Guidance for Selecting Cables for EtherNet/IP Networks

This guide is arranged to help the user select cabling based on the application, environmental conditions, and mechanical requirements.

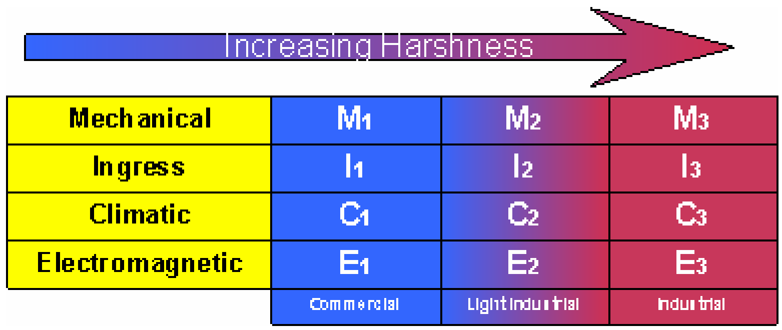
Introduction

Any Category 5 or higher cable will support 10/100BaseT traffic. However, Category 5 cabling will not necessarily provide the level of performance needed or survive long term in a harsh high noise industrial environment. One of the most important factors in selecting the correct cable is having a thorough understanding the environment where the cables will installed. The planner should already understand the application needs (i.e. 10Mb/s, 100Mb/s…) and will need to focus on environmental and mechanical aspects of the cabling. To aid in understanding the environment, this guide is based on a concept called MICE (Mechanical, Ingress, Climatic/Chemical and Electromagnetic). Cabling attributes and performance can be defined for the industrial areas based on the environments and conditions as defined by MICE severity levels called classifications. This guide will focus on the minimum cabling requirements to provide adequate performance in areas of E_1, E_2, and E_3 Electromagnetic interferences. Harsh attributes such as Mechanical, Ingress and Chemical (M,I,C) will be relatively straight forward. Given this, it is not adequate to simply specify cabling as Cat 5e, Cat 6, shielded, or unshielded.

This document will help the reader to select connectivity components based on zero mitigation. Mitigation is a method of converting one environment into a less harsh environment. Further, this document provides guidance in the selection of cabling components to minimize performance degradation due to effects from EMC.

About MICE

MICE is a method of categorizing the environment that supports three levels called classifications: $M_1I_1C_1E_1$, $M_2I_2C_2E_2$, and $M_3I_3C_3E_3$. The three classifications can be mapped to severity levels 1=Office, 2=Light Industrial, and 3=Industrial. Each increasing severity level is harsher. The industrial areas can be generalized into four typical areas: factory floor, work area, machine area, and control, equipment, telecommunications room as shown .in Figure 2 below.



Mechanical	M_1	M_2	M_3
Ingress	I_1	I_2	I_3
Climatic	C_1	C_2	C_3
Electromagnetic	E_1	E_2	E_3
	Commercial	Light Industrial	Industrial

Generally an area does not have the same level for all categories (Mechanical, Ingress, Climatic/Chemical and Electromagnetic). For example, a machine may be in an area where the vibration is very high, hence M_3, the area may be free of dust and liquids, hence I_1, the temperatures may be high, hence C_3, and the electromagnetic levels are low, hence E_1. The upper limits for each classification are described in the MICE Table 2, below. Figure 1 provides a brief overview of the subcategories for each category of M,I,C,E.

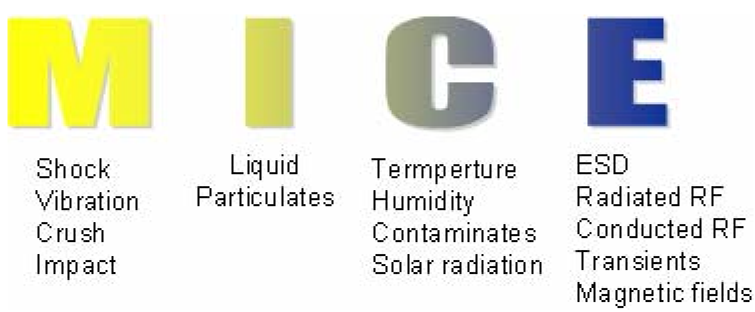


Figure 1: Subcategories for M,I,C,E

This concept is a formal approach used by planners of systems to systematically classify their areas thus helping to define the materials needed to build the network. Most industrial facilities can be defined by four areas as shown in Figure 2. These areas are the machine area (automation island), work area, factory floor, and telecommunications closet/enclosure/room. The telecommunications closet or enclosure houses commercial rated products and therefore may require HVAC to maintain a $M_1I_1C_1E_1$ environment.

