Auxiliary Power Distribution System for CIP Networks

Bob Lounsbury
Principal Engineer
Rockwell Automation

Presented at the ODVA
2009 CIP Networks Conference & 13th Annual Meeting
February 25, 2009
Howey-in-the-Hills, Florida USA

Abstract:
The need for high auxiliary power has become very common on communications devices. The customer base has been requesting that components be standardized including permissible noise limits. The Physical Layer SIGs have been working together to develop a Auxiliary power system for all CIP based networks. As a result a new distribution system is emerging within ODVA with the sole purpose is to distribute power to devices. This system defines power supply requirement, cabling requirements including connector pinning and topologies. This paper covers the technical aspects with this new power distribution system. Come and see how this affects your products.

Body:

Introduction:
This project began several years ago at the request of a large US automaker. There were numerous problems with electrical noise and connector wiring compatibility issues. The project has grown into a definition of a complete system providing topology, connector and wiring specifications. The objective of this specification is to capture best in class practices for Auxiliary power circuits by defining a set of consistent rules for components, devices and wiring practices. Each CIP physical layer Special Interest Group (SIG) provided input to this specification. Further studies of other consortia practices was performed to minimize incompatibilities and minimize the chance of cross circuit problems with communications networks using similar connectors.

Because of the vast numbers of products in the market place, that already support 24V Auxiliary power, the specification is being released as an informative addition to the ODVA CIP common standard. As a CIP specification, it provides unified solution for all CIP families. Example uses of this system are; E-stop systems, auxiliary power for I/O devices, PwE (Power with Ethernet). Until now, the auxiliary power systems in the field have been at best an ad-hoc system with no guidelines or specifications for manufactures or system builders. By defining the cabling components and power supply requirements, a true standardized system can be designed and built with some reasonable certainty that cables, connectors and devices are plug and play compatible.

Wiring Methods:
Factory automation commonly uses many different control voltages for machine control, 24V, 110V, 220V and up. Today it is a ad-hoc system with minimal sets of rules for wiring owing to it's flexibility. The first release of this specification addresses 24 Volt Auxiliary wiring meeting the extra low voltage directives. Future releases may enable support for higher voltage systems. With this in mind, this CIP enhancement for the 24V system is setting the stage for future releases of other auxiliary power voltages. It is important to note that this power bus does not support earthing conductors. It is not the intention of this system to provide earthing and bonding functions for automation equipment. By not providing earthing and bonding functions the system becomes a simple 4-wire system with two completely isolated power circuits with a minimal set of contacts. Since there are two V- wires

 ©2009 ODVA, Inc.

(instead of a shared V-) the available power in the system is twice that of a shared V- system. For maximum flexibility the 4-wire system provides a switched circuit and a non-switched circuit of equal power capability.

The system details examples of three basic physical topologies, Linear Bus, Daisy chain and last but not least a star. Figure 1 shows a liner bus constructed of a trunk cable, taps and drop cables.

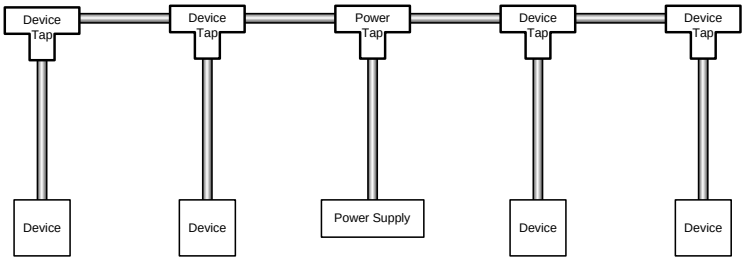


Figure 1 Linear bus topology

Figure 2 shows how a daisy chain system can be constructed. This requires that the devices be designed with two auxiliary connectors, one jack and one plug. The power must be applied to the device at the plug connector and the output to the next load is through the jack. This is done so that a dangling plug will not expose "hot" pins.

