populating an approved Node Termination Cap in place of any previously removed devices

Additional signal margin can be obtained by reducing the number of nodes or the cable length. Forty nodes have more total impact on signal margin than the full supportable length of 25 m of cable. The approximate impact is shown in the figure below.

Figure 2-2 Percent Signal Savings versus Connections

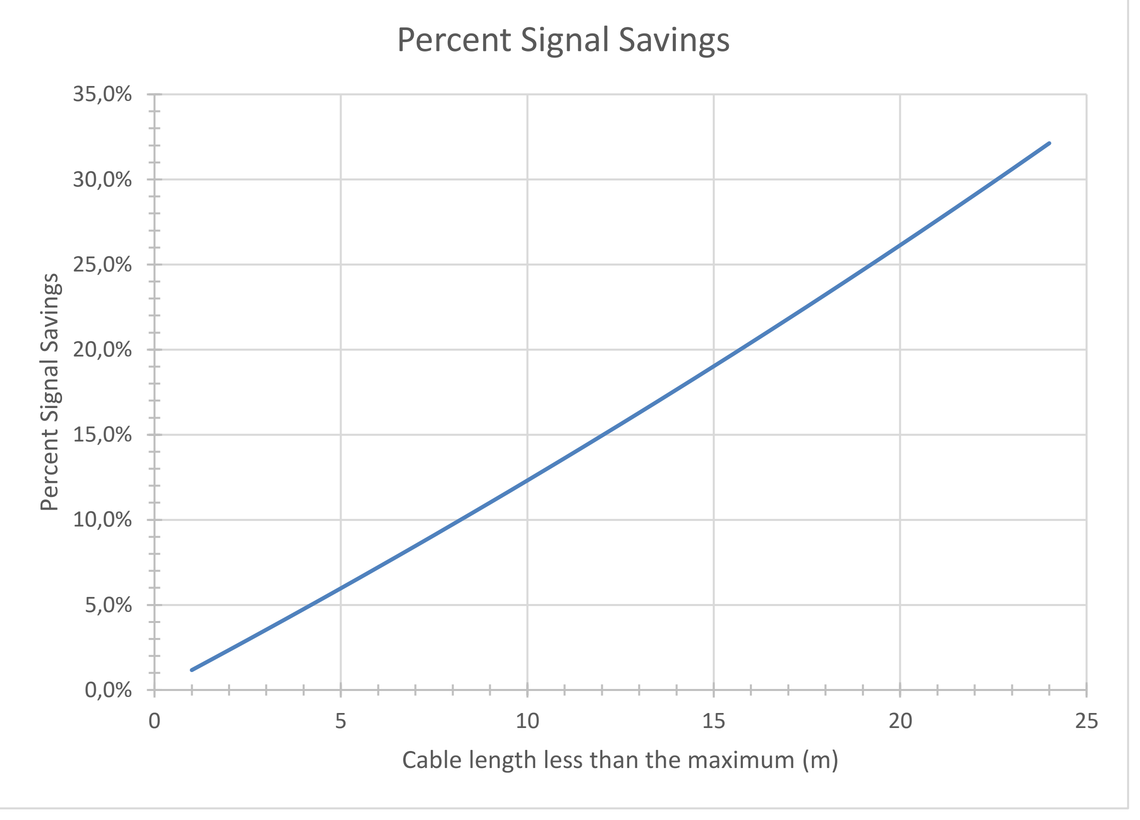


This indicates that by limiting a bus to less than 10 total nodes, the signal margin increases by a factor of 50%, and approximately 125% additional noise voltage can be tolerated before network errors may be seen.

2.4 Impact of cable length to signal loss and extended noise immunity

For EtherNet/IP In-Cabinet network, cable length also has an impact on the electromagnetic noise tolerance. Further system improvement and margin can be achieved by reducing the cable length needed for the number of devices specified. The approximate impact is shown in the figure below.

Figure 2-3 Percent Signal Savings versus Cable Length



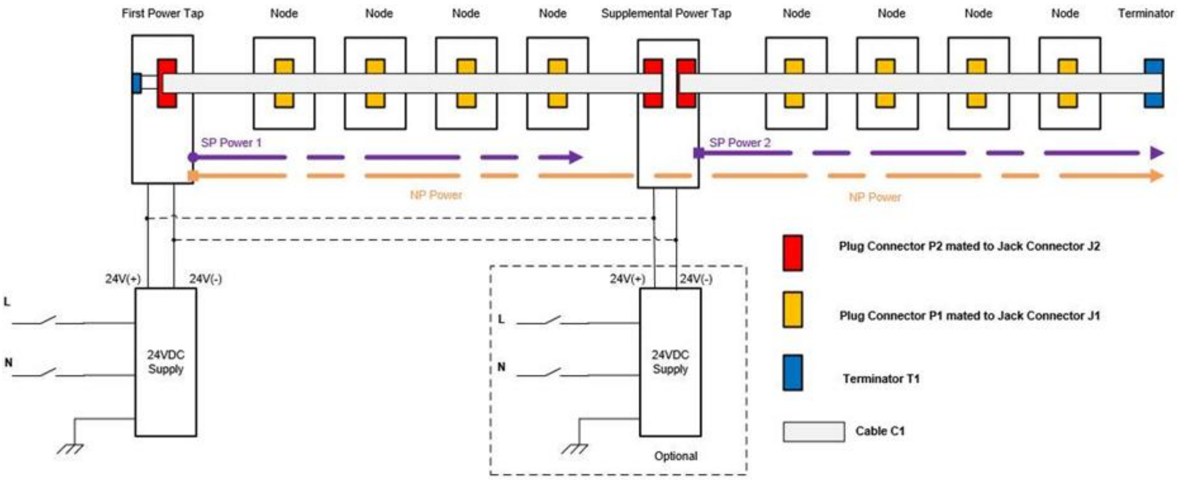
This indicates reducing cable length does not save as much as limiting the number of connections, but it still has a significant impact. Limiting the cable length to less than 10 meters will achieve approximately 20% savings which indicates an approximate 50% additional noise voltage can be tolerated before network errors may be seen.

2.5 Planning the Auxiliary Power Distribution

The network cable supplies two sets of power to the nodes as shown in Figure 2-4. The First Power Tap distributes network power (NP). This powers the communication circuitry of each node. No special consideration is necessary in design. NP powers all attached nodes up to the 40 node limit. A second power distribution is called switched power (SP). This powers the load circuity that is controlled by each node. It is also known as auxiliary power. The First Power Tap also distributes SP, however the need for switched power may be large and it may be required to boost SP by Supplemental Power Taps.

Spacing of Supplemental Power Taps should be set according to the total load of the auxiliary power circuits of the nodes. The auxiliary power propagates along the network and is disrupted and reestablished at the next Supplemental Power Tap. While the First Power Tap supplies both NP and SP to the network cable, NP is passed through and SP is boosted by the Supplemental Power Tap.

Figure 2-4 Supplemental Power Tap



Any segments of separated auxiliary power shall not exceed a 4 ARMS total loading. As such the devices auxiliary power loads should be tallied and Supplemental Power Tap spacing should follow guidelines below. To apply this guidance the total current of all nodes should be summed and then the corresponding length should be found from the figure below. This specifies the total span in which all nodes must be installed, as well as the cable length required between each supplemental power tap. For convenience, key load values have been produced from this graph in Table 2-1.