Table 1 shows the typical MICE classifications (levels) for each area within the factory.

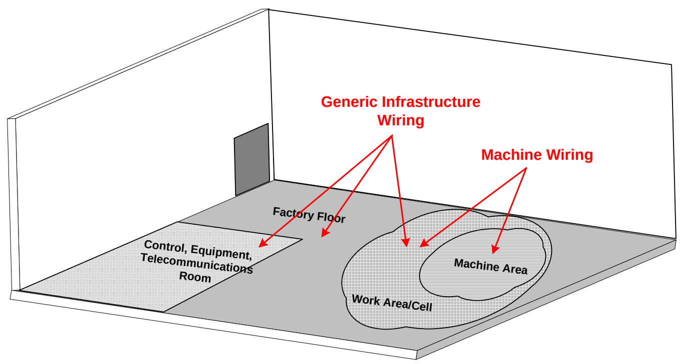


Figure 2: Typical Factory Areas

The machine area is surrounded by the work area and the machine and work area is generally located on the factory floor. A factory floor may consist of many machine areas and work areas. The converse is also true where the machine area covers the entire factory floor, thus one large machine or process such as tank farms and food processing.

Table 1 Classification of Industrial Areas

Typical MICE Classification and Industrial Areas			
Area	Factory Floor	Work area	Machine Area
Typical Classification (MICE)	1&2	2	2&3

Guidance on determining your MICE Classifications

Keeping the MICE concept in mind, each area that the cabling system is to be installed in or traverses through must be considered. For example, if the cable passes over a furnace whereby the temperature in the plenum area above the furnace is greater than 60ºC, then the cabling components must be selected to provide performance at this temperature.

The network designer should evaluate the installation coverage area completely. Decisions should be made to provide mitigation in areas in that exceed the MICE limits. Further mitigation should be considered in areas in which cost savings of the installation can be realized. For example, consider the previous scenario discussing the plenum area above an industrial furnace where the cabling needs to pass through. Rather than use expensive high temperature cabling components in this area, the designer may choose to provide heat deflectors to protect the cables or simply re-routed giving separation from the heat.

The complete MICE table is below in Table 2. The planner should familiarize his/her self with the table. Each area where the cabling is to be installed can be categorized and classified using the MICE table. Materials and/or mitigation can then be determined from the classification process for all components. For examples on how to use the MICE table to select components an/or mitigation techniques the reader should obtain a copy of the "MICE Tutorial" available from a number of sources such as ISO/IEC 24702, PDTR-29106, IEC 61918, and ODVA MICE Tutorial TD.

Table 2 MICE Table – Details of Environmental Classification

Mechanical	M_1	M_2	M_3
Shock/bump			
Peak acceleration	40 ms^{-2}	100 ms^{-2}	250 ms^{-2}
Vibration			
Displacement amplitude (2-9 Hz)	1,5 mm	7,0 mm	15,0 mm
Acceleration amplitude (9-500Hz)	5 ms^{-2}	20 ms^{-2}	50 ms^{-2}
Tensile force	See Note 1	See Note 1	See Note 1
Crush	45 N over 25 mm (linear) min.	1100 N over 150 mm (linear) min.	2200 N over 150 mm (linear) min.
Impact	1 J	10 J	30 J
Bending, flexing and torsion	See Note 1	See Note 1	See Note 1
Ingress	I_1	I_2	I_3
Particulate ingress (dia. max)	12.5 mm	50 mm	50 mm
Immersion	None	Intermittent liquid jet <=12,5 l/min >= 6,3 mm jet > 2,5 m distance	Intermittent liquid jet <=12,5 l/min >= 6,3 mm jet > 2,5 m distance and immersion (<=1 m for <=30 minutes)
Climatic and Chemicals	C_1	C_2	C_3
Ambient temperature	-10° C to +60° C	-25° C to +70° C	-40° C to +70° C
Rate of change of temperature	0,1° C per minute	1,0° C per minute	3,0° C per minute
Humidity	5% to 85% (non-condensing)	5% to 95% (condensing)	5% to 95% (condensing)
Solar radiation	700Wm^{-2}	1120 Wm^{-2}	1120 Wm^{-2}
Liquid pollution Contaminants			
Sodium chloride (salt/sea water) (µg/g)	0	<0,3	<0,3
Oil (µg/g)	0	<5,0	<500
Sodium stearate (soap)	None	5% aqueous non-gelling	>5% aqueous gelling
Detergent	None	ffs	ffs
Conductive materials in solution	None	Temporary (condensation)	Present

