Recent Changes in the Physical Layer (Chapter 8) for DeviceNet and EtherNet/IP

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Abstract:

Significant changes are being made to the physical layer (Chapter 8) in both DeviceNet™ and EtherNet/IP™ volumes. For DeviceNet, the changes are more clarification and design factors for both cable drop lengths. For EtherNet/IP, the changes are more technology changes for higher data rate of 1G in an industrial environment and harmonizing with IEC standards. Creating a technical guideline document for earthing (grounding) and bonding for all ODVA physical layers to use.

Keywords:

M12-8 X-Coding, IEC 61076-2-109, Earthing (grounding) and bonding, ISO/IEC 24702, IEC 61918, ANSI/TIA-1005-A, ISO/IEC 11801

Definition of terms (optional):

Bonding: Act of connecting together exposed conductive parts and extraneous conductive parts of apparatus, systems, or installations that are at essentially the same potential. {IEC61918}

Earthing: (verb) often referred to as, "Grounding" in the US influenced markets means to make an electrical connection between a given point in a system or in an installation or in equipment and the local earth. {IEC 61918}

Parallel Earthing Conductor or Potential Equalization cable: a conductor connected in parallel with the screens/shields of signal and/or data cables in order to limit the current flowing through the screens {IEC 61000-5-2, IEC60364-4-44}.

DeviceNet Chapter 8 Changes

Updating Cable profiles with additional information on Drop length

The current DeviceNet cable profiles do not provide any guidance on the maximum drop line current per drop length. The proposed changes will be providing both the table and graph showing the maximum drop line current per drop length. Calculations and values used to create both the table and graph will be provided in the specification. The maximum drop current for any cable profile is 3 Amps due to DeviceNet system design requirements.

Thick Cable profile updates are shown below:

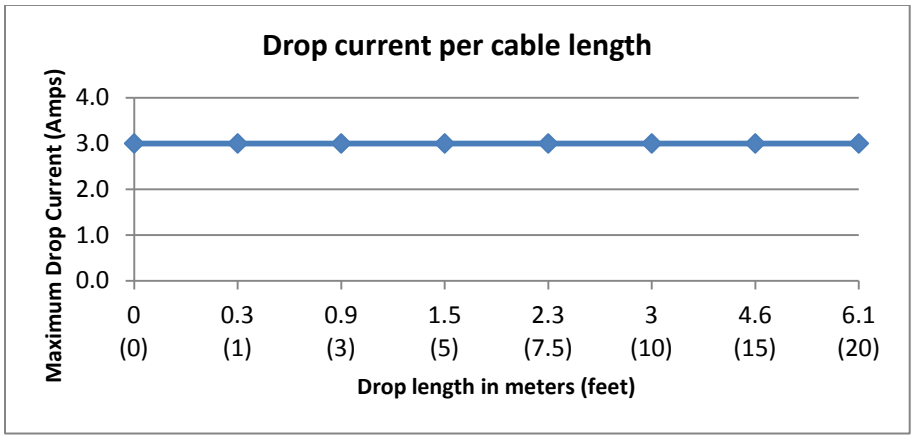


Figure 1: Drop current per cable length for thick cable

Drop Length in meters (feet)	0	0.3 (1)	0.9 (3)	1.5 (5)	2.3 (7.5)	3.0 (10)	4.6 (15)	6.1 (20)
Maximum Current in amps	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0

Table 1: Thick Cable Maximum Allowable Drop Line Current

The table above was computed by using the formula, with a maximum rating of 3 Amps:
I=0.35V/[(Cable DCR * Length of Drop) + (Contact DCR * Number of contacts)]

Where Cable DCR = 0.00445 ohms/ft at 80C. The equation for DCR at elevated temperature is;
$R = R_0*[1 + a(T - T_0)]$
R is the new DCR for copper at the new temperature (80C)
R_0 = 3.6 ohms/1000ft , DCR of copper at 20 degrees C
a = 0.00393/degrees C (coefficient for copper)
T = 80 (new temperature)
T_0 = 20

Contact DCR = 0.001 ohms
Number of contacts = 8 (4 connections with 2 contacts for each connection)

Thin Cable profile updates are shown below:

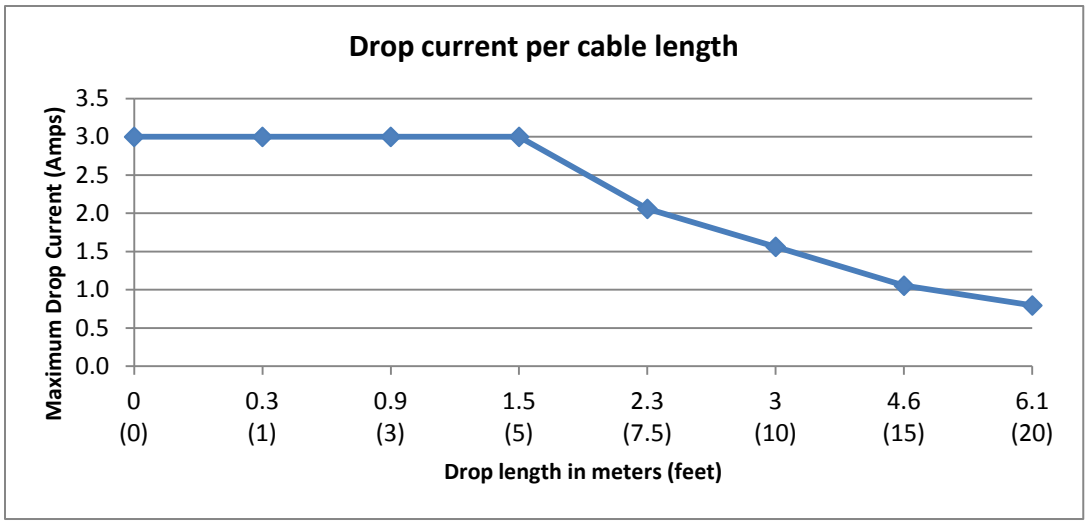


Figure 2: Drop current per cable length for thin cable

Drop Length in meters (feet)	0	0.3 (1)	0.9 (3)	1.5 (5)	2.3 (7.5)	3.0 (10)	4.6 (15)	6.1 (20)
Maximum Current in amps	3.0	3.0	3.0	3.0	2.1	1.6	1.1	0.8

Table 2: Thin Cable Maximum Allowable Drop Line Current

The table above was computed by using the formula, with a maximum rating of 3 Amps:
I=0.35V/[(Cable DCR * Length of Drop) + (Contact DCR * Number of contacts)]

Where Cable DCR = 0.0216 ohms/ft at 80C. The equation for DCR at elevated temperature is;
$R = R_0*[1 + a(T - T_0)]$
R is the new DCR for copper at the new temperature (80C)
R_0 = 17.5 ohms/1000ft , DCR of copper at 20 degrees C
a = 0.00393/degrees C (coefficient for copper)
T = 80 (new temperature)
T_0 = 20

Contact DCR = 0.001 ohms
Number of contacts = 8 (4 connections with 2 contacts for each connection)

EtherNet/IP Chapter 8 Changes

New sealed small form factor connector – M12-8 X-Coding

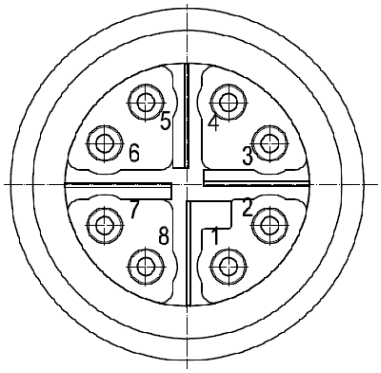
The M12-8 X-Coding is based on the current M12-4 D-Coding connector design. The features of the M12-8 X-Coding are the following:

- 4-pair shielded or unshielded cables
- Update to 10 Gigabit-Ethernet (10GBASE-T) transmission rates
- Complaint to IEC 61076-2-109
- Connector performance to ISO/IEC 11801 Category 6_A and IEC 60512-29-100
- Sealed to both IP65 and IP67 ingress ratings

- Accepted by both EtherNet/IP and PROFINET specifications
- Standardized in IEC 61918 and IEC 61784-5-x series