Figure 2-5 Supplemental Power Tap spacing vs. Total Auxiliary Current Load

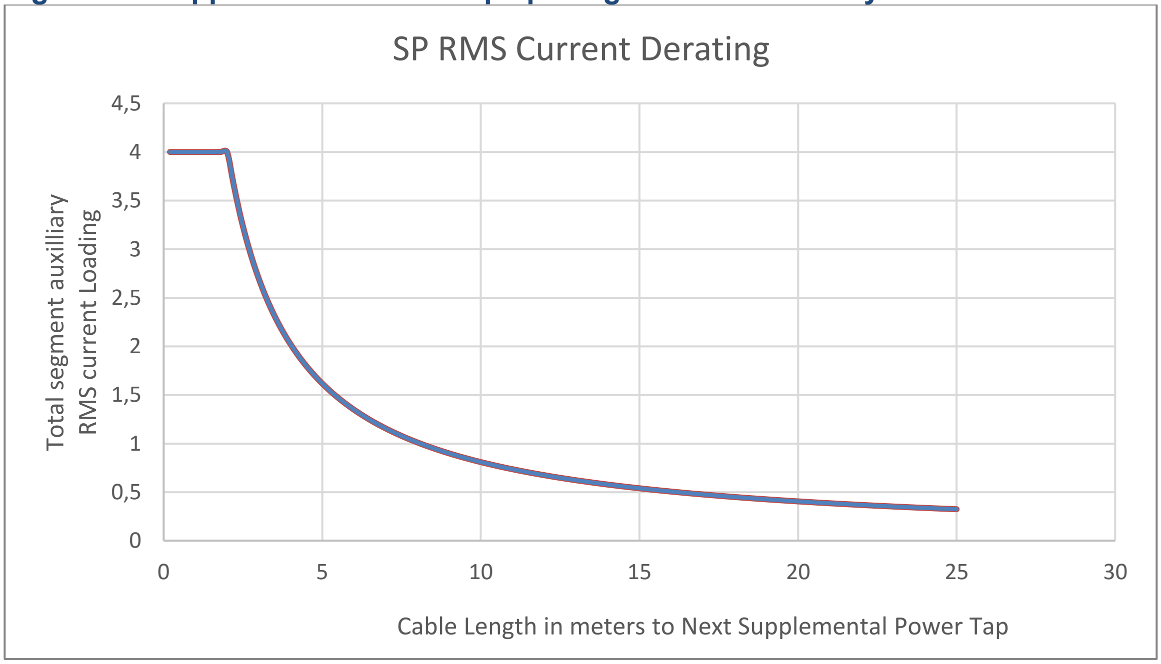


Table 2-1 Supplemental Power Tap spacing vs. Total Auxiliary Current Load – Reduced Table

RMS Current (A)	Length (m)
4	2
2	4
1.5	5.3
1	8
0.75	10.7
0.5	16
0.32	25

This guidance ensures sufficient auxiliary power operation following a simple total load consideration, additional length may be possible by applying appropriate engineering considering cable resistance and node placement and their impact to allowable voltage drop according to the voltage tolerance of all connected devices. For this basic calculation, a voltage threshold of 20.4 V (24V-15%) is assumed to be the required supplemental power voltage. It is derived from the minimum output of the Supplemental Power Tap allowing for a total voltage drop of 0.7 V. The cable is treated as 0.935 Ω for a 25 m length at 20 °C and will increase with a thermal coefficient of 0.4% per °C.

$$Maximum\ Length = \frac{0.7 * 25}{I_L * 2 * 0.935 * (1 + 0.004 * \Delta T)}$$

I_L = The total segment load current

ΔT = The expected ambient temperature difference above 20 °C

There are two conditions that allow calculation of larger separation between supplemental power taps. The first being if all nodes support a lower input SP voltage or if the input voltage to the power tap is ensured to be higher than the minimum allowable 21.6 V (24-10%). The second being if specific calculation is performed to consider the distribution of nodes based on the individual length between each node.

For the first the same simplified calculation as above can be applied using the different threshold for minimum input voltage

$$Maximum\ Length = \frac{(Powertap_{Vin} - 0.5 - node_{Vmin}) \ * 25}{I_L * 2 * 0.935 * (1 + 0.004 * \Delta T)}$$

$Powertap_{Vin}$ = The voltage provided at the input of the segment Supplemental Power Tap

$node_{Vmin}$ = The highest minimum input voltage within the operating range of all nodes within a power segment

Example Matlab Calculator to be built into an excel VBA calculator:

```
clear all
node_count=10;
lengths=[3 2 5 3 2 3 1 0.5 1];
currents=[0.5 0.5 1 0.1 1 0.1 0.5 0.5 0.5 0.1];
Vin=23.5;
Vthresh=20.4;
temp=60;
resist=0.935/25*lengths*2*(1+0.004*(temp-20));
Vnode(1)=Vin;
subresist=resist;
powertap_count=1;

if(sum(lengths)>25)
    disp('Error: Length exceeds 25m maximum')
elseif (length(currents)~=node_count)
    disp('Error: insufficient node information')
else
    for n=2:node_count
        Vdrop=currents(n)*sum(subresist(1:(n-1)));
        Vnode(n)=Vnode(n-1)-Vdrop;
       if Vnode(n)<Vthresh
           Vnode(n)=Vin;
           subresist=[zeros(1,n-2), resist((n-1):end)];
           powertap_count=powertap_count+1;
       end
    end
    disp('Voltage distribution by node is:')
    disp(Vnode)
    fprintf('Total Power taps needed is %d \n',powertap_count)
end
```

2.6 Provisioning for future bus expansion and maintenance

It is of high importance during the EtherNet/IP In-Cabinet-bus planning to consider provisions for future network maintenance. In the EtherNet/IP In-Cabinet-bus system, Supplemental Power Taps and splicers reduce available node count by 1 each even though they may not have any integrated node functions. Additionally, connections cannot be removed without adding a splicing tap to rejoin the network halves.

During the planning, the maintenance process should be understood and considered to evaluate the appropriate segmenting of the network. To add or remove power in connectors, power out connectors, node connectors, splicing connectors, or bus termination connectors to the system, the power must be taken offline. After the maintenance is performed, and then power is reapplied. Before bringing a system online, installation of all IDC style connections and population of their respective nodes or node termination caps must be completed.

If additional cable length is required to be added, a splicing connector may be added to join the two cable segments and then the splicing connector should be mechanically secured. If the cable to be extended was previously terminated, the bus termination cap must be removed by cutting the cable just before it and then terminating the cut cable end at the splicing connector. The excess cable length between the last node connector and the terminator should be selected with consideration for expected maintenance cycles over the system's service life.

2.7 Grounding and Bonding

The EtherNet/IP In-Cabinet-bus network is a single point grounded system. All provisions of grounding exist in the First Power Tap.

Figure 2-6 Grounding of First Power Tap

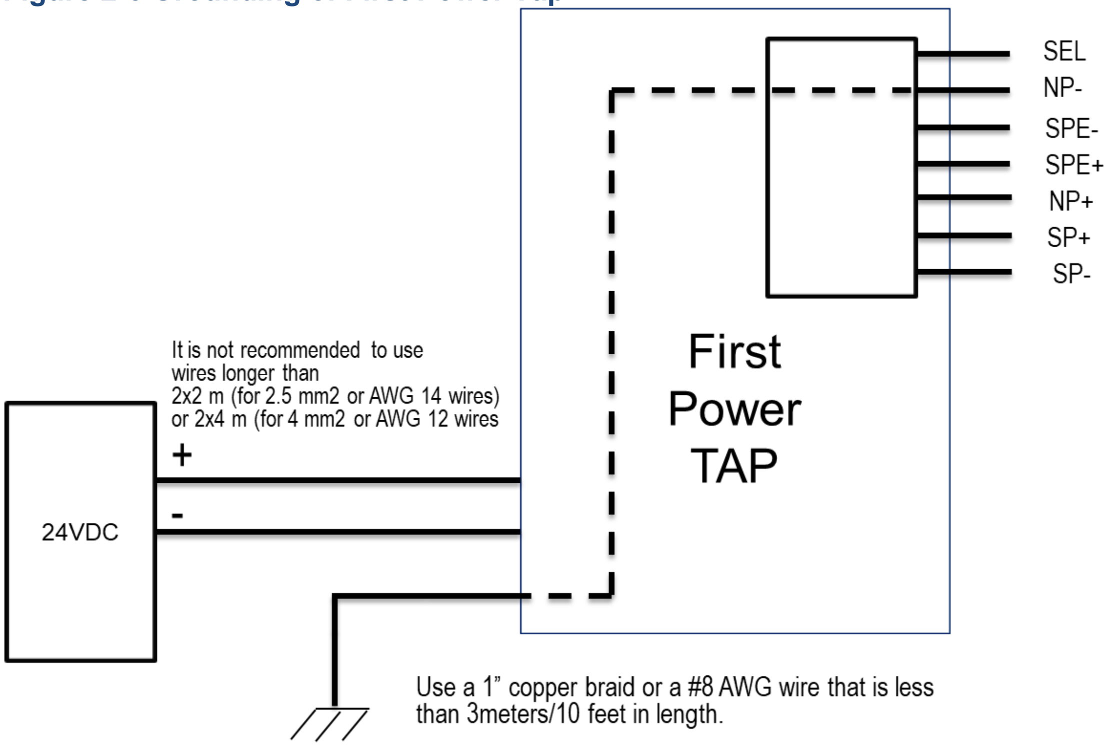
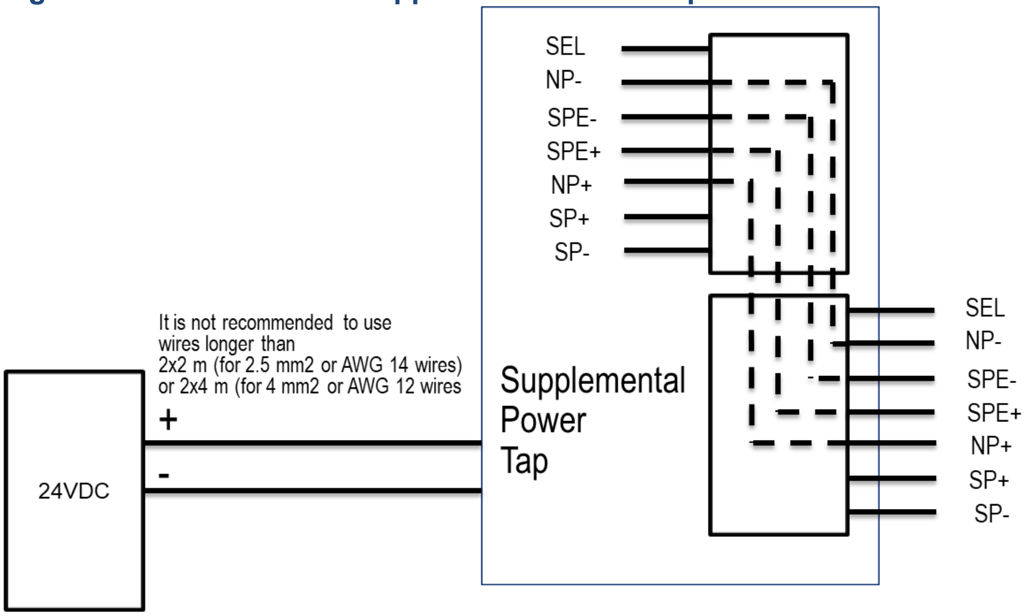


