Cable Testing Means More Uptime

Standards and Testing of Industrial Ethernet Copper Cabling

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Section Summary

- Understanding TIA-1005-A Industrial Premises standard for ICT
- Concepts of M.I.C.E and dynamics on plant floor
- MICE rated product selection for the plant floor
- Applying structured cabling from Enterprise to control panel

Why worry about the Network Physical Layer?

- More than half of failures in the network are in the data link and physical layer*
- Switch hardware will turn over 4X or more over the life of the plant cabling infrastructure
- 60% of plant floor nodes are on a variant of Ethernet

Todays topic: Effective network planning and testing for faster commissioning, increased uptime and improved OEE

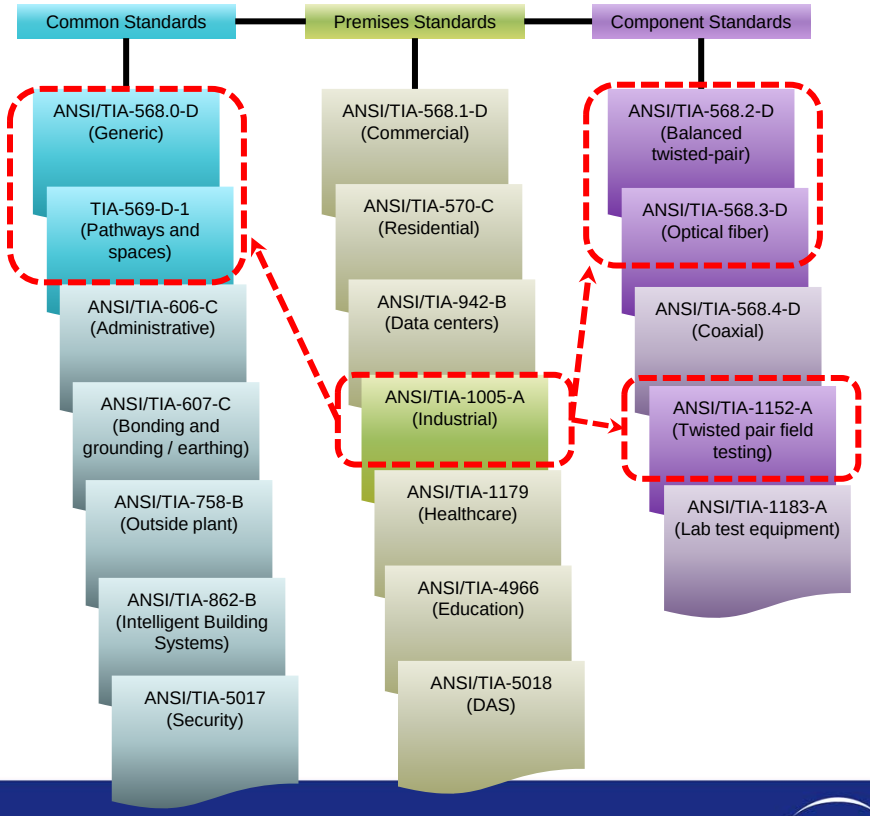
*source: ISA

Applicable Standards

Information and Communications Technology (ICT)

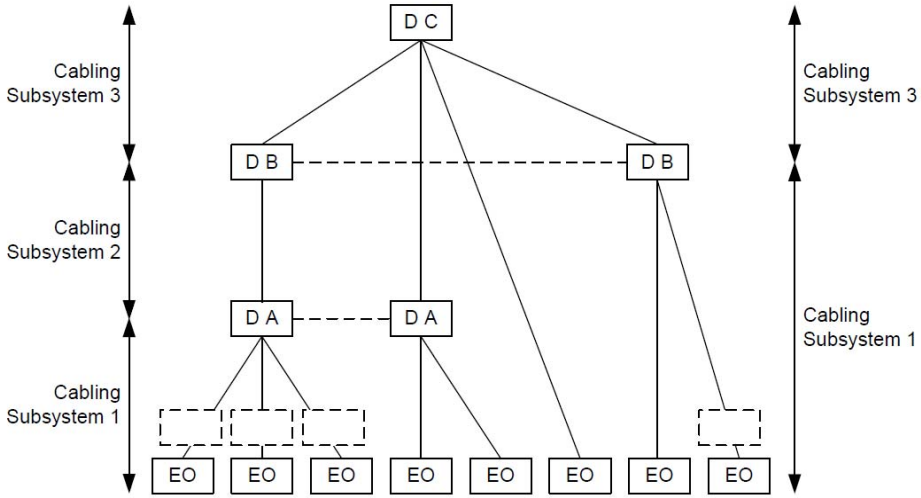
Telecommunications Standards

- TIA/EIA-568 Defines cabling types, distances, connectors, cable system architectures, cable termination standards and performance characteristics, cable installation requirements and methods of testing installed cable
- Defines the overall premises infrastructure for copper and fiber cabling
- Addresses components of the copper cabling system
- Addresses components of fiber optic cable systems
- ANSI/TIA-1005 is explicitly supported by the 568-cabling standard



The Telecommunications Industry Association (TIA)