The pictures below shows both the plug and jack views for the M12 X-Coding:

The figure below shows the plug and jack views with corresponding pin assignment:



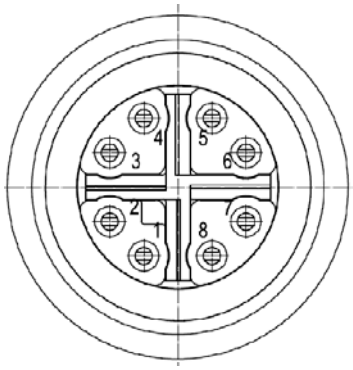


Figure 3: Plug connector with male pin contacts **Jack connector with female socket contacts**

PIN	Pin Assignment T568B	Pair Assignment	Pin Assignment T568A	Pair Assignment
1	White Orange	2	White Green	3
2	Orange		Green	
3	White Green	3	White Orange	2
4	Green		Orange	
5	White Brown	4	White Brown	4
6	Brown		Brown	
7	White Blue	1	White Blue	1
8	Blue		Blue	

Table 3: Sealed M12-8 X-Coding pin/pair designation and color coding for balanced cabling

1G Industrial cabling

The addition of 1G (1000BASE-T) for both commercial and industrial cabling to Chapter 8 is currently being finalized by the EtherNet/IP physical layer JSIG. The commercial (E1) cabling performance requirements are from one of the following standards:

- ISO/IEC 11801 – Information technology – Generic cabling for customer premises
- ISO/IEC 24702 - Information technology – Generic cabling for Industrial premises
- ANSI/TIA-1005-A – Telecommunications Infrastructure Standard for Industrial Premises

For 1G industrial cabling, which covers both E2 and E3 environments, the JSIG is working on defining the additional performance requirements that might be required for those environments beyond the current requirements in the standards stated above. The figure below shows the various MICE environments for an industrial area:

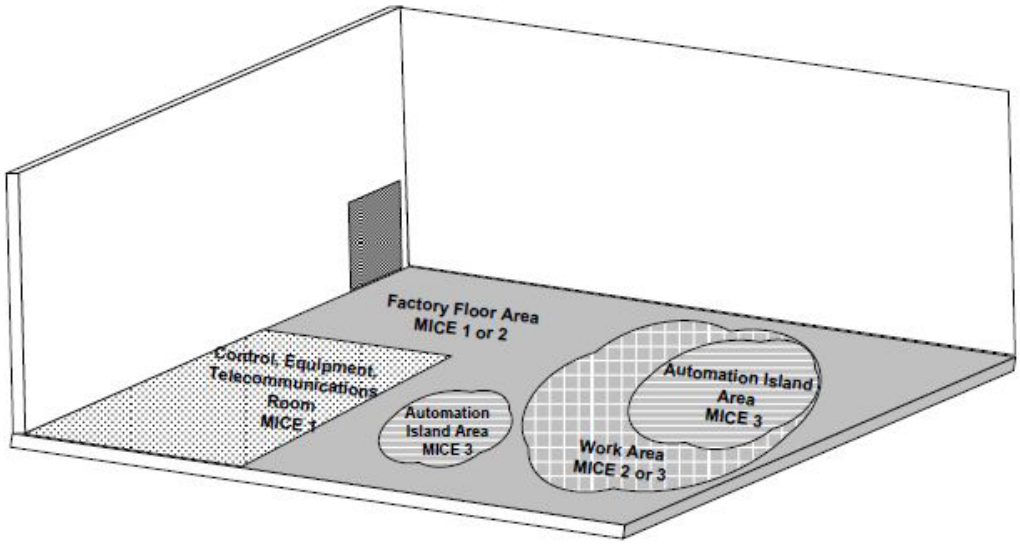


Figure 4: MICE environments for an industrial area

The major area of concern is the coupling of noise from adjacent conductors or devices causing the loss data packets. For motion control systems, the loss of three consecutive data packets will require the system to shut down for safety issues. Testing for both conducted radio-frequency (RF) fields per IEC 61000-4-6 and electrical fast transient burst immunity (EFT/B) per IEC 61000-4-4 on various industrial cabling are currently being conducted by members of the JSIG. After the completion of testing, the JSIG will determine if additional requirements for the cabling are needed for impedance, return loss, coupling attenuation for shielded cables, transverse conversion loss (TCL) for unshielded cables, and equal level transverse conversion transfer loss (ELTCTL) for unshielded cables.