Mechanical	M_1	M_2	M_3
Gaseous pollution Contaminants	Mean/Peak (Concentration X 10^{-6})	Mean/Peak (Concentration X 10^{-6})	Mean/Peak (Concentration X 10^{-6})
Hydrogen sulphide	<0,003/<0,01	<0,05/<0,5	<10/<50
Sulphur dioxide	<0,01/<0,03	<0,1/<0,3	<5/<15
Sulphur trioxide (ffs)	<0,01/<0,03	<0,1/<0,3	<5/<15
Chlorine wet (>50% humidity)	<0,0005/<0,001	<0,005/<0,03	<0,05/<0,3
Chlorine dry (<50% humidity)	<0,002/<0,01	<0,02/<0,1	<0,2/<1,0
Hydrogen chloride	-/<0,06	<0,06/<0,3	<0,6/3,0
Hydrogen fluoride	<0,001/<0,005	<0,01/<0,05	<0,1/<1,0
Ammonia	<1/<5	<10/<50	<50/<250
Oxides of Nitrogen	<0,05/<0,1	<0,5/<1	<5/<10
Ozone	<0,002/<0,005	<0,025/<0,05	<0,1/<1
Electromagnetic	E_1	E_2	E_3
Electrostatic discharge – Contact (0,667mC)	4 kV	4 kV	4 kV
Electrostatic discharge – Air (0,132mC)	8 kV	8 kV	8 kV
Radiated RF - AM	3V/m @ 80-2000MHz 3V/m @ 1400-2000MHz 1V/m @ 2000-2700MHz	3V/m @ 80-2000MHz 3V/m @ 1400-2000MHz 1V/m @ 2000-2700MHz	10V/m @ 80-1000MHz 3V/m @ 1400-2000MHz 1V/m @ 2000-2700MHz
Conducted RF	3V @ 150kHz-80MHz	3V @ 150kHz-80MHz	10V @ 150kHz-80MHz
EFT/B	500 V	1000 V	1000 V
Surge (transient ground potential difference) - Signal, line to earth	500V	1000V	1000 V
Magnetic Field (50/60 Hz)	1 Am^{-1}	3 Am^{-1}	30 Am^{-1}
Magnetic Field (60-20000Hz)	ffs	ffs	ffs
Bump: the repetitive nature of the shock experienced by the channel shall be taken into account.			

NOTE 1: This aspect of environmental classification is installation-specific and should be considered in association with IEC 61918 (in preparation)

Summary of the Steps in Selecting Cables

1. Determine the channel bandwidth requirements to suit the applications for example Channel Class or Category, see Table 3 below.
2. Determine 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. Select two pair or four pair cabling
5. Determine the M,I,C severity levels where the cables will be deployed
6. Determine additional attributes for the cabling, for example high flex, weld splatter etc.

Each of the 6 steps will be described in detail in the following paragraphs.