TIA-1005 Model



Structured cabling in industrial premise

Physical infrastructure model for cabling and connectivity design

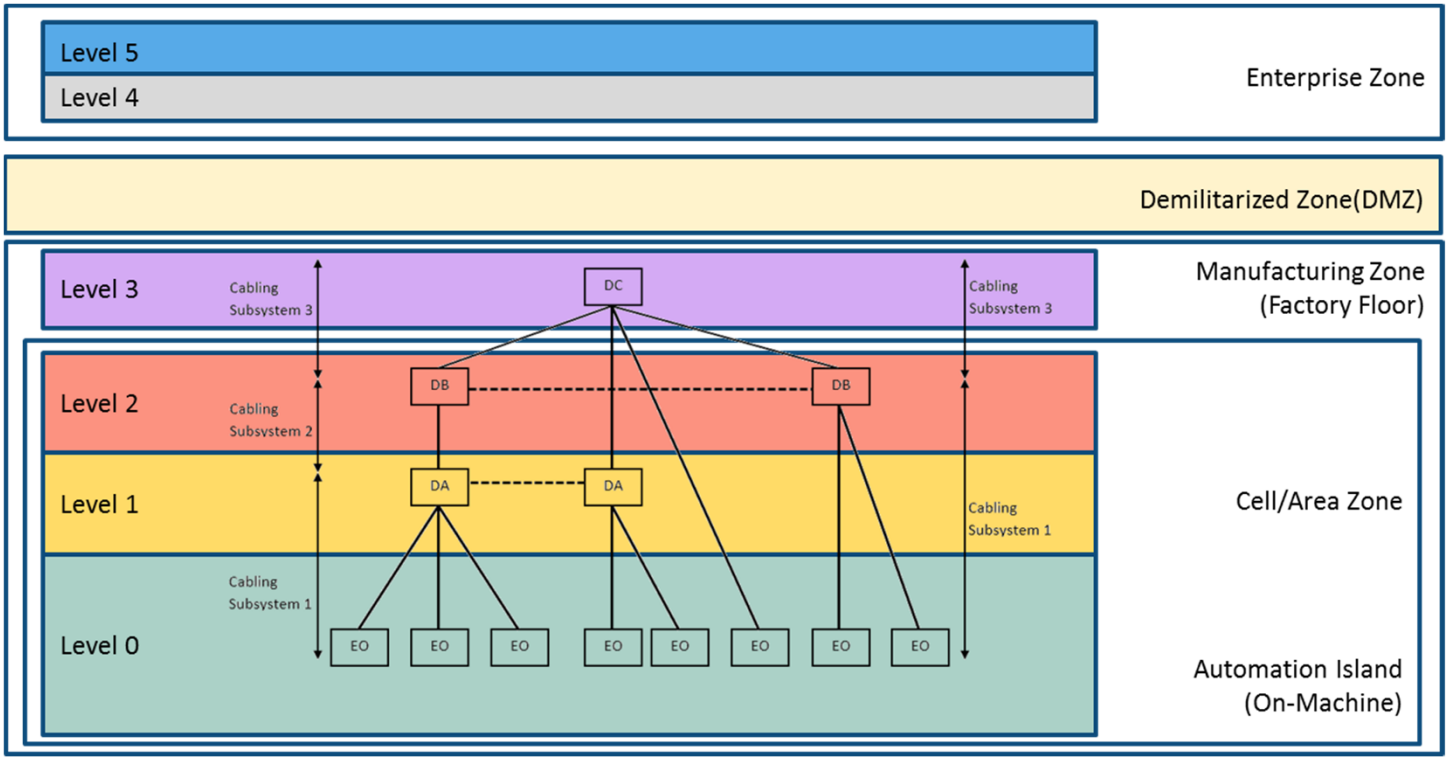
Flexible and scalable

Defines interconnects (to switch) and testable link/channel

D = Distributor (ER (MDF), TR (IDF), Access layer)

EO = Equipment Outlet

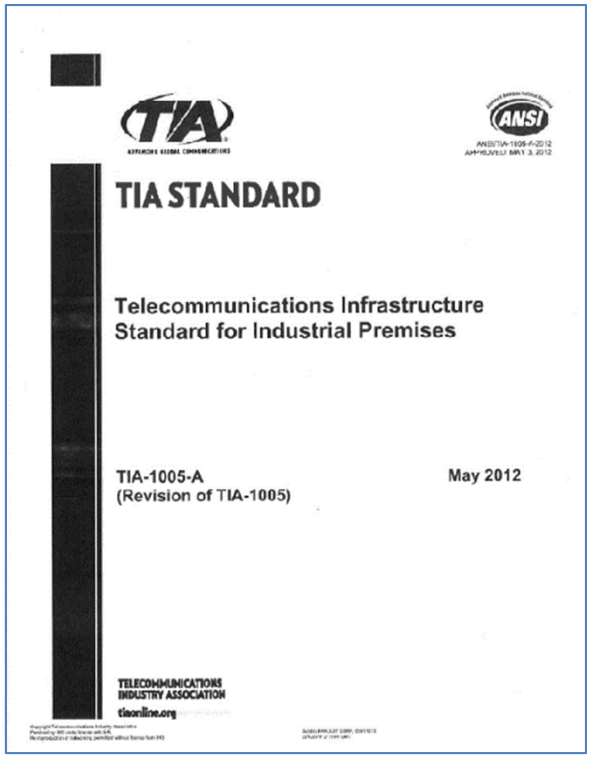
Industrial Networks and TIA-1005



Some Key Variations Between TIA-1005-A and TIA-568 Series

- M12 D-code
- M12 X-code (published in TIA-1005-A-1 in 2015)
- > 4 connector channel (6 connector)
- Introduction of Coupler/Adaptor
- M.I.C.E ratings

Office (Clean) to Industrial (Dirty)			
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



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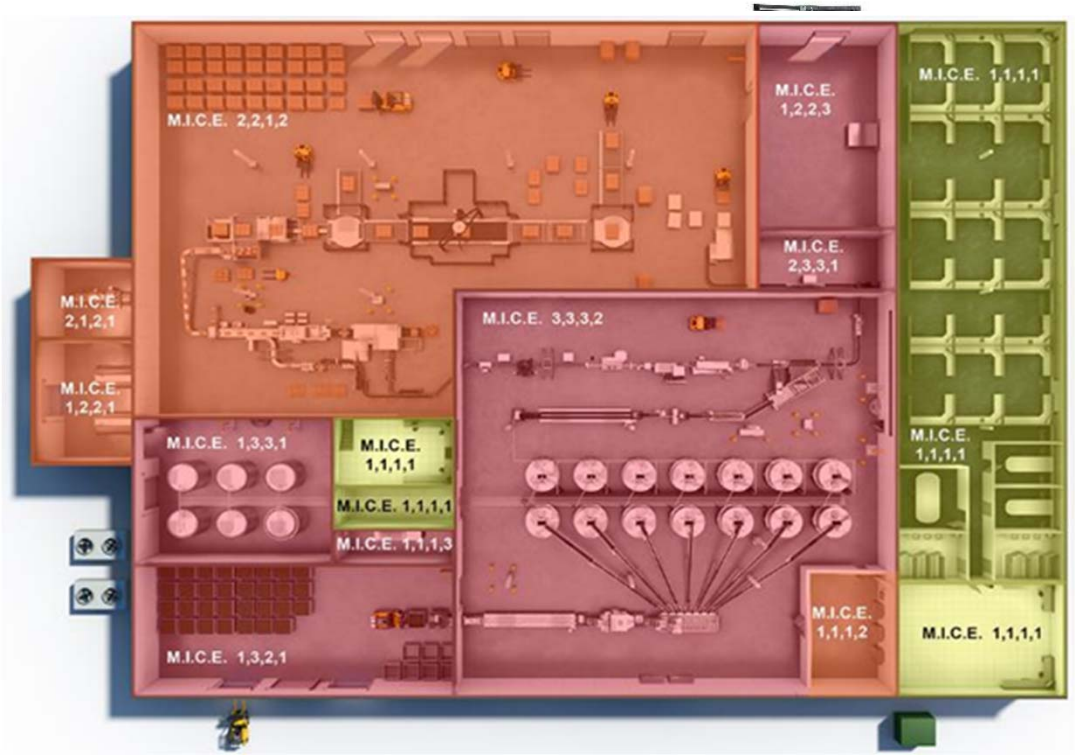
Global Industrial Ethernet Technology