Figure 2-7 Connection of Supplemental Power Tap



Inputs of both First Power Tap and Supplemental Power Tap support PELV and SELV supplies, but Supplemental Power Tap does not require a direct earthing connection. All network devices are required to maintain isolation between switched power and network power such as to avoid creation of ground loops with multi-point grounds.

2.8 General Wiring Guidelines

The EtherNet/IP In-Cabinet-bus network is intended to be installed within a NEMA or IP rated enclosure for internal component routing. Wiring should be neatly routed to and between devices with sufficient cable slack, to permit temporary removal of connectors without disturbing adjacent device connectors.

2.9 Tray and Conduit Spacings

Consult the cable manufacturer when installing EtherNet/IP In-Cabinet cables in a metallic cable pathway (e.g., conduit or a cable tray), as the electrical performance can be affected by the metal. Avoid routing near equipment that generates strong electric or magnetic fields. Cables must be properly supported (i.e., using hangers and within raceways) to prevent damage. Cable support loading requirements must be observed to prevent cable crushing. Industrial Ethernet cables are available with UL AWM 600 V recognition; per NFPA 79 guidelines, this 600 V construction and agency approval means these cables can be installed in cable trays near other 600 V cables (as long as all other requirements are met and installation best practices are observed). Refer to the manufacturer's instructions and local wiring codes for more information.

To guard against coupling interference from one conductor to another, follow the general guidelines in Table 3.10 of EtherNet/IP Media Planning and Installation Manual (PUB000148R0) when routing wires and cables both inside and outside of an enclosure.

2.10 Environmental Evaluation

Cabling components need evaluated for compatibility in accordance with the MICE environmental risk assessment process. This includes consideration of temperature and climate for heat and humidity considerations, consideration of shock and vibration for placement around heavy machinery, consideration of chemicals present that may corrode or absorb into jacket materials, as well as consideration of electromagnetic interference that may be present. Components can either be selected to be compatible or have mitigations apply to isolate or shield them from the more severe environmental conditions.

3 EtherNet/IP In-Cabinet Network Installation

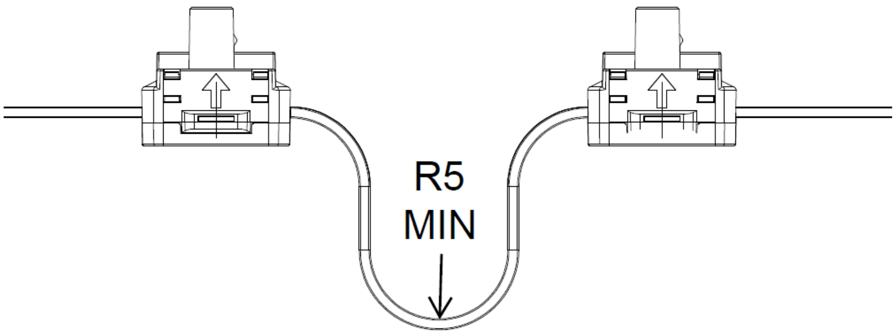
3.1 Installing the Cabling

3.1.1 Bending Radius

The cable bend radius should not be less than 5 mm in a static installation, but 30 mm (20X the cable thickness) for cable loops that move (i.e. at a door hinge).

Note: Flat cable media shall not be bent along its long dimension, except for slightly flexing momentarily during connector installation.

Figure 3-1 Bending Radius



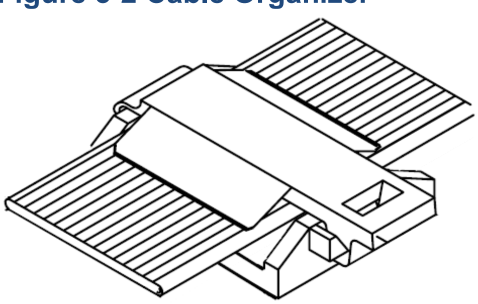
3.1.2 Pull Strength

Refer to manufactures guidelines for maximum pull tension. If the manufacturer's guidelines are not available, the pull strength should not exceed 25 lbs.

3.1.3 Strain relief recommendations

Flat cable mounts, such as Panduit FCM1-A-C14, provide strain relief when used with sufficient cable slack. Clamp at appropriate locations along the cable and secure to the enclosure.

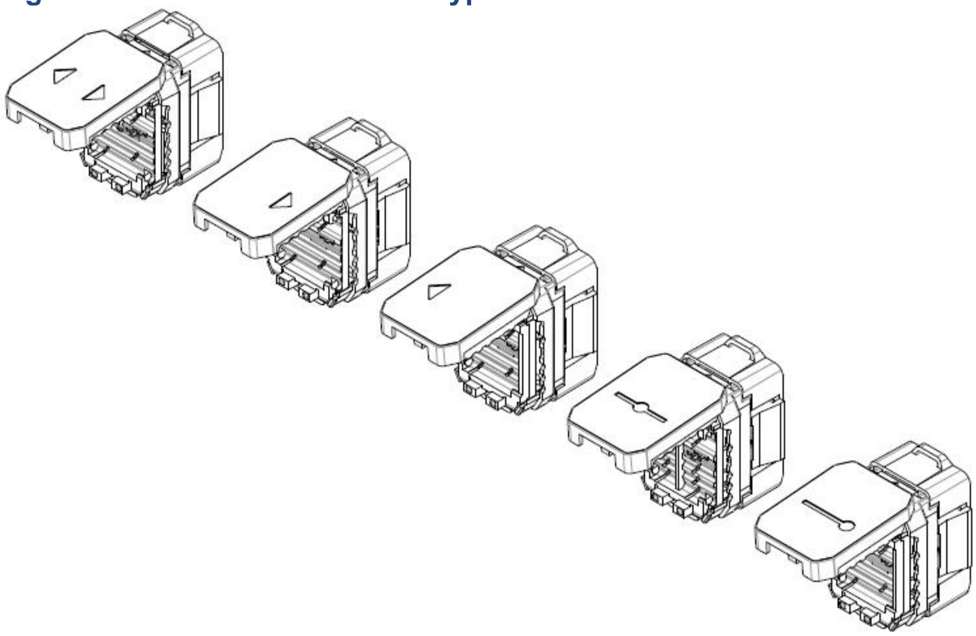
Figure 3-2 Cable Organizer



3.1.4 Field-terminating of Cable and Connectors

The performance of your system depends on the flat media cable termination. Careful cable end preparation is essential for proper connector installation and signal integrity. Different connectors are used, depending upon their location along a cable installation.