To help clarify each step, a cable specification will be determined based on an example justification. At the end of each step, the example will be specified in a table like the one shown here:

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					

There are a total of 6 steps in defining the correct cable(s) for the application(s) and environment(s). A network planner may have a need to specify any where from one or more cables dependent on the applications and number of environmental areas within the communications coverage area. The final number of cables will be based on cost and complexity of the network and level of mitigation. For example, cost may not be as important as having one cable construction in the entire system. In this case, a super cable, "*one cable does all*" may be specified. The planner may choose to reduce the number of cables needed by protecting the cables through mitigation techniques (Isolation and Separation). Any special attributes (defined in step 6 below), such as high flex, is certain to increase the cable count. Regardless of how many different cables are identified, the planner must consider the environment.

Below are the 6 steps that a planner can use to develop a cable specification. In general, all cabling and cabling components need to be complaint with TIA 568B and or ISO/IEC 11801 with the additional requirements.

The additional requirements below are consistent with requirements of ISO/IEC 24702 *Information Technology- Generic cabling –Industrial Premises*

Step 1) Channel Bandwidth

The channel bandwidth will be the easiest to determine. Table 3 provides channel bandwidth and cabling Category based on data rates.

Table 3 Channel Bandwidth VS Cabling Categories

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 1Gb/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

For example, If the channel needs to support 10/100Mb/s, then a minimum of Cat5e cabling and Class D (100MHz) channel is required. To provide additional margin in the channel design Category 6 is recommended. Note: Cat 5 cables are no longer supported by the standards. TIA Cat 5e is equivalent to ISO/IEC 11801(2002) Cat 5 cables.

Important: It is not recommended to mix category components in the same channel.

Using category 5e components and constructing the channel in accordance with the reference implementations as defined in ISO/IEC 11801 a Class D channel with a 100Mb/s bandwidth is guaranteed by the standard. The reference implementations allow for a maximum of 4 connections in a channel. Figure 3, Figure 4, and Figure 5 are reference implementations from ISO/IEC 11801.