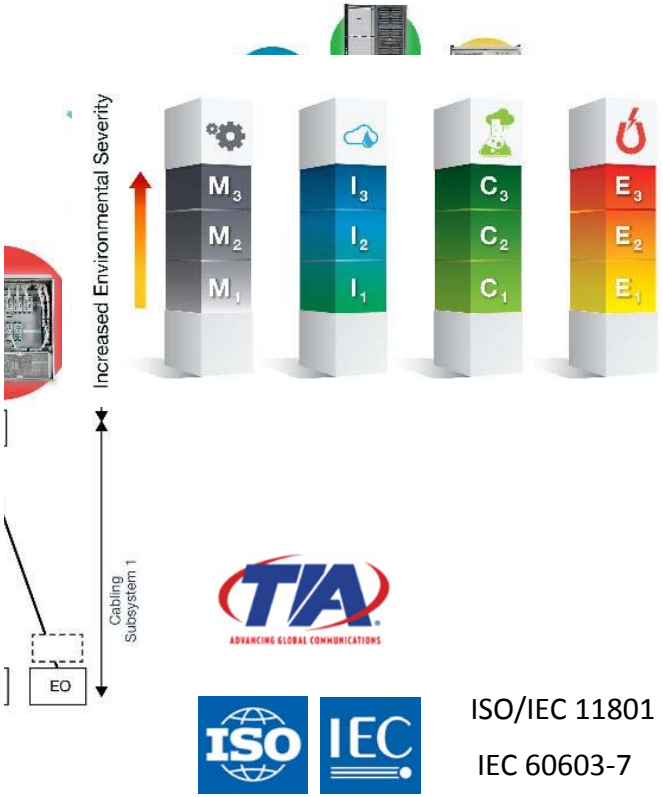
Standards

Ethernet	PROFINET	ETHERNET/IP	Modbus-IP
ISO/IEC 11801	ISO/IEC 11801-3	ISO/IEC 11801-3	ISO/IEC 11801-3
	IEC 61784-2 CPF3	IEC 61784-2 CPF2/2	IEC 61784-2 CPF15

Turning Standards into Solutions

Per TIA-1005-A





ISO/IEC 11801

IEC 60603-7

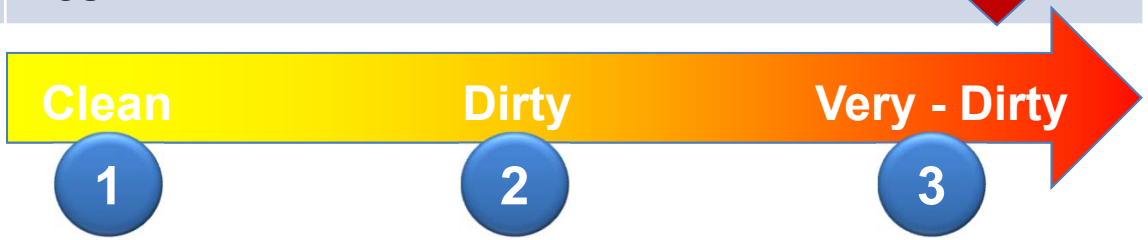
Benefits of Choosing M.I.C.E Rated Components

- Already tested to withstand the severity of the associated M.I.C.E element
- When choosing network cabling systems always consider the components that are able to withstand the worst-case environment to which it is exposed.
- Commercial grade network components ($M_1I_1C_1E_1$) can also be considered when applicable

How Product Selection Can be Affected by M.I.C.E Classifications

"M.I.C.E" characteristics change as a result of the routing products and methods used.

Route Type	Protected?
Hangers	No
Trays	No
Conduit	Yes
Lay-in Housing	Yes
Pull-thru Housing	Yes



Environment
M.I.C.E Level

How M.I.C.E. Can Affect Product Selection

Standard Enterprise Grade Patch Cord

Standard Enterprise Grade Equipment Cabinet

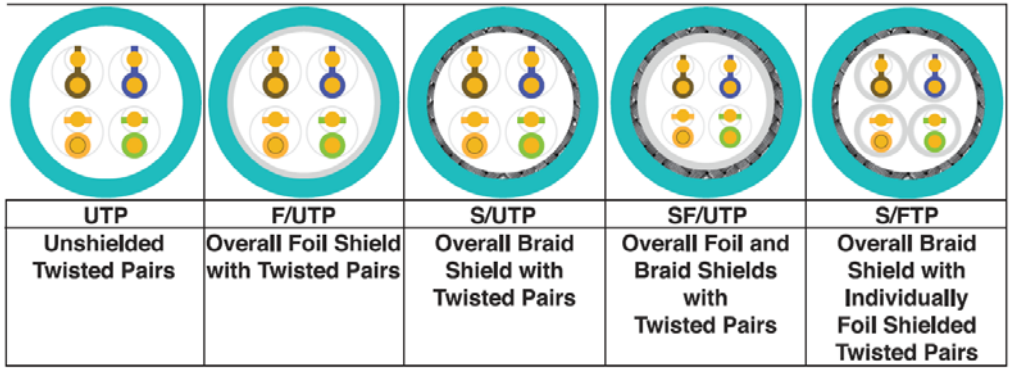
IP67 Industrial Grade Patch Cord

NEMA Type 12 Pre-Configured Micro Data Center

Shielded Cable for Ethernet Applications Industrial Environment

- The better the “electrical balance” of a cable the more protection from EMI
- Shielding cabling provides added layer(s) of protection
- Managing interference strongly tied to proper design and installation (including grounding & bonding)

Common designations for shielded and unshielded Ethernet cables, per ISO/IEC 11801:



UTP	F/UTP	S/UTP	SF/UTP	S/FTP
Unshielded Twisted Pairs	Overall Foil Shield with Twisted Pairs	Overall Braid Shield with Twisted Pairs	Overall Foil and Braid Shields with Twisted Pairs	Overall Braid Shield with Individually Foil Shielded Twisted Pairs

Areas addressed in TIA-1005-A:

- Equipotential/Mesh grounding system (conductor sizing)
- Star Grounding System (with ground isolation)
- RC Device Termination (resistor capacitor)

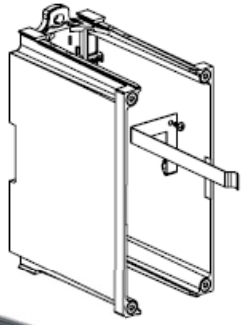
Examples of Shielding Solutions for Ethernet Cabling