Figure 3-3 Different Connector Type



3.1.5 Typical installation of Cable and Connectors

Table 3-1 Typical Installation of Cable and Connectors

from Gateway, Cable C1 running / exiting Right [1] →

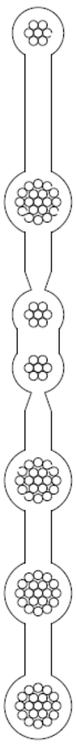
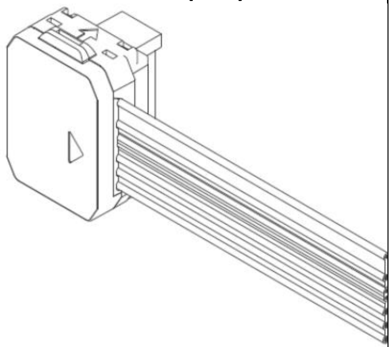
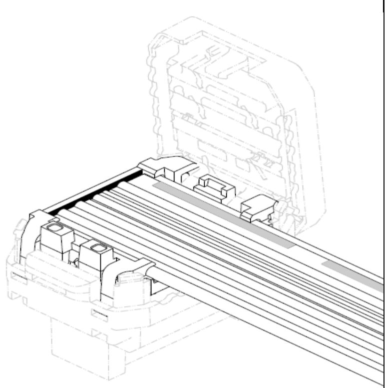
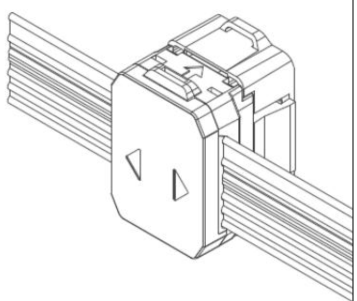
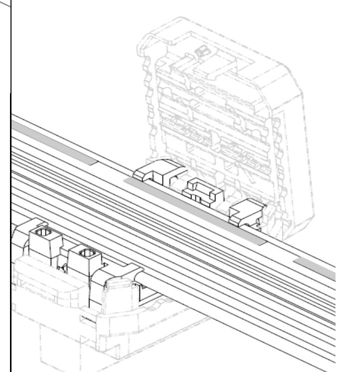
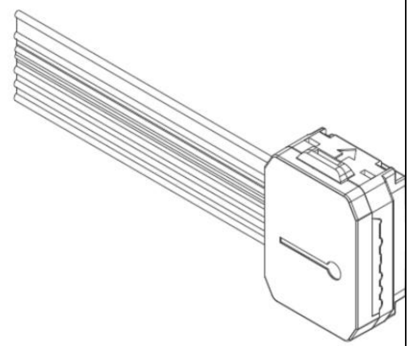
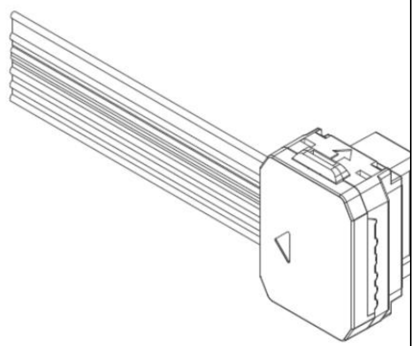
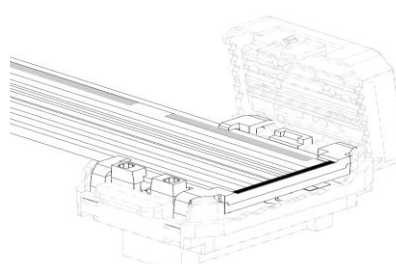
Cable (C1) 	Starting connection point at the Gateway uses a **Left Connector (P2L)**   **P2L** at the Left; closes off and covers the left cut edge of cable	Middle or intermediate connection points attach to various Communication Interface devices using: **Node Connectors (P1)**  	Finally, the ending connection point after the last Communication Interface device, is either a **Terminator (T1)**  or a **Right Connector (P2R)**  (e.g. into a Supplemental PowerTap to continue further with cabling installation)  **P2R** at the Right; closes off and covers the right cut edge of cable

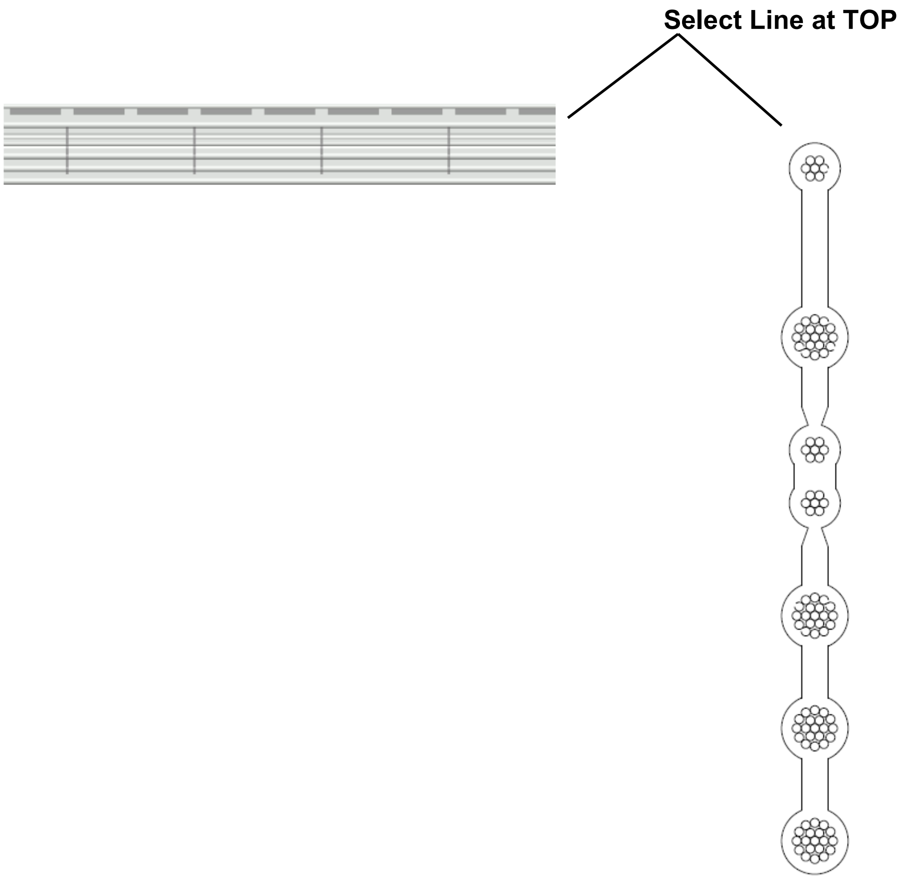
Table footnotes:

1. If the cable exits Left from the Gateway, then it typically begins with P2R and ends with T1, or the cable ends with P2L and continues with a new cable from the Supplemental Power Tap.

3.1.6 Cable and Connector Preparation

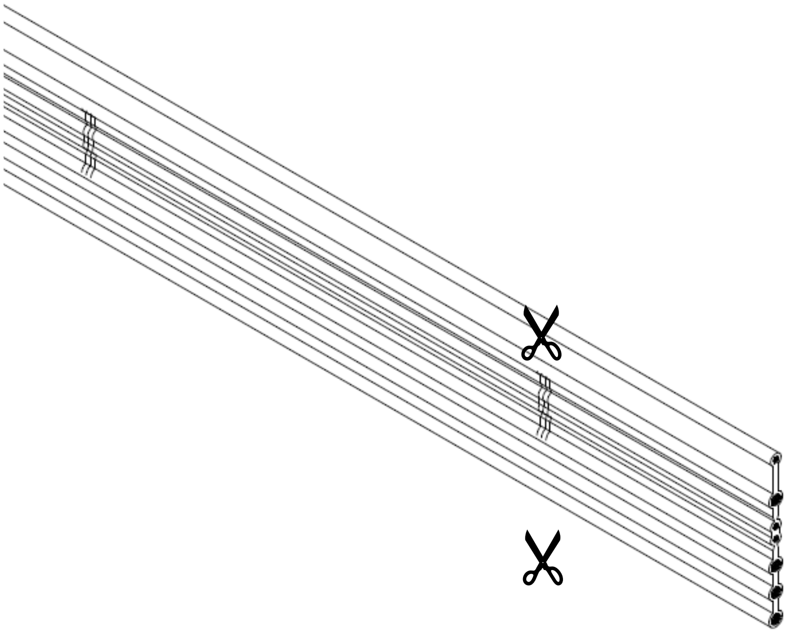
- Orient the Cable C1, with the Select Line conductor towards the TOP.