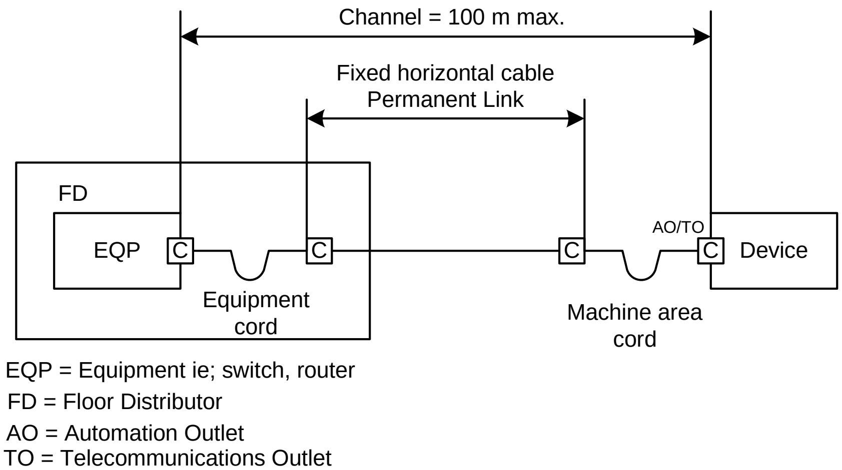


Figure 3: Cross Connect AO/TO Model

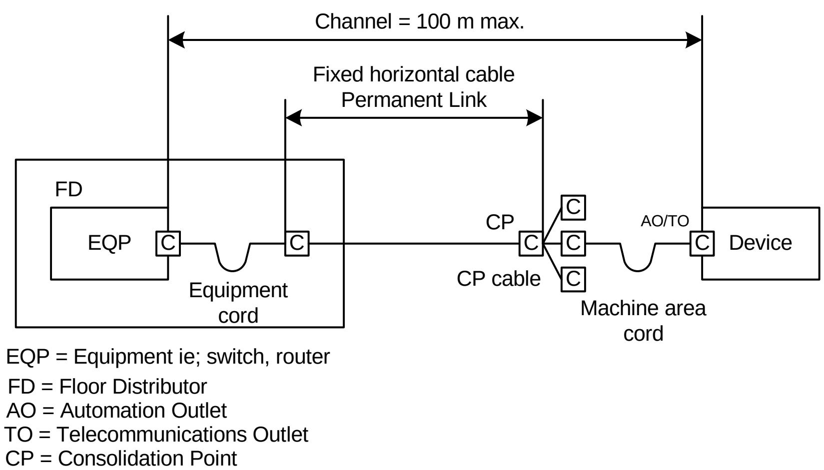


Figure 4: Cross Connect AO/TO with CP Model

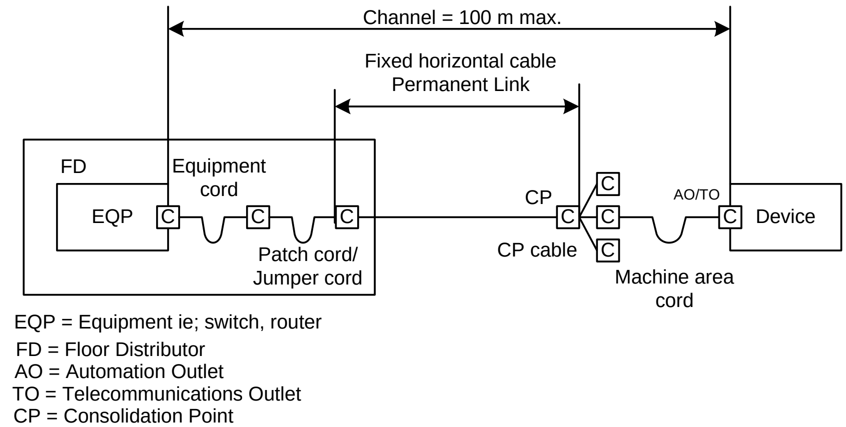


Figure 5: Cross Connect CP Model

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 Class D					
Specifications in addition to TIA 568B and ISO/IEC11801					

Step 2) Selecting shielded or unshielded media.

Cables with shields are sometimes referenced as ScTP, FTP, STP, etc. The differences in this cables is construction of the shield and naming preferences. Throughout this document they will be referenced in a generic sense as “STP”. Cables without shields are usually referenced as UTP cables, meaning Unshielded twisted pair cables. Likewise throughout this document they will be referenced as UTP cables. It is important to note that both cables (STP and UTP) are balanced 100 ohm twisted pair cables. There are a number of factors in determining if shielded cabling or unshielded should be used. Some geographical areas mandate that STP cabling be used. Some companies have policies regarding the use of STP or UTP cabling. Putting these aside there are technical reasons one or the other should or should not be used. This guide will focus on the technical aspects of selecting STP cabling over UTP cabling.

Shields help to reduce noise coupled to the balanced cables by providing a faraday shield around the conductors. However this is countered in some cable designs by using poorly balanced cable pairs. Shields can carry ground currents due to ground offsets with in the building grounding system. These currents at worse case can cause equipment damage. At the least, the currents can be disruptive to the network communications. EtherNet/IP reduces the chance of ground loops by isolating the shield at one end of the channel from ground. This is done through the use of an RC between the shield and local node ground connection. The RC is always in the device end and not at the switch end. The switch end of a shielded channel is always grounded if the switch is grounded. If properly grounded, shielded cables are useful in reducing communications error rates in the presence of high noise. The construction of a shielded cable is more complex than, and therefore not as robust in flexing applications, as an unshielded twisted pair cable (UTP). The following Table 4 below can be used as a guide in determining if shielded cables are appropriate.

Table 4 Selecting ScTP or UTP Cables

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 maintained. i.e.; 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	

NOTE: Transmission performance is the ability to meet a minimum level of transmission related parameters such as Return Loss (RL), Near End Cross Talk (NEXT) and Far End Cross Talk (FEXT) as required by TIA 568 series and ISO/IEC 11801 series standards. Meeting these parameters assures that the channel will provide a minimum required support for the application based on bandwidth.

- Shielded connectors are mandatory if shielded cables are used.
- 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 type to be arbitrary. For example, adding equalizing conductors in parallel with STP cables can be used to reduce the ground potential differences between two points that the channel spans.