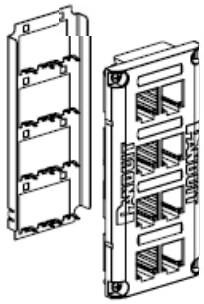
Shielded Wiring Duct

Shielded RJ-45 Jack

Shielded RJ-45 Field Terminable Plug

M12 X-code Field Terminable Plug





Shielded DIN Rail Copper Patching Solution

600 V rated patch cords, rated for control panel use

Braided Screen & Foil Screen Around Unshielded Twisted Pairs

SF/UTP

600 V rated 2 pair and 4 pair copper cable

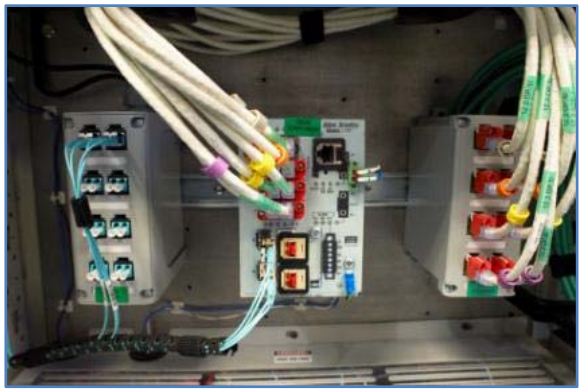
Structured and Point-to-Point Cabling

Point-to-Point Cabling

- Stranded cable field terminated with plugs
- Measurements infrequently done
- No standard exists to define the measurement method
- If the lights blink it's assumed it works!

Structured Cabling

- Solid horizontal cable terminated with jacks
- Typically installed and left in place; measured and warranted performance
- Connected to equipment with flexible patch cords

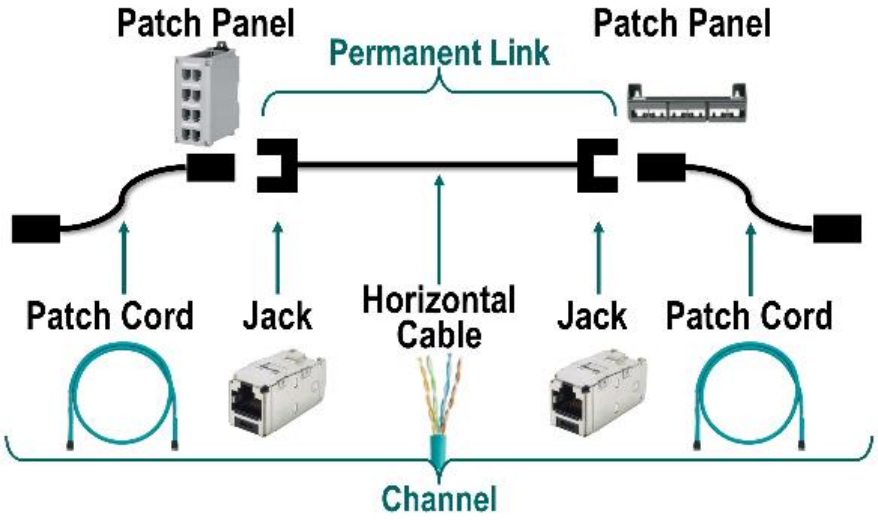


Why Structured Cabling on the Plant Floor Is a Best Practice

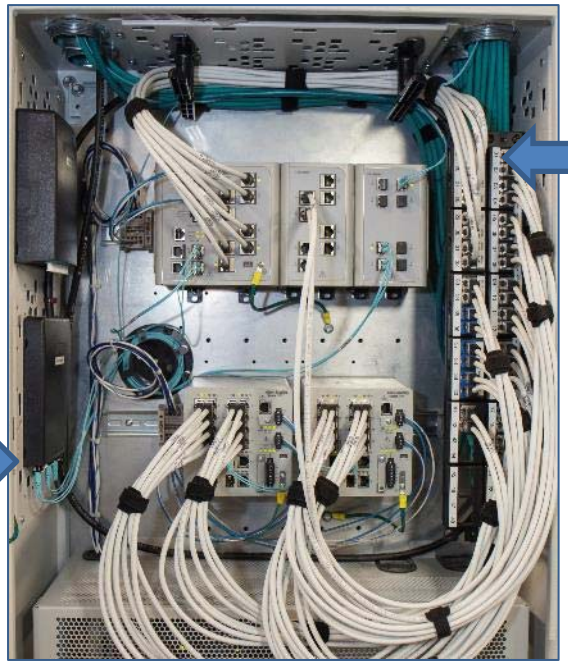
- Same cabling concept is used with I/O and terminal strips
- Manage the backbone separate from the patch to the controller – through a terminal strip or IFM
- Predictable and eases MACs