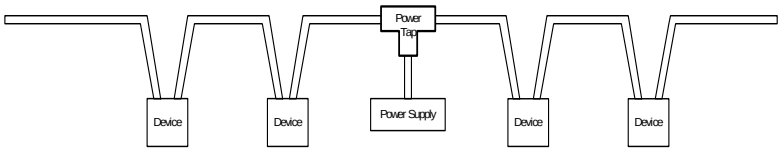


Figure 2 Daisy Chain Topology

Daisy chaining can also be accomplished using single port loads with a "T" tap installed on the load as shown in figure 3.

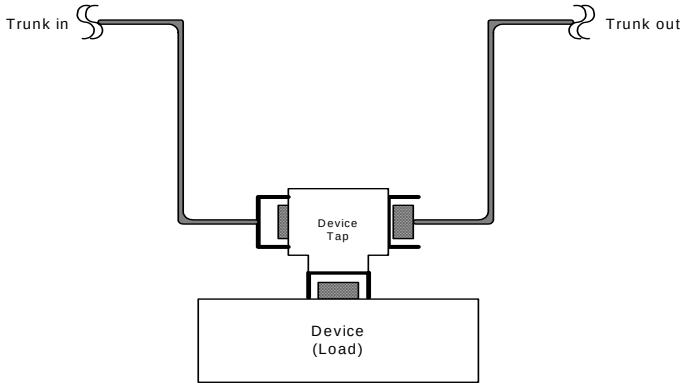


Figure 3 Example of a Daisy Chain Topology using a Device Tap

 ©2009 ODVA, Inc.

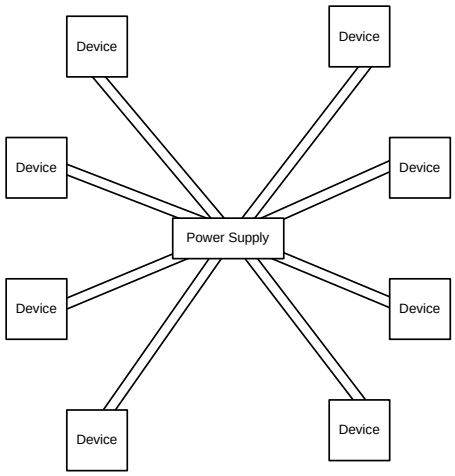


Figure 4 Star Topology

These basic topologies are only documented to aid the reader in understanding various configurations from a high level perspective. In reality, auxiliary power circuits have been wired in many different configurations, most of which are combinations of the three basic topologies. Of the three topologies, the Star in figure 4 requires a hub with a minimum one input and many outputs. In most cases this is simply a set of screw terminals in an enclosure but could be as elaborate as box with sealed bulkhead connectors fed by a centrally located power supply. It must be noted that the power supply may be remotely located from the hub if the installation requires.

Connectivity Components

The proposed standard includes 4 connectors, two of which are considered open style. Three of the 4 connectors provide sealing to IP 67. Since the Mini (7/8) and Micro (M12) family connectors have been used for many years as sealed I/O connectors, it makes sense to define them as connectors for use in AUX Power circuits. These connectors including the open style connector lend themselves easily to all bus topologies. The flat connector using the 4 screw terminals is ideal for all but the star topology. A product using this connector may connect directly to the bus by embedding the top assembly in the product or connect to the screw terminals via a short permanently attached cable.

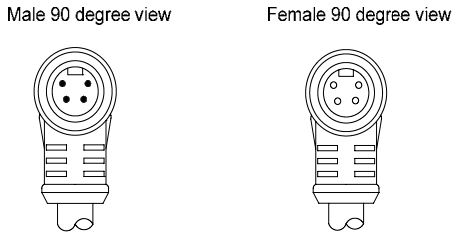


Figure 5 Mini (7/8) style

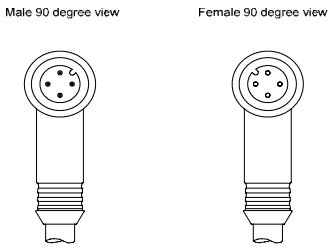


Figure 6 Micro Style

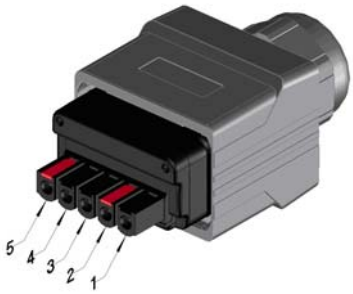


Figure 7 Open Style (sealed)

Note that the open style connector has two red keys. These keys distinguish this connector implementation from other voltage connectors such as 110V and 220V. This is the only 5 pin connector currently defined by the specification. The system currently only uses 4 of the 5 pins.