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 g rounds*				
Cat6 Class D	*UTP*				
Specifications in addition to TIA 568B and ISO/IEC11801					

Step 3) Additional Electrical Requirements (critical)

This is one of the most important steps in defining the cable. The planner has to have an understanding of the noise mechanisms, noise levels, and sources to accurately define the noise performance required of the cabling. The difficulty in doing this is that the planner may not have a way to quantify the noise levels. The following tables will help to empirically determine the ingress mechanism and level from the noise source while mapping into MICE $E_{1,2,3}$ classifications. Using the left hand column of Table 5 below, find the noise generating source(s) where the cabling will be installed. Knowing the distance of the cable from the source, determine the E classification (E_1, E_2 or E_3). From Table 6 below, again find the noise generating source(s) in the left hand column and find the ingress mechanism. Understanding the noise ingress mechanisms will help not only in the selection of the cables but also in understanding mitigation and installation techniques.

Table 5 Noise Generating Devices VS "E" Classification

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)	< 3 km	E_3
	≥ 3 km	E_1 or E_2
High HP motors (50 HP or greater)	< 3 m	E_3
	> 3 m	E_1
Drive Controllers	< 0.5 m	E_3
	0.5 < 3 m	E_2
	> 3 m	E_1
Induction Heating < 8 MW	< 0.5 m	E_3
	0.5 < 3 m	E_2
	> 3 m	E_1
Resistance Heating	< 0.5 m	E_2
	> 0.5 m	E_1
Fluorescent Lights	< 0.15 m	E_3
	> 0.15 m	E_1 or E_2
Thermostatic Switches 110 V to 230 V	< 0.5 m	E_2 - E_3
	> 0.5 m	E_1

Table 6 Noise Generating Devices VS Coupling Mechanism

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

NOTE: for an explanation of EFT and ESD see the glossary of terms at the end of this document.

After determining the E classification and the ingress mechanism from Table 5 and Table 6 respectively and knowing the channel bandwidth (Class D.E or F) from step 1, look up the TCL, ELTCTL, and coupling attenuation for the appropriate E classification and selected cable type (UTP or STP). Tables 7 and 8 are used for UTP cables and Table 9 is used if STP cables were selected. If the coupling mechanism is through ground offsets, the selection of STP cables may need to be revisited or mitigation may be required. An expectable method for reducing ground offsets is by adding equalizing conductors in parallel with the communications cables (see Figure 6). Note that there are other reasons to revisit the cable type selected such as if STP cables were selected and the EFT is determined to be greater than the level of E1.

Table 7 TCL VS "E" Classification for UTP Cable Types

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

Table 8 ELTCTL VS "E" Classification UTP Cable Types

Class	Frequency MHz	Environmental classification		
		E1	E2	E3
		Minimum ELTCTL (dB) UTP Cable Types		
D. E and F	$1 \leq f \leq 30$	30 – 20 x log (f)	40 – 20 x log (f)	50 – 20 x log (f). 40 max.

Table 9 Coupling Attenuation VS "E" Classification Shielded Cable Types

Class	Frequency MHz	Environmental classification		
		E1	E2	E3
		Minimum Coupling Attenuation (dB) Shielded Cable Types		
D	$30 \le f \le 100$	40	50	60
E	$30 \le f \le 250$	80 – 20 x log (*f*). 40 max.	90 – 20 x log (*f*). 50 max.	100 – 20 x log (*f*). 60 max.
F	$30 \le f \le 600$	80 – 20 x log (*f*). 40 max.	90 – 20 x log (*f*). 50 max.	100 – 20 x log (*f*). 60 max.

NOTE: Coupling attenuation applies to maximum frequency of class and beyond that to 1 GHz for general EMC information

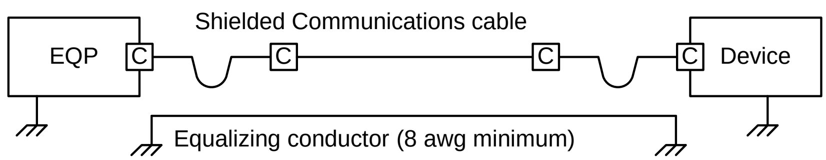


Figure 6 Ground offset Equalizing Conductor (Equipotential)

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 g rounds*	*E3 conducted*			
Cat6 Class D	*UTP*	*TCL =1 ≤ f ≤ 30. 73-15 x log (f). 40 max* *30 ≤ f ≤ 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 Four Pair

The selection of cables with respect to pair count is straight forward. In general, the two cable types are interchangeable with respect to the applications (for 10/100BaseT). The following bullets will provide the selection. Solid cable constructions should be avoided where frequent moving of the cables is expected.