Terminal Strips

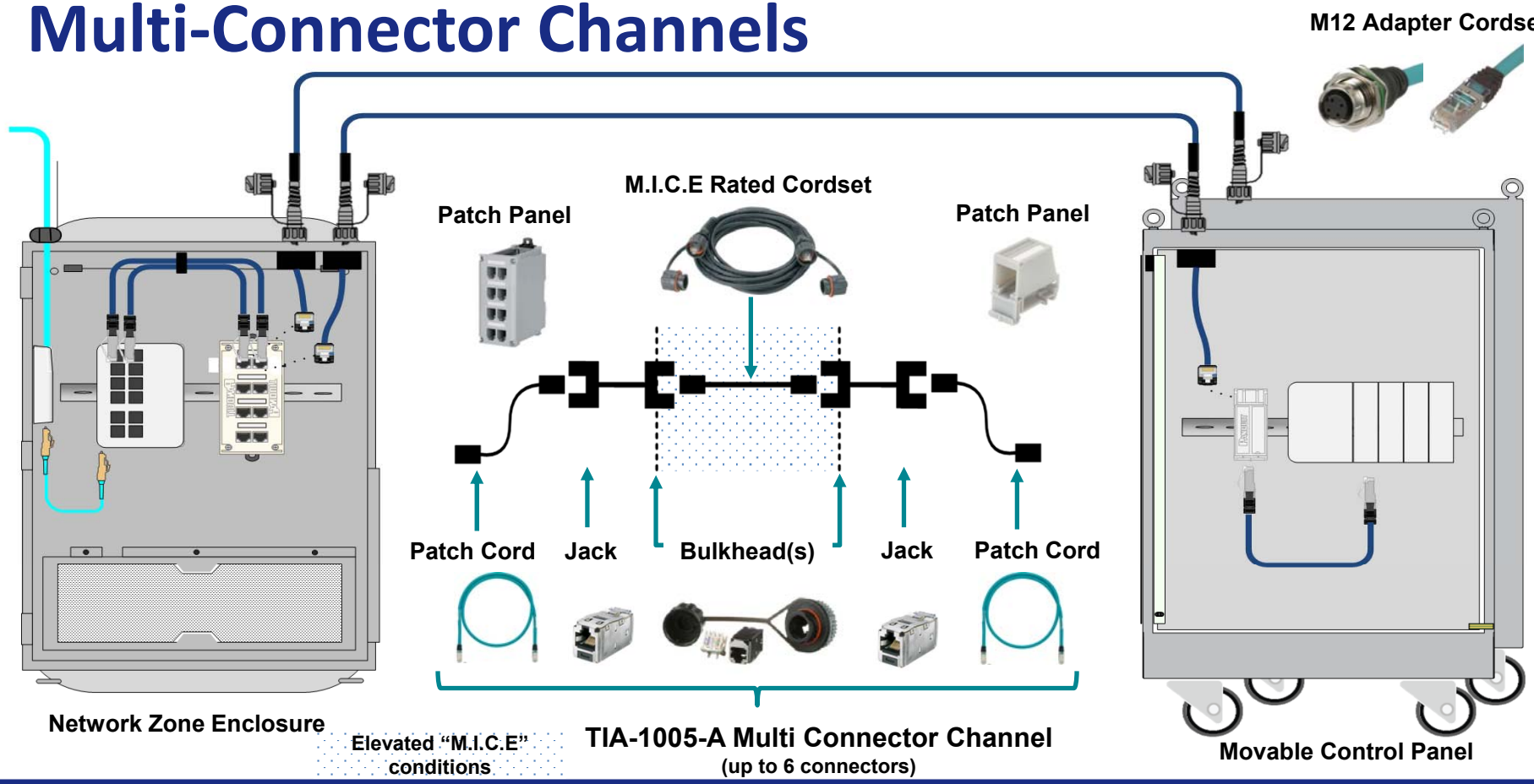
1492-IFM



Structured Cabling Within Zone Enclosure



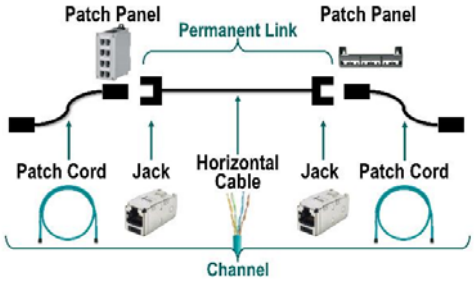
Multi-Connector Channels



Commissioning & Performance Validation

Channel Testing with the TIA model

- Channel testing should be done at each cabling subsystem level
- This includes subsystem 1, including field level 1-0 connections
- Testing will typically be done just prior to commissioning stage in a project
- ANSI/TIA/EIA 568 & 1152-A cover testing & field test equipment (including channel testing, and wire map)



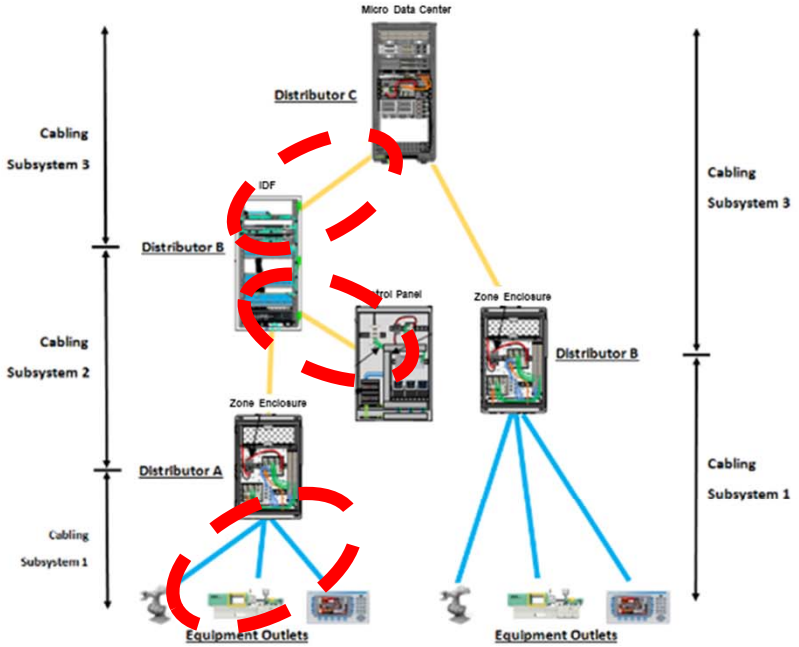


Fig 2: TIA 1005 Model shown with industrial enclosures

Section Summary

- Review your internal standards for the network physical layer
  - Reference TIA 1005-A (available at TIAonline.com)
- Use TIA 1005-A and the MICE concept to improve designs and to mitigate environmental factors
- Learn and follow controls vendors Industrial Ethernet physical recommendations

Field Testing of Installed Cabling for Industrial Environments

Jim Davis

Regional Marketing Engineer

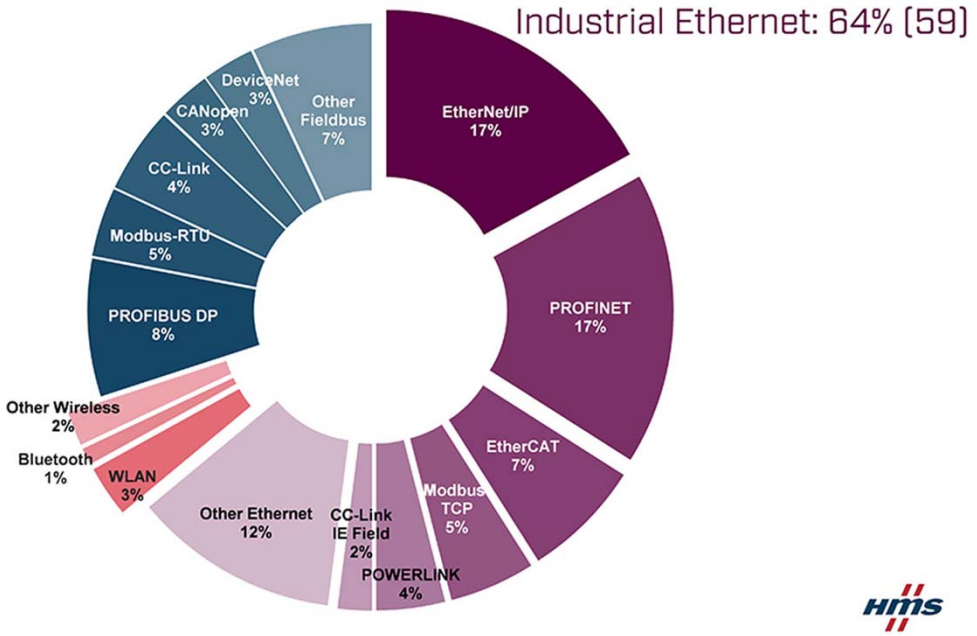
Fluke Networks

In this session…

- Cable Performance basics – Signal to Noise ratio
- Specific cabling problems in E2 and E3 MICE environments and how to mitigate them
- Fluke Networks Cable Test equipment