For 1G copper industrial cabling, the JSIG is specifying to use either the sealed RJ-45 variant 1 of IEC 61076-3-106 or the M12-8 X-coding of IEC 61076-2-109. For the cable, the JSIG will determine the category level and if both shielded and unshielded cable will be used from the E_3 testing.

Harmonize with International standards

Members of the JSIG are actively working with various ISO/IEC and IEC standard bodies to harmonize EtherNet/IP specifications to the various standards. The following list of ISO/IEC, IEC, and ANSI standard groups that the members are involved with:

- ISO/IEC JTC1/SC25/WG3 – Customer premises cabling
- IEC SC65C JWG10 – Industrial cabling
- IEC 48B WG3 – Electrical Connectors
- ANSI/TIA TR42.9 – Industrial Telecommunications Infrastructure

The various standard groups above work on defining the connector component, cable component, cabling performance, fieldbus cabling. With the involvement of the members from the JSIG in the various international standards, common components and performance requirements are standardized and are not fragment between the various standards. This enables companies to have a standard physical layer cabling for the various industrial fieldbuses.

Chapter 8 new formatting allows expanding to future higher data transmission speeds

With the addition of 1G (1000BASE-T) to the specification, the JSIG decided to re-format the tables and chapter layout to allow for future expansion of higher data transmission speeds. An example of this would be the section on IEEE 802.3 PMD/MDI interfaces

Service	PMD/MDI			
Data Rate	**PMD Clause**	**PMA**	**Other relevant Clauses**	**Auto Negotiation**
10BASE-T	**9**	**14**	**ANSI X3.263-1995**	
100BASE-X	**24**		**ISO/IEC 9314, ANSI X3T12 (FDDI)**	
100BASE-TX	**25**		**ANSI X3.263-1995**	
1000BASE-X	**36**	**36**	**PMD ANSI X3.230-1994 Clauses 6 and 7 , Clause 66**	**37**
1000BASE-T	**40**	**40**		**28**

Table 4: IEEE 802.3 relevant clauses for PMD/MDI interfaces

Another example is the creation of a new table for industrial copper connectors with a listing of electrical and mechanical specifications.

Industrial EtherNet/IP Connector Specifications and Requirements				
Specification	**Type**			
Electrical	**RJ-45-Shielded**	**RJ-45**	**M12-4 D-Coding**	**M12-8 X-Coding**
Conductors	8 + 1 Shield	8	4	8
Insertion Loss	ANSI/TIA-568-C.2 Category 5E	ANSI/TIA-568-C.2 Category 5E	IEC 61076-2-101	IEC 61076-2-109
RL	ANSI/TIA-568-C.2 Category 5E	ANSI/TIA-568-C.2 Category 5E	IEC 61076-2-101	IEC 61076-2-109
NEXT Loss	ANSI/TIA-568-C.2 Category 5E	ANSI/TIA-568-C.2 Category 5E	IEC 61076-2-101	IEC 61076-2-109
Shielding Effectiveness	ANSI/TIA-568-C.2 Category 5E	N/A	IEC 61076-2-101	IEC 61076-2-109
Coupling Attenuation [1]	ANSI/TIA-568-C.2	NA		IEC 61076-2-109
TCL	ANSI/TIA-568-C.2	ANSI/TIA-568-C.2		IEC 61076-2-109
TCTL	ANSI/TIA-568-C.2	ANSI/TIA-568-C.2		IEC 61076-2-109
1 This specification is marked FFS in the referencing standard.				