2 pair cabling may be used for:

- 10/100BaseT applications.
- M12-4 “D” coded connectors (see note below).
- 4 circuit. 8-Way modular connectors (RJ45).
- High flex applications.
- On machine.
- Limited panel space (allows the use of M12 “D” coded connectors).
- Applications where wire way space is limited (In general, the diameter of a 2 pair cable is smaller than a 4 pair cable).
- Field termination is less complicated.
- Applications where you want to avoid star quad cable designs (star quad designs have all four conductors twisted). These designs are known to have less noise rejection capabilities.

Use 4 pair cabling for:

- Back bone and uplink ports.
- Areas where future requirements may require data rates greater than 100BaseT.
- Where the cabling requires support of all “generic applications” such as Voice and Video.
- POE+, or POE mid span.

Note: Do not mix 2 pair and 4 pair cables in the same channel unless the un-used pairs are differentially terminated. Do not use 4 pair cables in a 2 pair (4 circuit) connector. See additional rules in step 5.

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. Doing so helps to determine the cabling requirements and attributes. Most areas within the communications coverage area should be able to map into the MICE table. This step focuses on "$M_nI_nC_n$" aspects of the environment. For example, for cabling on a machine, the planner must know the approximate levels of vibration, dust, liquids, temperatures, and chemicals. The M.I.C classifications and categories can then be mapped into the MICE table and the M.I.C classifications can be placed on the cabling specification. In some cases the classifications may not be known. If this is the case, estimations will be required. For example, if the cabling is to be installed on machines were the vibration displacement is ≥ 15 mm and acceleration is ≥ 50 ms^{-2} then the Mechanical classification is M_3. The same process is used for I and C classifications.

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 (critical)

The additional mechanical attributes need to be considered as these usually require special cable constructions. Missing one of these mechanical requirements will cause premature failure of the cabling components. Therefore thorough consideration is required. For example, if the cable is installed outdoors where exposed to direct sunlight, UV protected cabling is required unless mitigated. The color of the cable may factor into the cable temperature when exposed to direct sunlight. This may then require a high temperature cable design. The following is a list of possible application requirements that have a direct impact on the cabling design;

- 2/4 pair. Pair count has a direct bearing on connectors used and vise versa. Generally M12-4 "D" coded connectors require less space than RJ45 sealed connectors.
  - 2 pair cables can be used with 8 circuit connectors such as RJ45 connectors.
  - 4 pair cables cannot be used with 4 circuit connectors such as M12-4 "D" coded connectors.
  - Pair count shall not change within a channel without terminating the un-used pairs. Differential termination is preferred since there is no reference to ground.
- TPE. PVC. FEP and PUR jacket requirements (avoid silicone constructions)
  - Generally TPE is good for oil and weld splatter environments.
  - PVC is an all around material.
- Oil Resist II and common cutting fluids per UL 1277 and UL 13.
- Sunlight Resistant (UV).
- High Temp > 60 ºC (may require channel length de-rating and special materials).

- IP 67 (water) (some PVCs may absorb liquids causing latent failures).
- Weld Splatter.
- High Flex (1.5 million minimum).
- Flexible cabling (cord sets and fixed cabling). Stranded cable constructions should be used where frequent moving of the cables either through reconfiguration or vibration is expected.

These additional mechanical requirements are over and above standard cables and will need to be added to the cable specification.

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					

This cable selection process must be repeated for each environmental area within the communications coverage area.

Glossary

EFT Electrical Fast Transient, primarily caused by lightning strikes and large electrical loads. EFT is fully described in the IEC 61000 series standards

ESD Electro Static Discharge, primarily caused by friction of two dissimilar moving surfaces. ESD is fully described in the IEC 61000 series standards.

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