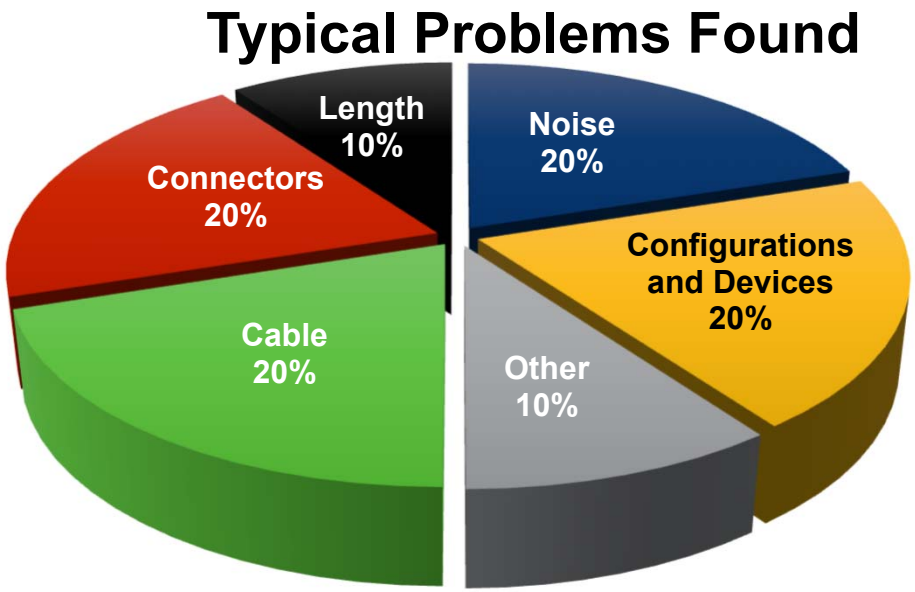
Industrial Protocol Market Shares - 2020

- Fieldbuses are in decline, wireless is stable, Industrial Ethernet share up from 59 to 64% in last year
- Ethernet/IP and Profinet are the dominant Industrial Ethernet variant with 17% market share each



https://hms-networks.com/news-and-insights/news-from-hms/2020/05/29/industrial-network-market-shares-2020-according-to-hms-networks

Cabling Produces Half of Industrial Ethernet Problems



Field Terminated Cables

- Wired wrong
- Untwisted causing noise susceptibility
- Shield Integrity
- Damaged during and after installation
- Loose connections

Pre-Terminated Cables

- Damaged during installation
- Damaged after installation
- Loose connections

Loose connections cause intermittent problems

- Vibration
- Moisture
- Oxidation
- Susceptible to noise

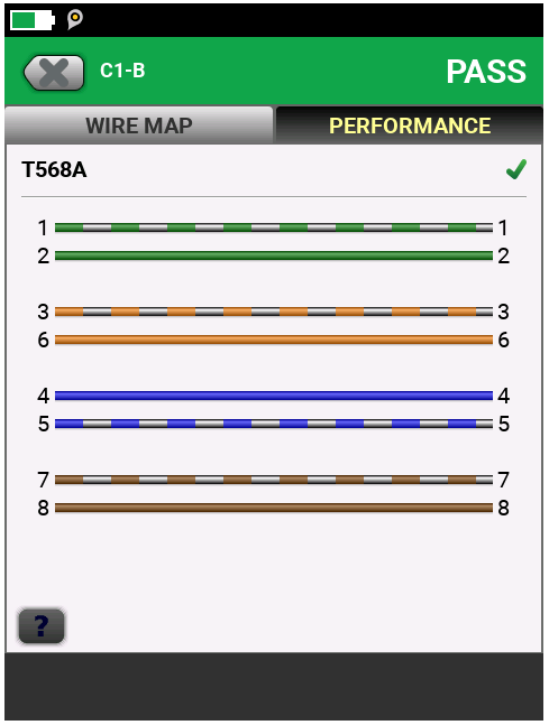
Why test cabling as part of commissioning?

- Be sure that the installed cabling meets the performance you are paying for. An untested cable is a source of doubt.
  - Cat 6a Jack + Cat 6a Cable + Cat 6a Installer ≠ Cat 6a
- To get paid for the job
- Experience has shown that Certified networks run faster and support future applications
  - CRC/FCS errors lead to re-transmissions
  - How long will that cable be in the wall?
  - Reduce New Machine Start-up Time
  - Reduce Production Down Time
- Beware of those who offer to save $ on the installation by not certifying

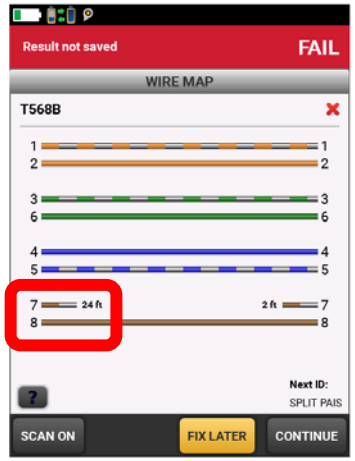
What parameters are measured?

- The capacity of a cable to support high speed data is based on measurements of signal and noise
- Continuity, or Wire Map, is not sufficient to support Gigabit Ethernet
- Signal Strength, or loss, is measured as Attenuation or Insertion Loss
- Noise is made up of two parameters, NEXT and Return Loss
- Putting together these measurement we get a Signal to Noise Ratio
- The greater the frequency where we can maintain a positive SNR, the faster we can communicate