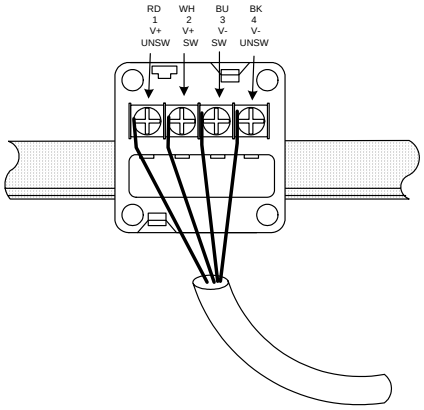


Figure 8 Flat Connector (IDC)

For compatibility, the CIPSE requires that devices (loads) be designed with male connectors. This assures that all drop cables end with a female connector to minimize the potential for shorting to ground.

Cable

Currently there are three cables defined for auxiliary power systems, Auxiliary Power Trunk cable, Auxiliary Power Drop cable and a Auxiliary Power Flat Cable. Each has unique cable parameters. While they technically could be used anywhere in the system (trunk for drop, drop for trunk) they do have different D.C resistance (DCR) values that limit the system length for a given current. The specification details the current versus the length for each cable.

The system is based on a maximum 6 volt drop between the power supply and any load. Therefore the minimum voltage on a typical auxiliary power bus is 18V. As a result the cable lengths are based on the IR drops in the system of which the cable is the majority contributor of the power losses. Each cable type has it's own DCR per meter or feet as shown in the ODVA Spec, which assumes that all loads are at the end of the cable. In reality the loads are distributed along the power bus. Later in this paper I will present some example calculations for a system where loads are distributed along the bus.

Taps

Device Taps , (and power taps) are designed to prevent exposed contacts. This concept requires that the device tap be constructed of two female connectors and one male connector. The input side of a device tap is a male.

Connection to the device (drop) and trunk is through female connectors, see figure 9. A device and power taps have a maximum DCR that is shown in table 1 below.

Keeping with the rule of not having exposed, live contacts, the power tap is designed with a male for the input power and two female connectors to feed the trunk line in both up stream and down stream directions see figure 9. Theoretically a device tap could be use as a power tap if fuses are not needed.

Cords
If the power taps, device taps and loads are designed with the correct connector gender, all cords whether power supply, drop or trunk will then be designed with one jack and one plug as shown in Figure 9

