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Specifying Cables and Connectors for Industrial EtherNet/IP Networks

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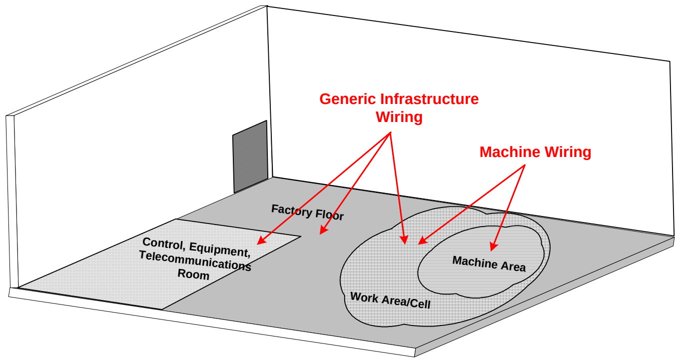
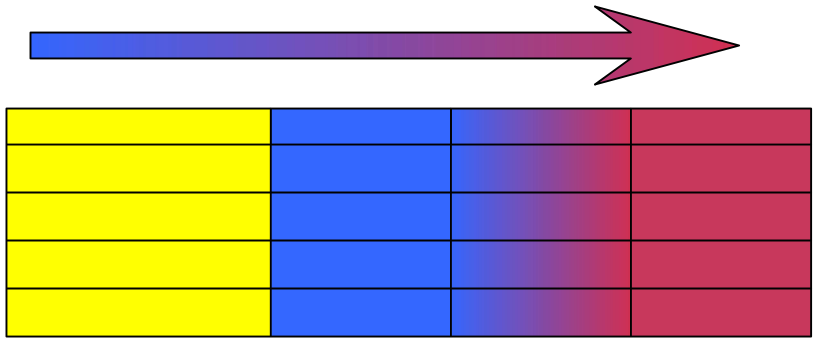
Abstract

It is true that EtherNet/IP is compatible with Off the shelf Category 5 cabling. It is not true that Category 5 cabling will provide a level of performance needed to survive long term in a environmentally harsh environment. One of the most important factors in selecting the correct cable is understanding the environment where the cables will be installed. This paper will step a planner through the cable specification process based on the MICE concept and the needs of the application. It is assumed that zero mitigation will be used in this process.

About MICE

- MICE is a method of categorizing the environment that supports three levels called “Classifications”.
- An area on the factory floor typically will not be defined in one classification
- Within a parameter, there may be more than one classification.





MICE Tutorial (condensed)

M I C E

MECHANICAL
- Shock
- Vibration
- Crush
- Impact

INGRESS
- Liquid
- Particles

CLIMATIC / Chemical
- Temperature
- Humidity
- Contaminants – (dry and liquid)
- Solar Radiation

EMI
- ESD
- Radiated and Conducted Transients
- Magnetic fields

More Information on MICE can be found in February 2006 white papers

Summary of Steps

- Defining cables and connectors to be compatible with the environment and application is a simple 6 step process;
  1. Determine the channel bandwidth needed for the application,
  2. Determine the cable type (shielded or unshielded),
  3. Determine additional electrical attributes needed based on E_1, E_2 or E_3 noise types and levels,
  4. Determine Two pair or four pair cabling,
  5. Determine the M,I and C severity levels where the cables will be deployed,
  6. Determine any additional attributes for the cabling, for example high flex, weld splatter etc.

Example Cable Specification

- At the completion of the 6 steps this example table will be completely filled in.
- Physical parameters are set by TIA standards such as cable diameter, conductor diameter and maximum wire size in conjunction with connector specifications

Example Cable Specification					
Step 1 Channel	**Step 2 Cable type**	**Step 3 EMI Performance**	**Step 4 2/4 pair**	**Step 5 M,I,C, severity classifications**	**Step 6 Additional mech. attributes**
Justification	*Justification*	*Justification*	*Justification*	*Justification*	*Justification*
Specification	*Specification*	*Specification*	*Specification*	*Specification*	*Specification*
Specifications in addition to TIA 568B and ISO/IEC11801					

Step 1 – Channel Bandwidth

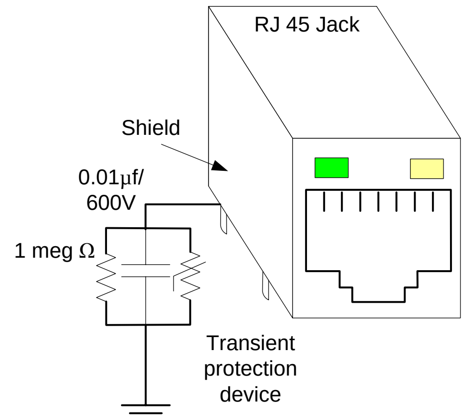
- Determine the bandwidth for the application based on the following table.