Mechanical	**RJ-45-Shielded**	**RJ-45**	**M12-4 D-Coding**	**M12-8 X-Coding**
Gender	Plug and Socket	Plug and Socket	IEC 61076-2-101	IEC 61076-2-109
Mating Specification	IEC 60603-7-3 or IEC 60603-7-5	IEC 60603-7-2 or IEC 60603-7-4	IEC 61076-2-101	IEC 61076-2-109

Contact plating	50u inches min. gold over 100u inches min. nickel or equivalent plating system	50u inches min. gold over 100u inches min. nickel or equivalent plating system	IEC 61076-2-101	IEC 61076-2-109
Contact LLCR over life	< 20 mΩ	< 20 mΩ	IEC 61076-2-101	IEC 61076-2-109
Initial Contact Low Level Contact Resistance	<=2.5 mΩ	<=2.5 mΩ	IEC 61076-2-101	IEC 61076-2-109
Minimum contact force	100 grams	100 grams	IEC 61076-2-101	IEC 61076-2-109
Minimum plug retention force [2]	133 N	133 N	IEC 61076-2-101	IEC 61076-2-109
Contact Life	750 insertions and extractions min.	750 insertions and extractions min.	IEC 61076-2-101	IEC 61076-2-109

[1] Required when the connector is used as a standalone connector (not in a protective shell)

Table 5: Industrial EtherNet/IP copper connector specifications and requirements

Both of these new table formats allows for additional connectors for future data transmission speeds simply by adding additional row to the bottom of the PMD/MDI table and a column to the right for the connector table.

Earthing (Grounding) and Bonding Technical Guideline

Technical guideline document is currently under development by the members EtherNet/IP physical layer JSIG. Once approved by the JSIG, the document will be reviewed by the other ODVA physical layer SIGs. The scope of the document is the following:

> **Scope:**
> The intended audience of this document is Vendors, designers, installers, integrators and end-users. This document is intended for the planning, installation, and maintenance phases of CIP networks. This document describes two earthing systems commonly implemented. The two systems are called equipotential/mesh earthing systems and star earthing systems. Bonding methods are also described.
>
> These methods are intended to provide a low noise earthing system for the CIP communications system and not meant to replace the building electrical earthing and bonding system.

The document terminology is standardized using international terms of earthing, instead of North America terminology of grounding as defined below.

Key definitions:
Bonding: Act of connecting together exposed conductive parts and extraneous conductive parts of apparatus, systems, or installations that are at essentially the same potential. {IEC61918}

Earthing: (verb) often referred to as, "Grounding" in the US influenced markets means to make an electrical connection between a given point in a system or in an installation or in equipment and the local earth. {IEC 61918}

Parallel Earthing Conductor or Potential Equalization cable: a conductor connected in parallel with the screens/shields of signal and/or data cables in order to limit the current flowing through the screens {IEC 61000-5-2, IEC60364-4-44}.

Ground currents on sensitive equipment such as communications cabling can be minimized by controlling the ground offset currents in ether the building wire or auxiliary earthing wiring. The two earthing methods are shown below in figures 5 & 6.