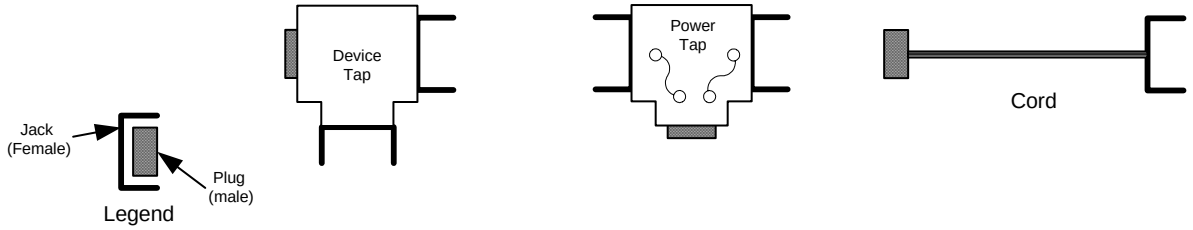


Figure 9 Device and Power Tap and Cord

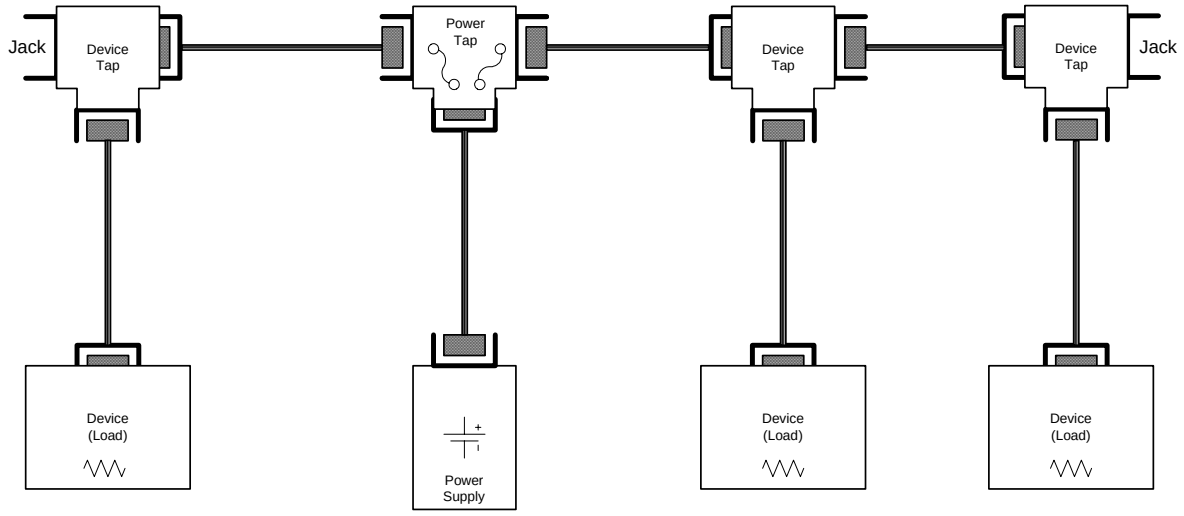
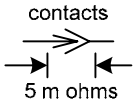
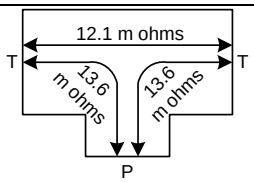
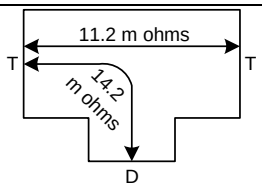
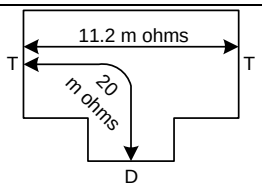


Figure 10 Example System

System Length;
The limiting factor for length is voltage drop in the system. Since the system is designed to provide a minimum of 18V to all loads, there can be no more than 6 volts nominal drop in the cabling. The word nominal is used because of the allowed power supply tolerance of. The power supply output voltage is 24 volts +/- 1% if fixed and 22-27.2 volts if adjustable. The system IR drop can be pushed by using a adjustable power supply. A word of caution is in order because the specification stills requires that the power supply output voltage be 24 volts +/- 1%. In other words, adjusting the voltage up to compensate for voltage drops to devices at the far end of the trunk could result in excessively high voltage for devices that are near the supply.

The following table details the DCR for each of the cabling elements in the auxiliary power system.

Table 1 Resistance Values for Cabling Components

Cabling Element		DCR	Note	Schematic
Connector DCR		5 mohms	Over life, per contact	
Power Tap DCR		12.1 mohms trunk to trunk, 13.6 m Ohms trunk to drop	Includes contacts and internal wiring	
Device Tap DCR	Mini to Mini 7/8	11.2 mohms trunk – trunk 14.2 m ohms trunk - drop	Includes contacts and internal wiring	
	Mini to Micro & Micro to Micro	11.2 mohms trunk – trunk 20 mohms trunk - drop		
Cable DCR/length	Trunk	16 (4.9)	m(ft)	@ 20 deg C
	Drop	22.6 (6.9)	m(ft)	
	Flat	16 (4.9)	m(ft)	

Equations:

The current in any segment of cable (cable between taps) is the sum of currents in each current sharing the segment. Consider the following system . Unlike DeviceNet, there are no rules for the length of cable between the power supply and the power tap. However one should keep in mind that all of the current for the power bus goes through this cable and any IR drop is wasted power. Therefore the length should be kept to a minimum by placing the power supply in close proximity. When this is not possible, the size of the cable should be sized such that the IR drop is negligible.