Data Rate	Minimum Category to support data rate TIA 568B.1	Recommended Category	Channel Class ISO/IEC 11801	Channel Bandwidth ISO/IEC 11801
10Mb/s	Cat 3	Cat 5	Class C	16 MHz
100Mb/s	Cat 5e	Cat 5e, Cat 6	Class D	100 MHz
1Gb/s 10Gb/s	Cat 6	Cat 6 and Cat 6a	Class E	250 MHz

Example Cable Specification					
Step 1 **Channel**	**Step 2** **Cable type**	**Step 3** **EMI Performance**	**Step 4** **2/4 pair**	**Step 5** **M,I,C, severity classifications**	**Step 6** **Additional mech. attributes**
My application requires 10/100mb/s					
Cat6 ClassD					
Specifications in addition to TIA 568B and ISO/IEC11801					

Step 2 - Selecting Cable Type

- Select cable type, shielded (STP) or unshielded (UTP)
  - In general unshielded cables are recommended
  - Shields provide a faraday shield around the conductors, however they also provide a path for ground off-sets in the building grounding system
  - ODVA active interfaces use a RC to isolate the cable shield from ground.



  - If you use a shielded cable, then shielded connectors are mandatory

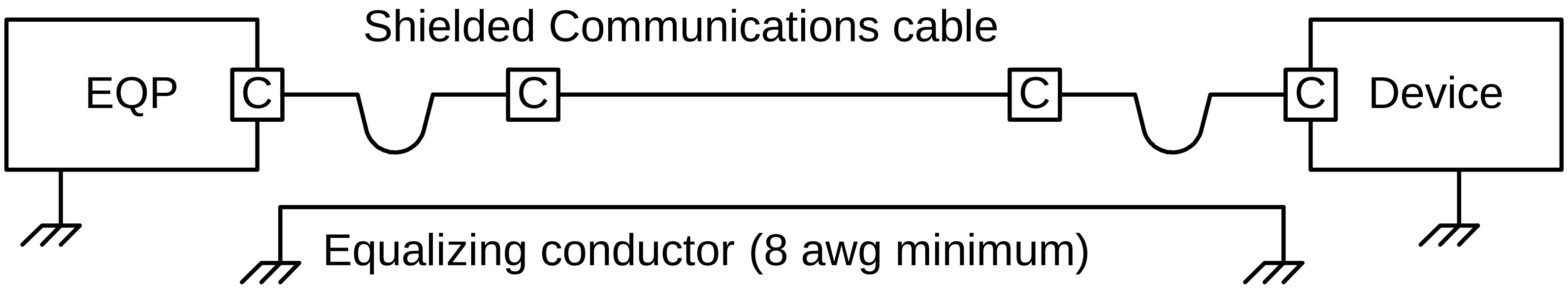
When to use Shielded or Unshielded cables

- The following table can be used to help decide if shielded cables are appropriate.

General Guidance for Selecting Media Type (STP or UTP)		
Use Shielded	**Use UTP or other Media**	**Comments**
	Poor building grounds, any locations where the ground off sets are > 1V in the cabling coverage area.	Fiber may be used as an alternative to UTP
Installations in conduit		UTP acceptable if transmission performance is maintain ie; RL, FEXT, NEXT, Attenuation (see note)
When EFT > E_1		See Step 3 for additional guidance and use of UTP
Conducted or radiated EMI is > E_3		
High ESD discharge E_1 or greater		Fiber is also acceptable
	High flex applications	Some shielded constructions are ok (braided shields)
	Surge > E_1	

Additional Factors

- Shields shall be terminated in accordance with the ODVA Planning and Installation Manual
- Mitigation may be used to solve any of the issues above, allowing the cable selection to be arbitrary. For Example, adding an equalizing conductor in parallel with the shielded cable.