Figure 3-4 Flat Ribbon Cable



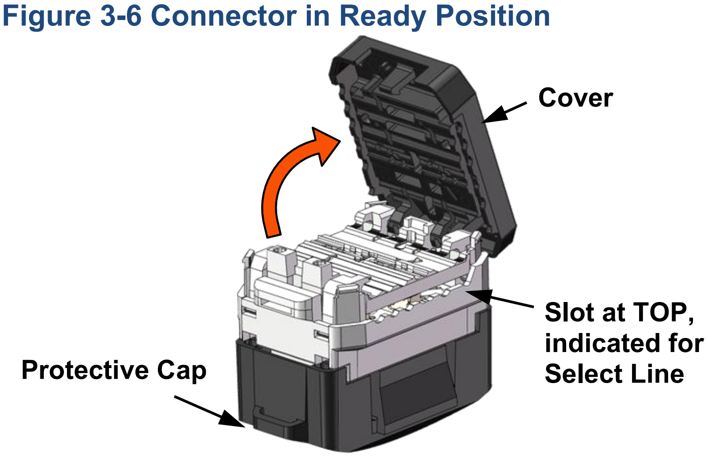
- Evenly trim the cable with a clean, sharp pair of shear blades or scissors, in a direction perpendicular to the running length of the cable direction. (e.g. reference tool RONAN Multi-Cut 401 Cutting Tool)

Figure 3-5 Flat Ribbon Cable with Cut



- Ensure the connector is in the ready to terminate position (i.e., cover is open, or cover is off if removable)

Figure 3-6 Connector in Ready Position

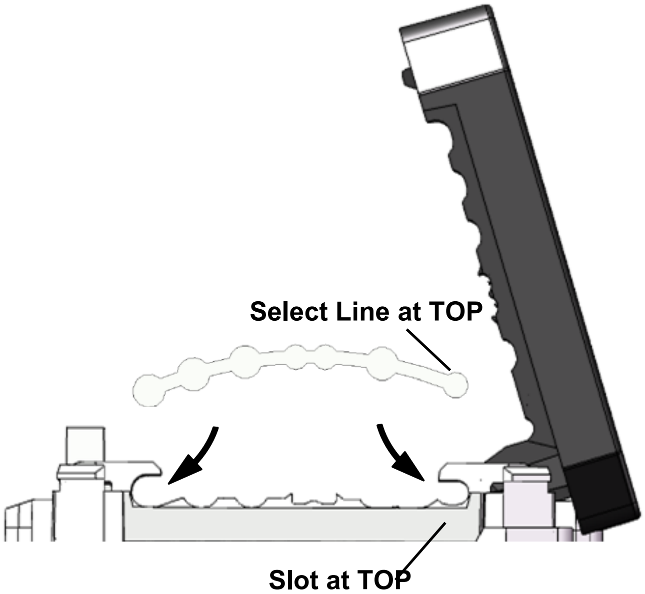


ODVA guidelines mirror the guidelines for The Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources in IEEE standard 518-1982. When planning the cable system, there are certain installation considerations depending on the application.

3.1.7 Insertion of Cable into Connectors

Insert the cable into the connector body, slightly flex as needed into any retaining features to grip the cable outer conductor edges.

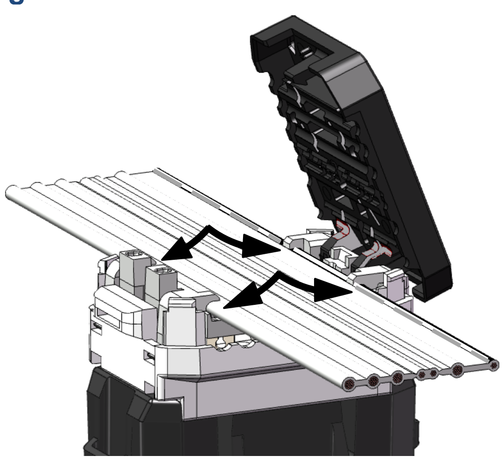
Figure 3-7 Insertion of Cable into Connector



Important: The Select Line must match into the indicated Select slot of the connector.

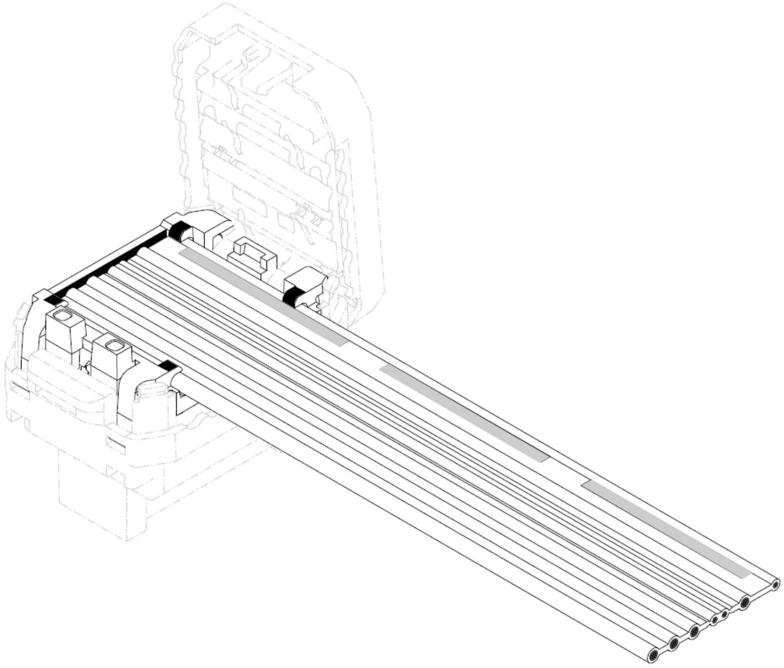
- Press the cable into position. The connector accepts and mimics the asymmetric profile of the cable, to properly position and align the 7 conductors.

Figure 3-8 Press Cable into Connector



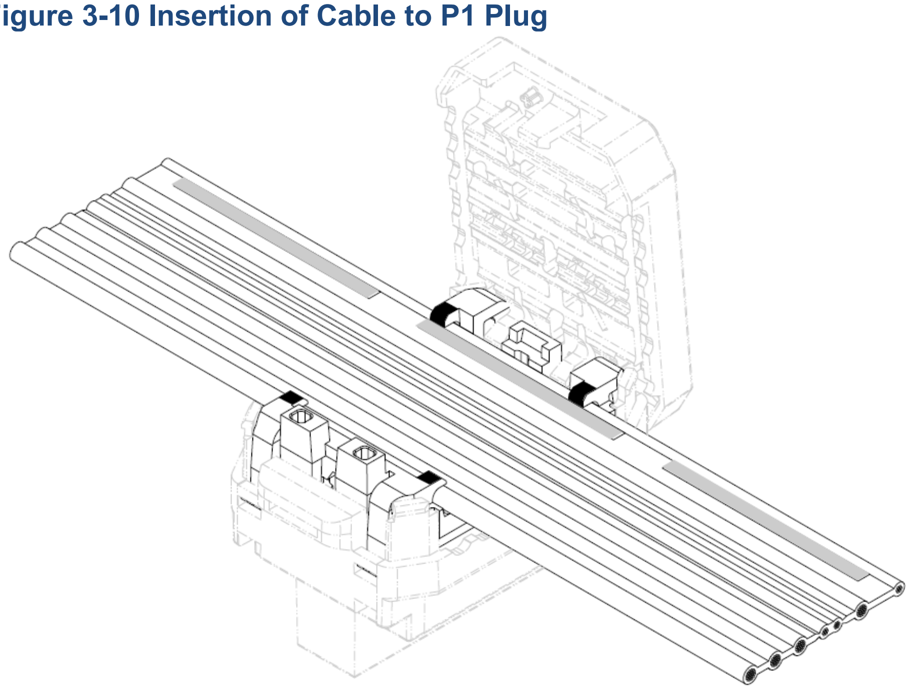
P2 Plug Connector (at Left): Insert the beginning section of the cable into the connector - until the cut edge fully abuts the left internal wall of the left connector body. Ensure the cable outer conductors remain positioned and retained.