 ©2009 ODVA, Inc.

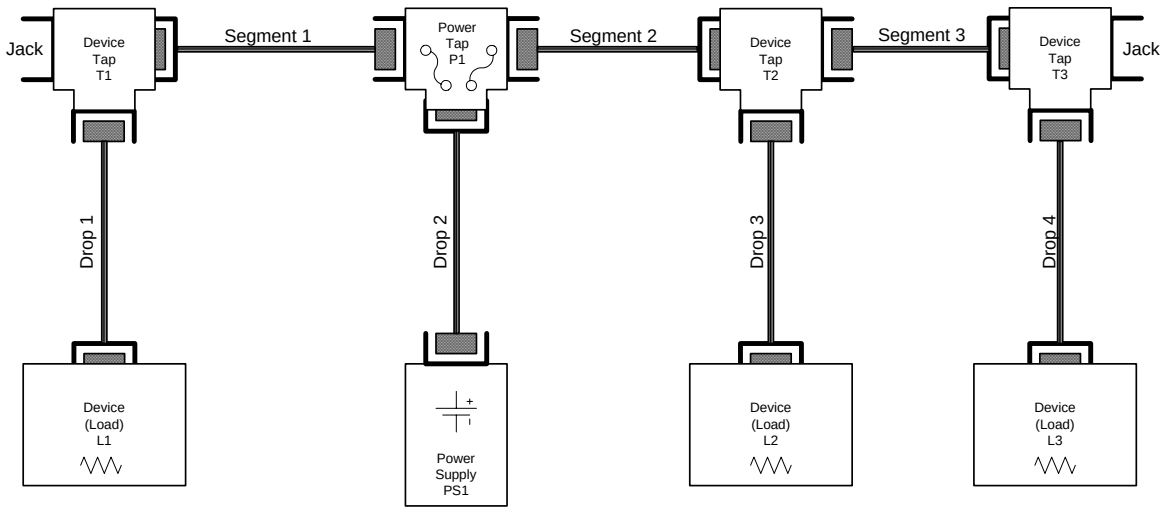


Figure 11 Example Auxiliary Power Circuit with 3 loads

The total current in the system, as seen by the power supply (PS1), is the sum of the currents at each device (load). Therefore the current in this example

$$I_{total} = I_{L1} + I_{L2} + I_{L3}$$

By calculating the voltage drop in each element and adding them together the voltage at each load can be determined. The following formulas are an example of the necessary calculations.

The voltage drop is a function of the current through each path to the load times the path resistance. Therefore the voltage drop at each load is the sum of the voltage drops between the power supply and the load.

Tap IR Drops

$$Vd_{T1_TD} = R_{T_TD} \cdot I_{L1}$$ IR drop from trunk to drop for L1

$$Vd_{T2_TD} = R_{T_TD} \cdot I_{L2}$$ IR drop from trunk to drop for L2

$$Vd_{T2_TT} = R_{T_TT} \cdot I_{L3}$$ IR drop from trunk to trunk for L3

$$Vd_{T3_TD} = R_{T_TD} \cdot I_{L3}$$ IR trunk to drop for L3

Segment IR Drops

$$Vd_{Seg1} = \left(R_{Trunk} \cdot Len_{Seg1}\right) \cdot I_{L1}$$

$$Vd_{Seg2} = \left(R_{Trunk} \cdot Len_{Seg2}\right) \cdot \left(I_{L2} + I_{L3}\right)$$

$$Vd_{Seg3} = R_{Trunk} \cdot Len_{Seg3} \cdot I_{L3}$$

 ©2009 ODVA, Inc.