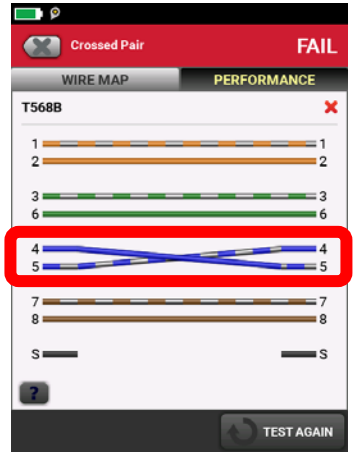
First, Continuity



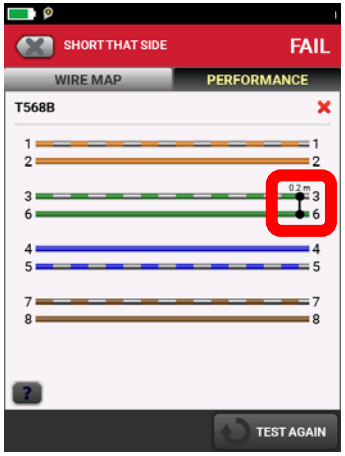
Most Common Problem: Bad Wire Map



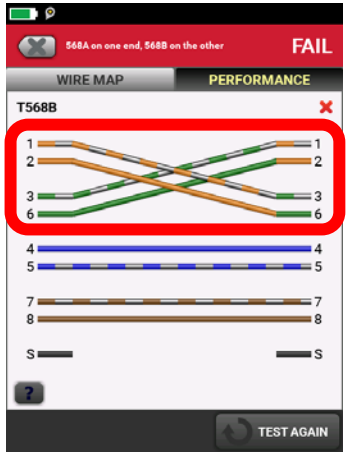
Open Pairs



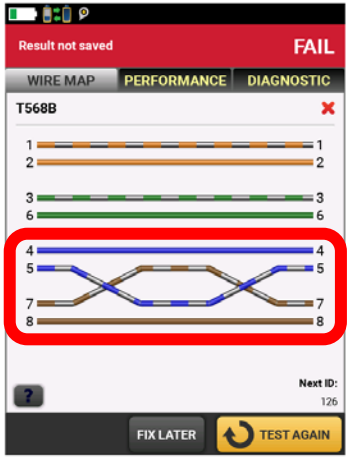
Flipped Pair



Short



T568A vs T568B



Split Pair

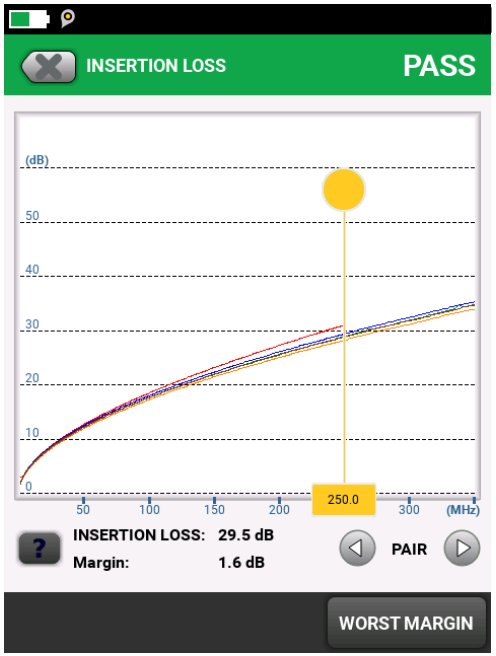
Signal Strength – Insertion Loss

Insertion Loss:

- In dB, the signal loss down the cable

Signal Loss increased with:

- Length
- Frequency
- Temperature
  - Cables in hot locations may not reach 100 meters



Temperature De-rating

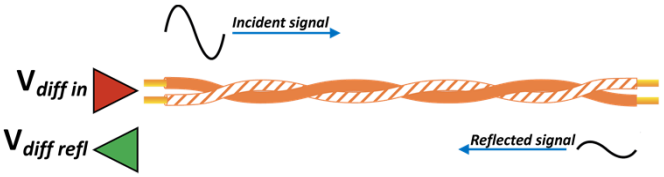
- TIA-568 and ISO 11801 lengths are based on an ambient temperature of 20c
- The standard does not permit the limits in the tester to be relaxed
- You may need to reduce the acceptable length of your links
  - Be sure to specify a maximum length in your bid documents if it is less than 100 meters for the channel

Temperature (ºC (ºF))	Maximum horizontal unscreened cable length (m)	Maximum horizontal screened cable length (m)	Length de-rating (m) (unscreened)	Length de-rating (m) (screened)
20 (68)	90.0	90.0	0.0	0.0
25 (77)	89.0	89.5	1.0	0.5
30 (86)	87.0	88.5	3.0	1.5
35 (95)	85.5	87.7	4.5	2.3
40 (104)	84.0	87.0	6.0	3.0
45 (113)	81.7	86.5	8.3	3.5
50 (122)	79.5	85.5	10.5	4.5
55 (131)	77.2	84.7	12.8	5.3
60 (140)	75.0	83.0	15.0	6.0

Noise – Return Loss

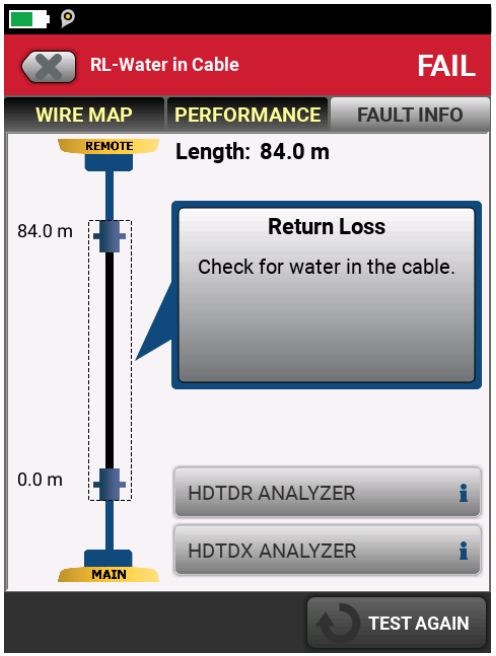
Return Loss:

- In dB, the reflected signal on the same pair



Return Loss increases with:

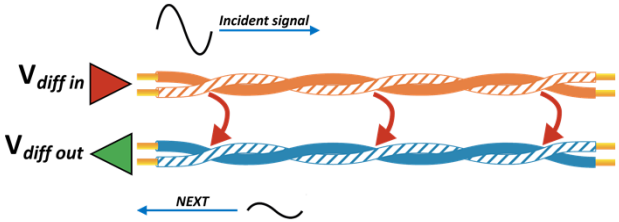
- Badly made / damaged cable
- Pairs being separated
- Water in the cable
  - The cable isn't bad, it's the wrong cable for this application



Noise – NEXT (Near-end Crosstalk)

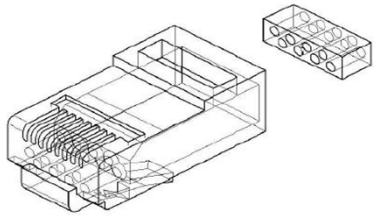
NEXT:

- In dB, the disturbed signal on an adjacent pair



NEXT is increased by:

- The 4,5 pair being inside the 3,6 pair
- Badly made / damaged cable
- Not maintaining the twist of the pair in the connector
- Incorrect test limit / category of cable



SNR = ACR (Attenuation Crosstalk Ratio)