Figure 3-9 Insertion of Cable to P2 Plug



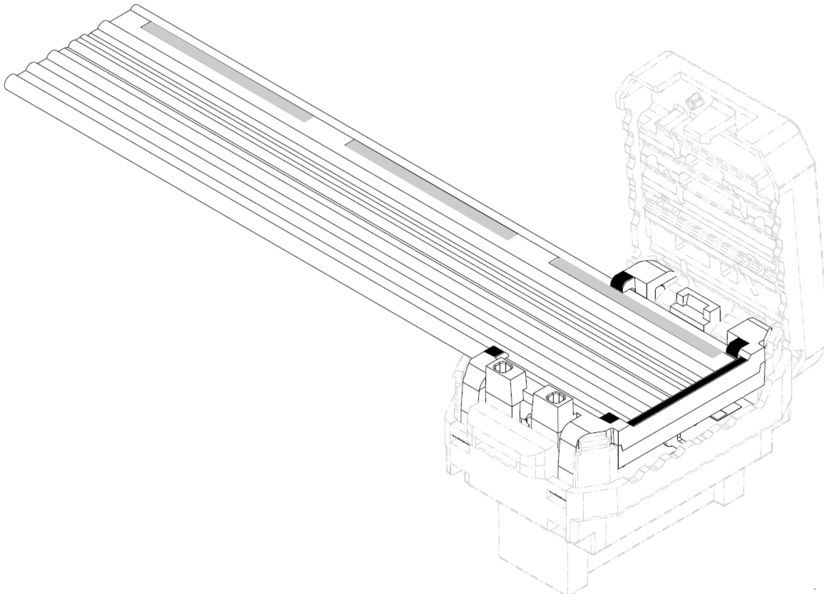
P1 Plug Connector (Node): Insert the desired middle section of the cable into the connector - near the desired attachment location of your Active Device. Ensure the cable outer conductors remain positioned and retained. Final positioning can still be done after the next step.

Figure 3-10 Insertion of Cable to P1 Plug



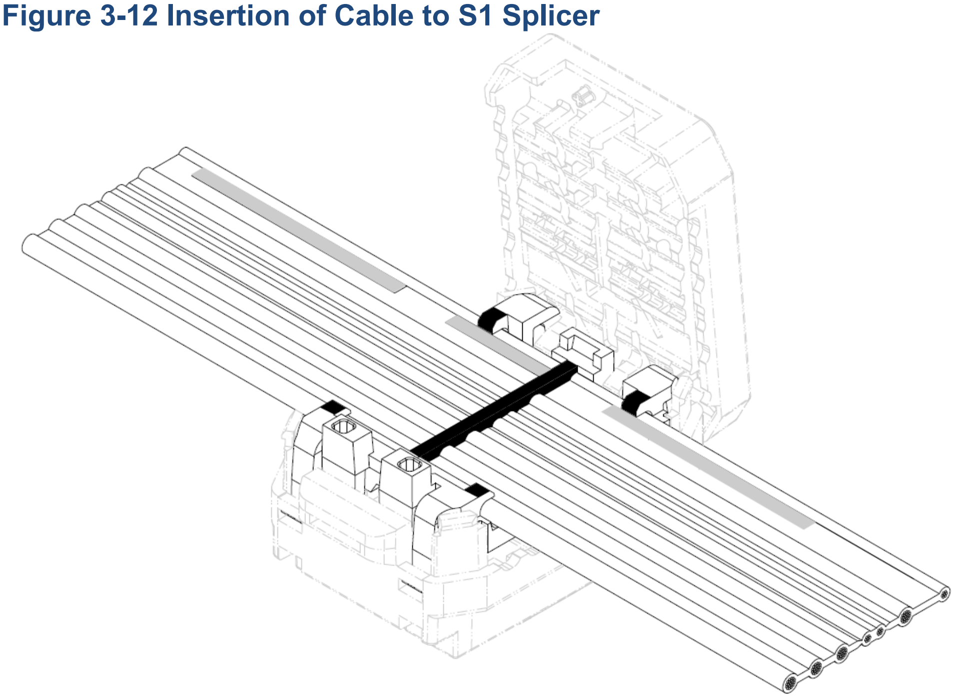
P2 Plug Connector (at Right) or T1 Terminator: Insert the ending section of the cable into the connector - until the cut edge fully abuts the right internal wall of the right connector body or terminator body. Ensure the cable outer conductors remain positioned and retained.

Figure 3-11 Insertion of Cable to P2 Plug Right



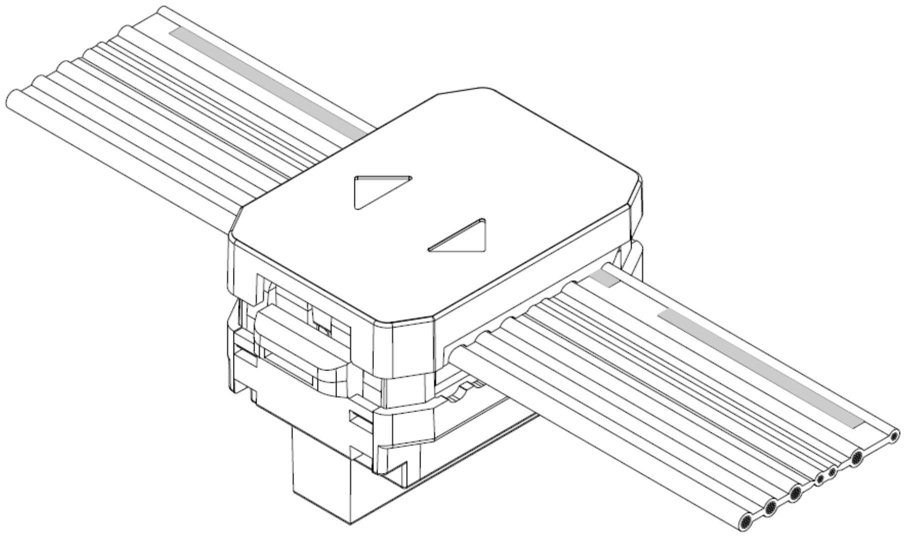
S1 Splicer: Insert the ending sections of two cables; Ensure the cable outer conductors remain positioned and retained, and the cut cable edges fully abut the center internal wall of the splicer body.

Figure 3-12 Insertion of Cable to S1 Splicer



- By hand, press the connector cover over and onto the cable, until it first clicks and latches into the connector body to further seat the cable.

Figure 3-13 Press Connector Cover onto Cable



P2 Plug Connector at Left: Assure that the cut edge still abuts and is pushed against the left internal wall of the left connector body.

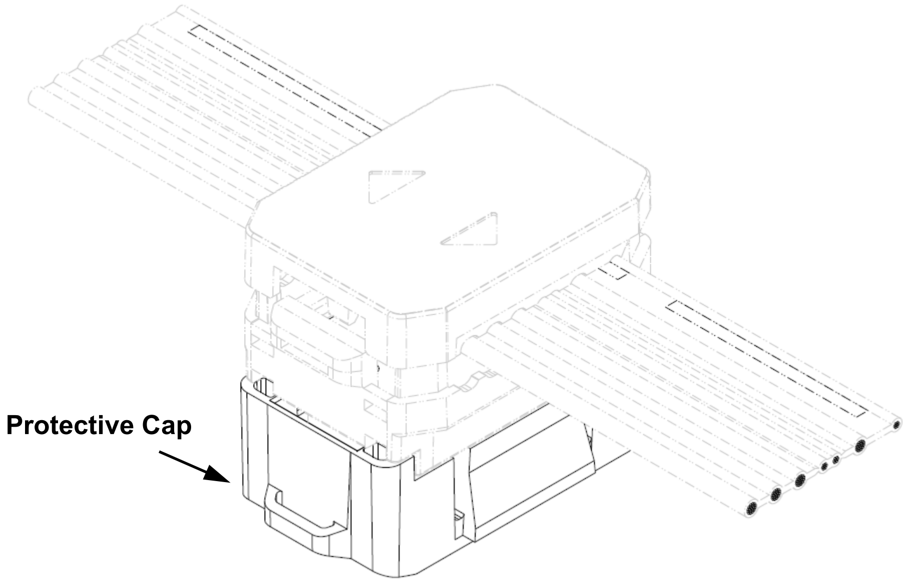
P1 Plug Connector: Slide the node connector to the desired location.

P2 Plug Connector at Right: Assure that the cut edge still abuts and is pushed against the right internal wall of the right connector body or terminator body.