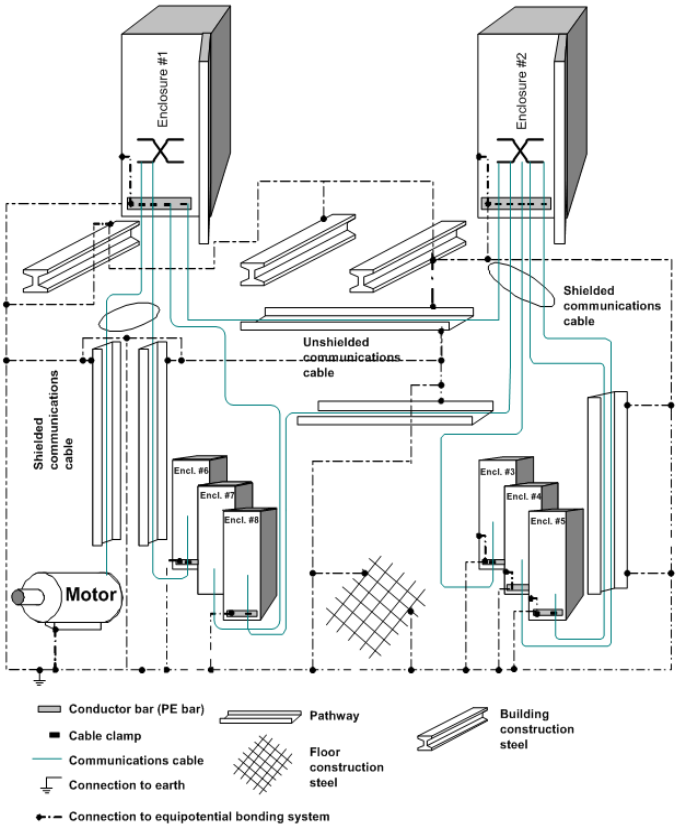


Figure 5: Equipotential/mesh bonding network at building level

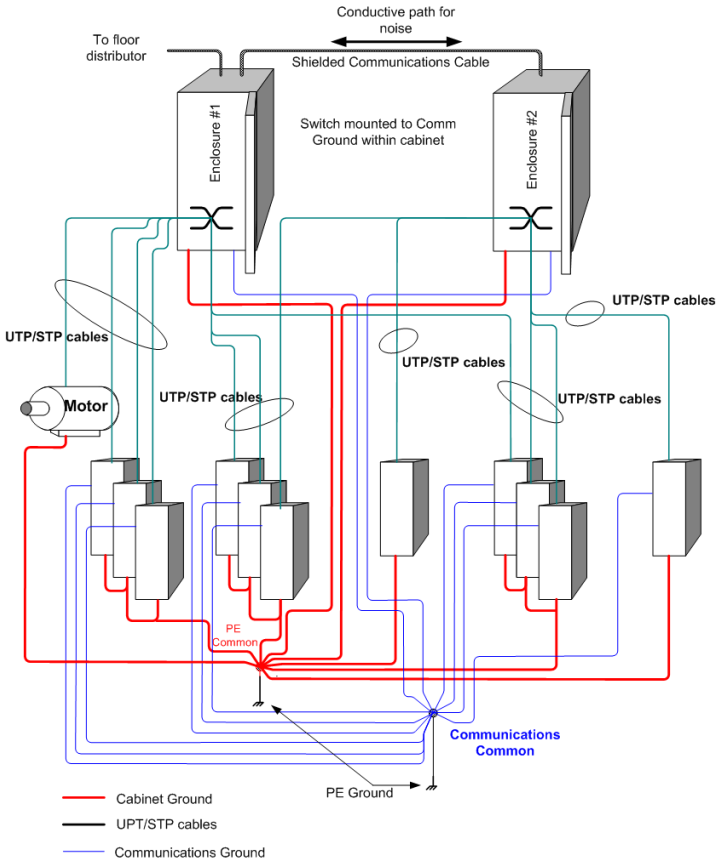


Figure 6: Star grounding schematic

Harmonize with International standards

The guideline document uses the following International standards as reference:

- IEC 61918 – Industrial communication networks – Installation of communication networks in industrial premises
- IEC 61000-5-2 – Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling
- IEC 60364-4-44 – Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances

Members of the JSIG are actively working with various ISO/IEC and IEC standard bodies to harmonize EtherNet/IP specifications to the various standards. The following list of ISO/IEC, IEC, and ANSI standard groups that the members are involved with:

- ISO/IEC JTC1/SC25/WG3 – Customer premises cabling
- IEC SC65C JWG10 – Industrial cabling
- ANSI/TIA TR42.16 – Premises Telecommunications Bonding & Grounding

The various standard groups above work on defining the connector component, cable component, cabling performance, fieldbus cabling. With the various members involvement, common components and performance requirements are standardized and are not fragment between the various standards. This enables companies to have a standard physical layer cabling for the various industrial fieldbuses.

References (optional):

- IEC 61076-2-109 – Connectors for electronic equipment – Product requirements – Part 2-109: Circular connectors – Detail specification for connectors M12 x 1 with screw-locking, for data transmissions with frequency up to 500 MHz
- ISO/IEC 11801 – Information technology – Generic cabling for customer premises
- ISO/IEC 24702 - Information technology – Generic cabling for Industrial premises
- ANSI/TIA-1005-A – Telecommunications Infrastructure Standard for Industrial Premises
- IEC 61918 – Industrial communication networks – Installation of communication networks in industrial premises
- IEC 61000-5-2 – Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling
- IEC 60364-4-44 – Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances

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