Cable Type Selection

- Poor or unknown condition building grounds

Example Cable Specification					
Step 1 Channel	**Step 2 Cable type**	**Step 3 EMI Performance**	**Step 4 2/4 pair**	**Step 5 M,I,C, severity classifications**	**Step 6 Additional mech. attributes**
Application requires 10/100mb/s	*Poor bldg grounds*				
Cat6 Class D	*UTP*				
Specifications in addition to TIA 568B and ISO/IEC11801					

Step 3 - Additional Electrical Requirements

- This step is critical for noise immunity
- This step requires that the planner determine the MICE E_1, E_2 or E_3 levels.
- Noise levels are hard to quantify without making actual measurements
- Actual noise levels cannot be measured at a greenfield site.
- Levels can be predicted by knowing what type of equipment is going to or is installed and the proximity to the noise

Determining Noise Levels

- Identifying the noise generators in the vicinity of the cabling helps to understand the noise mechanism's

Noise Generating Device	Noise	Coupling mechanism
Electric Motors	Surge and EFT	Local Ground. Conducted
Drive Controllers	Conducted and Surge	Local Ground. Conducted
Relays and Contactors	EFT	Radiated. Conducted
Welding	EFT. Induction	Radiated Magnetic
RF Induction Welding	Radio Frequency	Radiated. Conducted
Material handling (paper/textile)	ESD	Radiated
Heating	EFT	Local Ground. Conducted. Radiated
Induction Heating	EFT. Magnetic	Local Ground. Conducted. Radiated
Radio Communications	Radio Frequency	Radiated

E Classification

- Estimate E_1, E_2 or E_3 based on the noise type and the proximity to the noise carrying conductors and generators.
- Partial table below.

Noise Generating Device	Distance from cabling	"E" Classification
Contactor Relay	< 0.5 m	E_2
	> 0.5 m	E_1
Transmitters (<1 W)	< 0.5 m	E_3
	≥ 0.5 m	E_1 or E_2
Transmitters (1 W to 3 W)	< 1.0 m	E_3
	≥ 1.0 m	E_1 or E_2
Transmitters (TV Radio. mobile base station)	< 0.3 km	E_3
	≥ 0.3 km	E_1 or E_2

Cable Balance

- The cable balance (TCL and ELTCTL) is then determined by using the tables and the EMI level (E_1, E_2 or E_3) selected in the previous slide and the Channel Class selected in Step 1

Class	Frequency MHz	Environmental classification		
		E1	E2	E3
		Minimum TCL (dB) UTP Cable Types		
D	$1 \leq f \leq 30$	53-15 x log (*f*). 40 max	63-15 x log (*f*). 40 max	73-15 x log (*f*). 40 max
	$30 \leq f \leq 100$	60.4 – 20 x log (*f*)	70.4 – 20 x log (*f*)	80.4 – 20 x log (*f*)
E	$1 \leq f \leq 30$	53 – 15 x log (*f*)	63 – 15 x log (*f*). 40 max	73 – 15 x log (*f*). 40 max
	$30 \leq f \leq 250$	60.4 – 20 x log (*f*)	70.4 – 20 x log (*f*)	80.4 – 20 x log (*f*)
F	$1 \leq f \leq 30$	53 – 15 x log (*f*)	63 – 15 x log (*f*). 40 max	73 – 15 x log (*f*). 40 max
	$30 \leq f \leq 600$	60.4 – 20 x log (*f*)	70.4 – 20 x log (*f*)	80.4 – 20 x log (*f*)
NOTE: Values above 100 MHz are for information only				

Determining Noise Levels

- TCL and ELTCTL is determined by tables provided in ISO/IEC 24702
- E3 is necessary in this example because noise is conducted and proximity is < 0.5m

Example Cable Specification					
Step 1 Channel	**Step 2 Cable type**	**Step 3 EMI Performance**	**Step 4 2/4 pair**	**Step 5 M.I.C. severity classifications**	**Step 6 Additional mech. attributes**
Application requires 10/100mb/s	*Poor bldg grounds*	***E3 conducted***			
Cat6 Class D	*UTP*	***TCL =1 $\le f \le$ 30. 73-15 x log (f). 40 max*** ***30 $\le f \le$ 100. 80.4 – 20 x log (f)*** ***ELTCTL =*** **50 – 20 x log (*f*). 40 max.**			
Specifications in addition to TIA 568B and ISO/IEC11801					

Step 4, Two Pair or 4 Pair

- The selection of pair count is straight forward.
- In general the cable types are interchangeable with respect to the applications for 10/100mb/s
- The following table will guide the planner through the decision process.