Drop cable IR drop

$$Vd_{Drop1} = \left(R_{Drop} \cdot Len_{Drop1} + R_{Contact}\right) \cdot I_{L1}$$

$$Vd_{Drop2} = \left(R_{Drop} \cdot Len_{Drop2} + R_{Contact}\right) \cdot \left(I_{L1} + I_{L2} + I_{L3}\right)$$

$$Vd_{Drop3} = \left(R_{Drop} \cdot Len_{Drop3} + R_{Contact}\right) \cdot I_{L2}$$

$$Vd_{Drop4} = \left(R_{Drop} \cdot Len_{Drop4} + R_{Contact}\right) \cdot I_{L3}$$

Power Tap IR drops

$Vd_{P1b} = R_{P_TD} \cdot \left(I_{L2} + I_{L3}\right)$ for direction to the right

$Vd_{P1a} = R_{P_TD} \cdot I_{L1}$ for direction to the left

Final calculations

$$Vd_{L3} = Vd_{Drop2} + Vd_{P1b} + Vd_{Seg2} + Vd_{T2_TT} + Vd_{Seg3} + Vd_{T3_TD} + Vd_{Drop4}$$

$$Vd_{L2} = Vd_{Drop2} + Vd_{P1b} + Vd_{Seg2} + Vd_{T2_TD} + Vd_{Drop3}$$

$$Vd_{L1} = Vd_{Drop2} + Vd_{P1a} + Vd_{Seg1} + Vd_{T1_TD} + Vd_{Drop1}$$

Consider the following parameters for each device in this simple network in figure 11 above based on the parameters below.

Load Current Requirements	Segment lengths;	Drop Lengths;
Current at Load 1 = 1.25 Amps	Segment 1 = 200 feet	Drop 1 = 25 feet
Current at Load 2 = 2.75 Amps	Segment 2 = 85 feet	Drop 2 = 20 feet
Current at Load 3 = 1.00 Amps	Segment 3 = 400 feet	Drop 3 = 35 feet
		Drop 4 = 10 feet

The voltage drop at each load for each path is defined as;

$$Vd_{L3} := \left(Vd_{Drop2} + Vd_{P1b} + Vd_{Seg2} + Vd_{T2_TT} + Vd_{Seg3} + Vd_{T3_TD} + Vd_{Drop4}\right)$$

$$Vd_{L3} = 4.387$$

$$Vd_{L2} := \left(Vd_{Drop2} + Vd_{P1b} + Vd_{Seg2} + Vd_{T2_TD} + Vd_{Drop3}\right)$$

$$Vd_{L2} = 3.045$$

$$Vd_{L1} := \left(Vd_{Drop2} + Vd_{P1a} + Vd_{Seg1} + Vd_{T1_TD} + Vd_{Drop1}\right)$$

$$Vd_{L1} = 2.197$$

The system meets specification since each load receives greater than 18V (24-Vd >18)

 ©2009 ODVA, Inc.

****
The ideas, opinions, and recommendations expressed herein are intended to describe concepts of the author(s) for the possible use of CIP Networks and do not reflect the ideas, opinions, and recommendation of ODVA per se. Because CIP Networks may be applied in many diverse situations and in conjunction with products and systems from multiple vendors, the reader and those responsible for specifying CIP Networks must determine for themselves the suitability and the suitability of ideas, opinions, and recommendations expressed herein for intended use. Copyright ©2009 ODVA, Inc. All rights reserved. For permission to reproduce excerpts of this material, with appropriate attribution to the author(s), please contact ODVA on: TEL +1 734-975-8840 FAX +1 734-922-0027 EMAIL odva@odva.org WEB www.odva.org

CIP, Common Industrial Protocol, CIP Motion, CIP Safety, CIP Sync, CompoNet, CompoNet CONFORMANCE TESTED, ControlNet, ControlNet CONFORMANCE TESTED, DeviceNet, EtherNet/IP, EtherNet/IP CONFORMANCE TESTED are trademarks of ODVA, Inc. DeviceNet CONFORMANCE TESTED is a registered trademark of ODVA, Inc. All other trademarks are property of their respective owners.