3.1.1 Crimping Connectors onto Cable

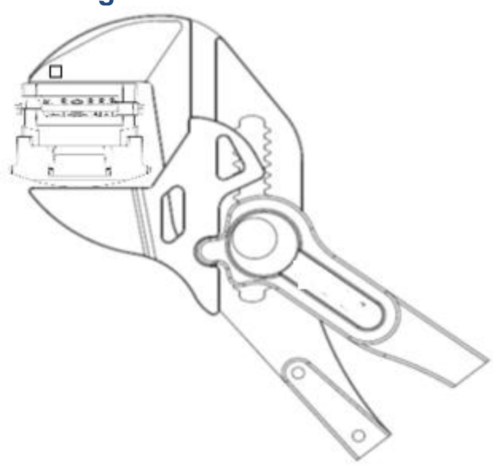
- Insert a protective cap over the connector body if not already present.

Figure 3-14 Insertion of Protective Cap over Connector Body



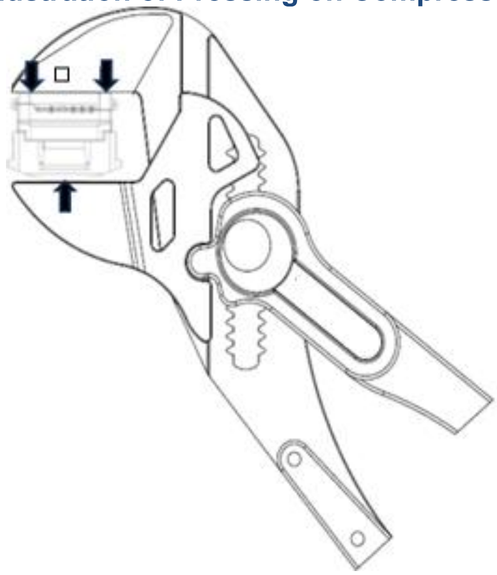
- Using a pair of adjustable type pliers, adjust the jaw openings to achieve sufficient parallel opening. (e.g. KNIPEX 86 03 250 parallel-action jaw pliers; Kobalt 2 pc Magnum Grip Pliers Set Innovative Extra Strong Parallel Jaws 0404860)

Figure 3-15 Illustration of Plier



Compress the connector cover and the protective cap together, until the connector cover is flush with the connector body.

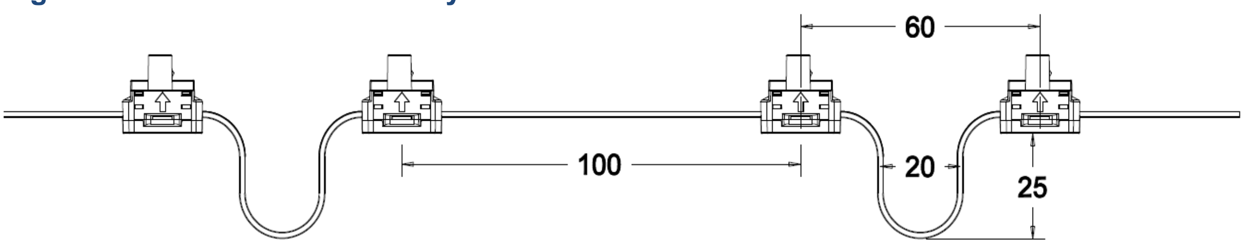
Figure 3-16 Illustration of Pressing on Compress Connector with Plier



- Repeat the installation for the remaining connectors.
  As a start, approximately 100 mm spacing between connections is recommended to allow for cable slack for connector insertion/re-insertion; adjust based upon adjacent device dimensions.

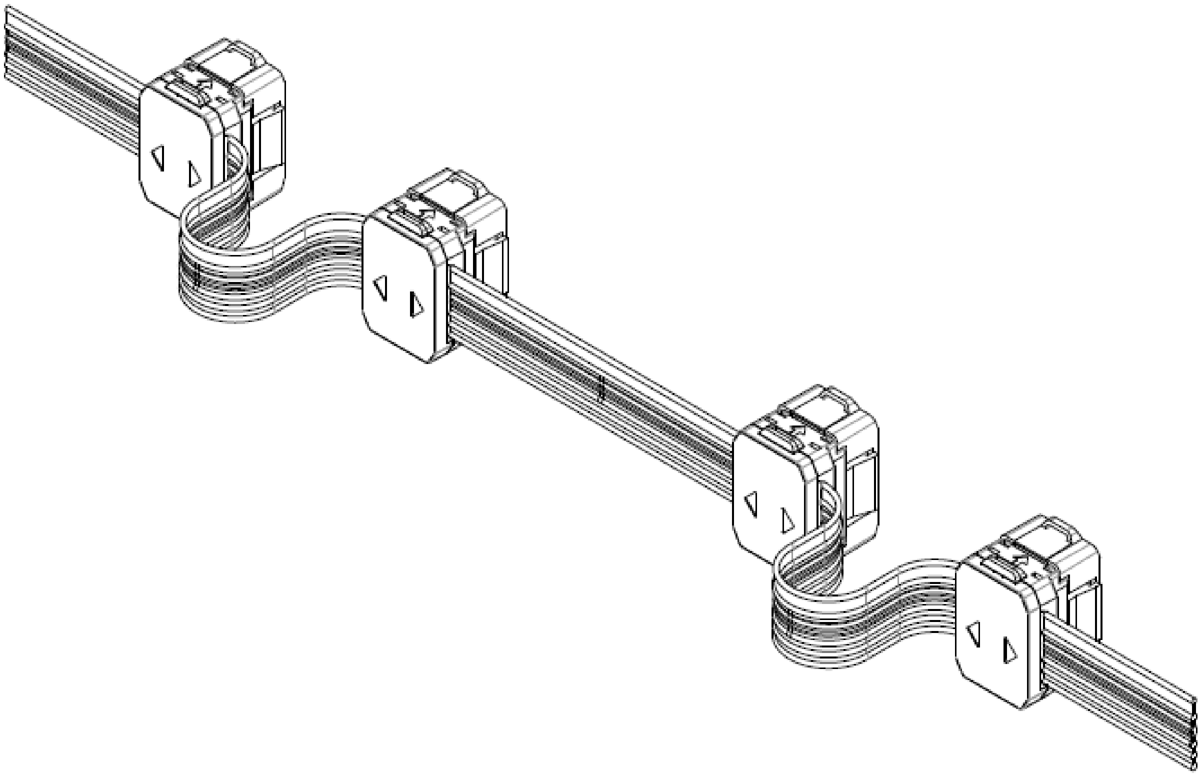
Example layout:

Figure 3-17 Cable Connector Layout



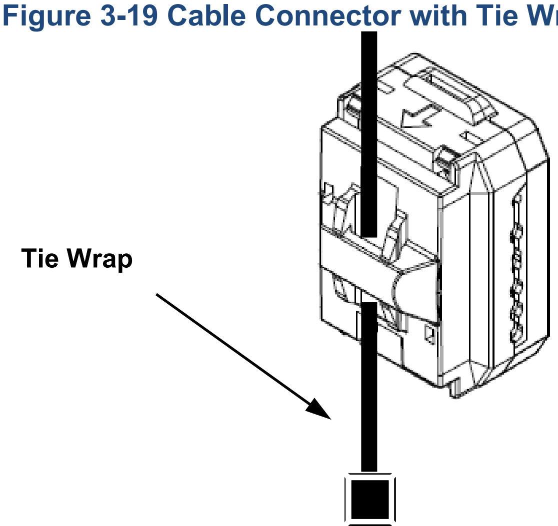
The perpendicular lines indexed every 50 mm can be used as a guide

Figure 3-18 Illustration of Cable Connector Assembly



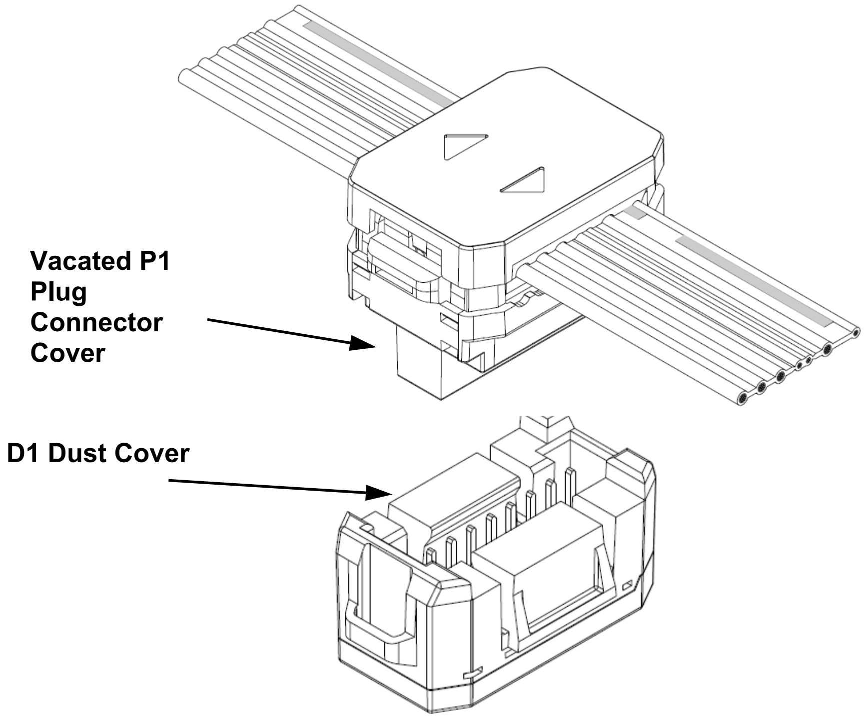
- Optionally use tie wraps to attach the back of the bus terminator or splicer connector to a secure surface.