Two Pair Cables May Be Used	Four Pair Shall be Used
10/100BaseT application	Back Bone and UP link port
M12-4 "D" coding (any two pair connector) If selected 2 pair cabling is mandatory	Areas where future requirements may require data rates greater than 100mb/s
4 circuit, 8 way modular connectors	Where cabling requires support of all "generic application" such as Voice, Video.
High Flex Applications	POE+ or POE mid span
On Machine	
Where panel space or wireway spaces are limited	
Field termination is less complicated	

Step 4 - Two Pair or Four Pair

- Space is limited and data rate is 10/100mbs, sealed media is needed
- 2 pair and M12-4 “D” coding connector was chosen

Example Cable Specification					
Step 1 Channel	**Step 2 Cable type**	**Step 3 EMI Performance**	**Step 4 2/4 pair**	**Step 5 M.I.C. severity classifications**	**Step 6 Additional mech. attributes**
Application requires 10/100mb/s	*Poor bldg grounds*	*E3 conducted*	***M12-4 “D” coded***		
Cat6 Class D	*UTP*	*TCL = 73-15 x log (f). 40 max* *ELTCTL =* 50 – 20 x log (*f*). 40 max.	***2 pair***		
Specifications in addition to TIA 568B and ISO/IEC11801					

Step 5 - MIC Severity Levels

- The planner should evaluate each area against the MICE categories and Classifications
- Most areas within the communications area can be mapped into the MICE table.
- Attributes to consider in this step are;
  - Shock and vibration
  - Dust, liquids
  - Temperature and humidity

Step 5 continued

- Chemicals are the most difficult in this process. Finding components that can withstand all chemicals is difficult to impossible

Example Cable Specification					
Step 1 Channel	**Step 2 Cable type**	**Step 3 EMI Performance**	**Step 4 2/4 pair**	**Step 5 M.I.C. severity classifications**	**Step 6 Additional mech. attributes**
Application requires 10/100mb/s	*Poor bldg grounds*	*E3 conducted*	*M12-4 "D" coded sealed required*	***Installed over steam vessel***	
Cat6 Class D	*UTP*	*TCL = 73-15 x log (f). 40 max* *ELTCTL =* 50 – 20 x log (*f*). 40 max.	*2 pair*	***$M_1.I_3.C_3$. Liquid condensate (+70ºC)***	
Specifications in addition to TIA 568B and ISO/IEC11801					

Step 6 - Additional Mechanical Attributes

- This step is critical, missing one of these attributes will most certainly cause premature failures of the cabling system
- In this step the planner considers mechanical requirements such as;
  - Weld splatter
  - High flex
  - Direct long term exposure to sun light
- Each of these special attributes requires special cable constructions that may not be standard.

Step 6 - continued

- The cable specification is now complete.
- These attributes are in addition and/or supersede those of standard cables as described in TIA 568B.1, TIA 568B.2 TIA 1005[1] or ISO/IEC 11801 and ISO/IEC 24702

Example Final Cable Specification					
Step 1 Channel	**Step 2 EMI Performance**	**Step 3 Cable type**	**Step 4 2/4 pair**	**Step 5 M.I.C. severity classifications**	**Step 6 Additional mech. attributes**
Application requires 10/100mb/s	*E3 conducted*	*Poor bldg grounds*	*M12-4 "D" coded sealed*	*Installed over steam vessel*	***Moisture. rolling C track***
Cat6 Class D	*TCL = 73-15 x log (f). 40 max ELTCTL =* 50 – 20 x log (*f*). 40 max.	*UTP*	*2 pair*	$M_1.I_1.C_3$. (+70ºC)	***IP67. UV and High Flex***
Specifications in addition to TIA 568B and ISO/IEC11801					

1 TIA 1005 is at PN stage and not publicly available until 2008