Figure 3-19 Cable Connector with Tie Wrap



- In place of Communication Interfaces that were removed from an installation, snap a Dust Cover D1 onto any vacated / unused P1 Plug Connectors:

Figure 3-20 P1 Plug with Dust Cover



3.1.2 Connection of Verification and Maintenance Equipment

A critical aspect of network maintenance is properly identifying nodes to be maintained. In an EtherNet/IP network this is managed by a node IP address. In an EtherNet/IP In-Cabinet network, the addresses are automatically assigned at start-up via the gateway and addresses will be retained on power cycle.

It should be noted that because of the flexibility of installation and commissioning, there may not be a clear or obvious pattern to node numbering and as such it is generally recommended that during the installation and commissioning process, the nodes are labelled with an appropriate identification to facilitate identification during maintenance.

4 EtherNet/IP In-Cabinet Network Verification

4.1 Verifying Terminated Cable Segments

Each cable segment on the network should be verified for proper connection as the segment is installed and connectorized. A variety of test tools are available to perform verification and diagnostics on the network.

4.1.1 List of recommended Specialized Equipment

- Digital Multimeter (DMM)
- Single Pair Ethernet compliance testing solution
- Network Analyzer

Primary verification parameters are listed below.

- Jacketed Length
- Number of Connections
- Bend radius
- Terminating Dust caps for unterminated connectors
- Cable end terminations
- Labeling per design documentation
- Routing of cables with respect to other EMC 1, 2 and 3 circuits

Note: EMC 1, 2 and 3 circuits are defined in Table 3.9 of EtherNet/IP Media Planning and Installation Manual, PUB000148R0.

4.1.2 Length

The physical length of the channel is the sum of the physical lengths of the cables between the two terminations. Physical length of the channel may be determined by physically measuring the length(s) of the cable(s) or determined from the length index markings on the cable(s). The total length of the cable should be less than 25 meters.

4.1.3 Number of connections

The total number of connections for one EtherNet/IP In-Cabinet network needs to be no more than 40. The numbers of Plug connector P1, P2 and Splicer S1 need to be added together for the total count.

4.1.4 Cable end terminations

EtherNet/IP In-Cabinet network needs to be terminated at both ends of the cable. The termination can be provided by terminator T1 or reside within the First Power Tap.

5 EtherNet/IP In-Cabinet Network Troubleshooting

5.1 Tools for Determining Network Failures

5.1.1 Device Indicators

Device indicators offer a simple means to assess the general health of In-Cabinet devices. While normal indicator states reflect expected operation, atypical states can be used to more quickly identify the source of errors when network issues are observed. Module Network Status (MNS) indicator is typically available for EtherNet/IP In-Cabinet device.

Table 5-1 MNS Indicator State

Indicator State	Summary	Requirement
Steady Off	Not Powered, no IP Address	The device is powered off or is powered on but with no IP address configured.
Flashing Green	No Connections	An IP address is configured, but no CIP connections are established, and an Exclusive Owner connection has not timed out.
Steady Green	Connected	An IP address is configured, at least one CIP connection is established, and an Exclusive Owner connection has not timed out.
Flashing Red	Connection Timeout or Major Recoverable Fault	An IP address is configured, and an Exclusive Owner connection for which this device is the target has timed out. Indicator returns to steady green only when Exclusive Owner connection is reestablished. Timeout of other connections shall not cause indicator to flash red. Flashing Red applies to target connections only. Incorrect configuration is Major Recoverable Fault.
Steady Red	Duplicate IP or Major Unrecoverable Fault	For devices that support duplicate IP detection, the device detected its IP is already in use.
Flashing Green/Red	Self-Test	During power-up testing, this indicator performs required test sequence

5.1.2 Diagnostic Error Counters

Communications error counters are extremely useful in predicting a future failure. Alarms can be set at error counter thresholds with communication management software to warn operators that failure is imminent. A network that exhibits slowly increasing error rates over time is an indication of a degrading network. This can be caused by failing connectors, moisture ingress or even temperature rises. Error counters that show burst behavior are often indicative of electrical noise, which may result from a poorly designed network, cables routed too close to noise generating machinery, or a failing grounding system.

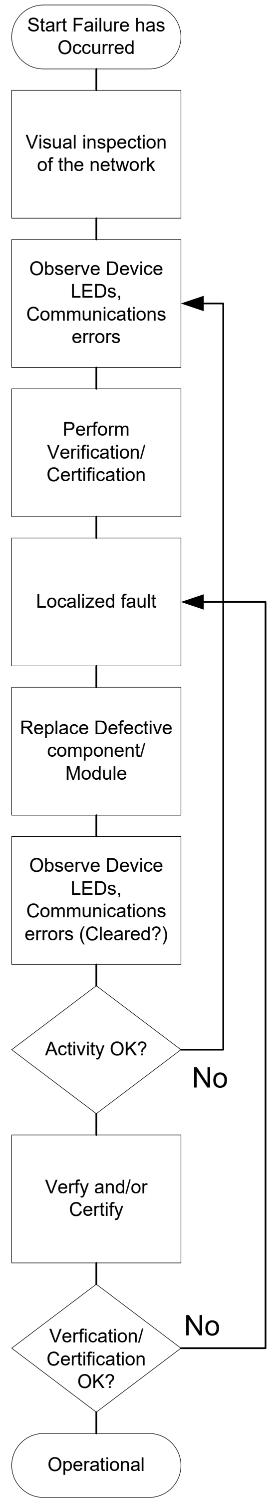
5.1.3 Determining Network Failure

In some cases, it may be obvious that a network failure has occurred, when a machine unexpectedly stops operating. In other cases, the network failure may not be obvious. These scenarios frequently involve intermittent or noise-related issues, which are often closely related. EtherNet/IP In-Cabinet network provides built-in diagnostic and error reporting capabilities at the device level. Communication management software can collect and present this information to operators as a diagnostic aid. This information can help determine the source of a failure that has occurred. Error counter histograms are particularly effective for correlating communication errors with system events, such as a drive transitioning online.

5.2 Quick Troubleshooting

A systematic approach should be used for troubleshooting. Figure 5-1 is an example of a basic troubleshooting process.

Figure 5-1 Basic Troubleshooting Flow Chart



5.3 Common Symptoms / Causes of Failures

Table 5-2 provides common symptoms and causes of failures to help with the troubleshooting process.

Table 5-2 Network failures and possible causes

Symptom	Possible Cause	Suggested Action
High error rate	• Damaged cable • Electrical Noise Nearby • Wrong cabling used	• Perform verification
No communications	• Severed cable • Disconnected node • No termination	• Check for power connections to Power Tap and Device • Correct wiring and connection
No Link Indication	• Severed Cable • Disconnected connector. • No termination	• Correct cut or disconnected cable/connector • Defective Switch/Device • Correct power
Burst Error Indication	• Noise generating device • Poor cabling • Grounded Shield	• Correlate burst noise to burst errors. Provide additional separation, check for improper grounding • Check for low noise cabling.
Continuous error condition (some data getting through)	• Incorrect cabling for application or noise level.	• Use proper cabling to support application • Connect earth grounding to first power tap
Continuous error condition (no data getting through)	• Severed cable • Check Link indicator • Disconnected node	• Check for power to Switch and Device • No power to switch or device • Defective Gateway