Putting I/L and NEXT together

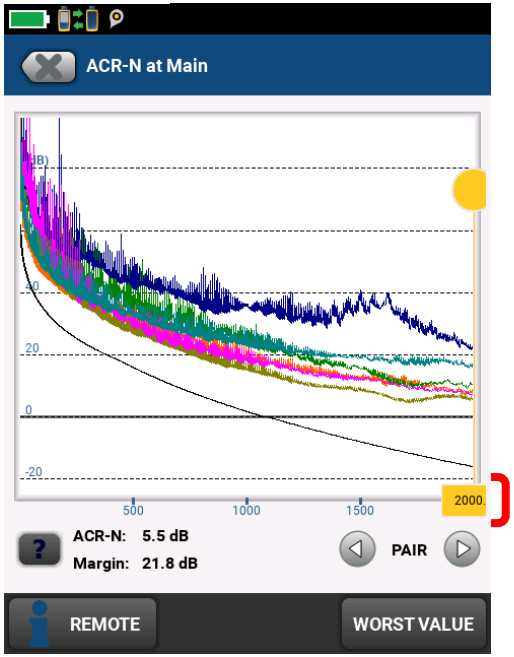
- In dB, the signal to noise ratio of a given pair

ACR is a calculation

- NEXT minus Insertion Loss

Better ACR, faster communications

- Category 5e to 100 MHz - Supports up to 5GBASE-T
- Category 6 to 250 MHz - Can support 10GBASE-T to 55 meters
- Category 6a to 500 MHz - Supports 10GBASE-T to 100 meters



How to Read a Test Report

The Logo of the Company that did the testing

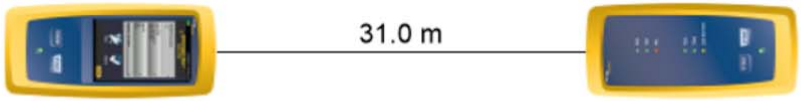
Cable ID: of the port that was tested **Test Summary: PASS**

Date / Time:
Headroom 11.9 dB (RL 45)
Test Limit: TIA Cat 6 Perm. Link
Cable Type: affects the NVP
NVP: 69.0%

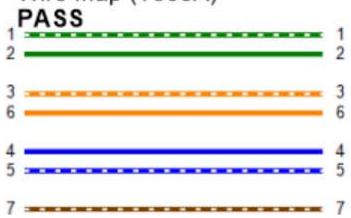
Operator: of the test equipment
Software Version: V5.0 Build 3
Limits Version: V5.0
Calibration Date:
Main (Module): 03/11/2016
Remote (Module): 03/11/2016

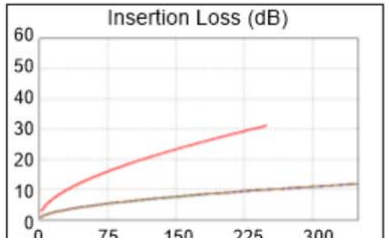
Model: DSX-5000
Main S/N:
Remote S/N:
Main Adapter: DSX-PLA004
Remote Adapter: DSX-PLA004

Length (m), Limit 90.0	[Pair 45]	31.0
Prop. Delay (ns), Limit 498	[Pair 36]	161
Delay Skew (ns), Limit 44	[Pair 36]	11
Resistance (ohms)	[Pair 12]	5.08
Insertion Loss Margin (dB)	[Pair 12]	21.3
Frequency (MHz)	[Pair 12]	250.0
Limit (dB)	[Pair 12]	31.1



Wire Map (T568A)
PASS





	Worst Case Margin		Worst Case Value	
PASS	MAIN	SR	MAIN	SR

Did the Test Pass?

The Logo of the Company that did the testing

Yes! ✓

Cable ID: of the port that was tested **Test Summary: PASS**

Date / Time:
Headroom 11.9 dB (RL 45)
Test Limit: TIA Cat 6 Perm. Link
Cable Type: affects the NVP
NVP: 69.0%

Operator: of the test equipment
Software Version: V5.0 Build 3
Limits Version: V5.0
Calibration Date:
Main (Module): 03/11/2016
Remote (Module): 03/11/2016

Model: DSX-[illegible]
Main S/N:
Remote S/N:
Main Adapter: DSX-PLA004
Remote Adapter: DSX-PLA004

Length (m), Limit 90.0	[Pair 45]	31.0
Prop. Delay (ns), Limit 498	[Pair 36]	161
Delay Skew (ns), Limit 44	[Pair 36]	11
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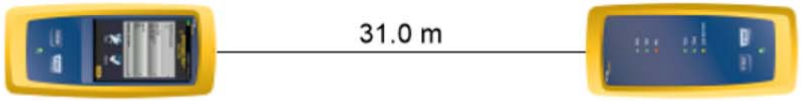
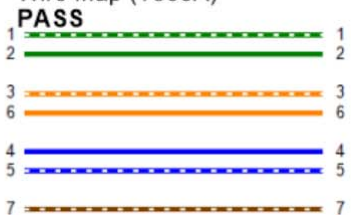
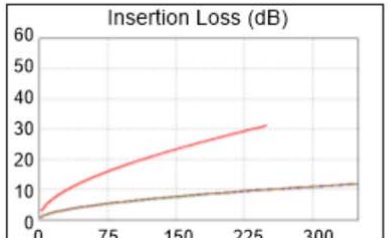


Wire Map (T568A)
PASS





	Worst Case Margin		Worst Case Value	
PASS	MAIN	SR	MAIN	SR

What Test Limit was Passed?

The Logo of the Company that did the testing

Category 6 – Permanent Link

Cable ID: of the port that was tested

Test Summary: PASS

Date / Time:

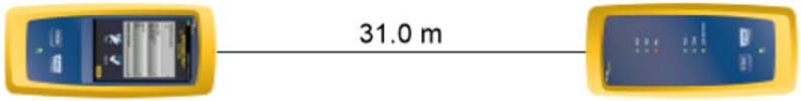
Test Limit: TIA Cat 6 Perm. Link

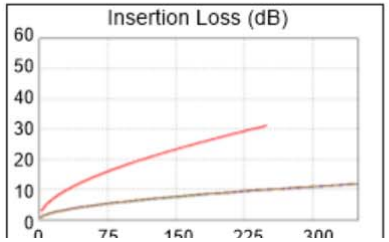
NVP: 69.0%

Operator: of the test equipment
Software Version: V5.0 Build 3
Limits Version: V5.0
Calibration Date:
Main (Module): 03/11/2016
Remote (Module): 03/11/2016

Model: DSX-5000
Main S/N:
Remote S/N:
Main Adapter: DSX-PLA004
Remote Adapter: DSX-PLA004

Length (m), Limit 90.0	[Pair 45]	31.0
Prop. Delay (ns), Limit 498	[Pair 36]	161
Delay Skew (ns), Limit 44	[Pair 36]	11
Resistance (ohms)	[Pair 12]	5.08
Insertion Loss Margin (dB)	[Pair 12]	21.3
Frequency (MHz)	[Pair 12]	250.0
Limit (dB)	[Pair 12]	31.1

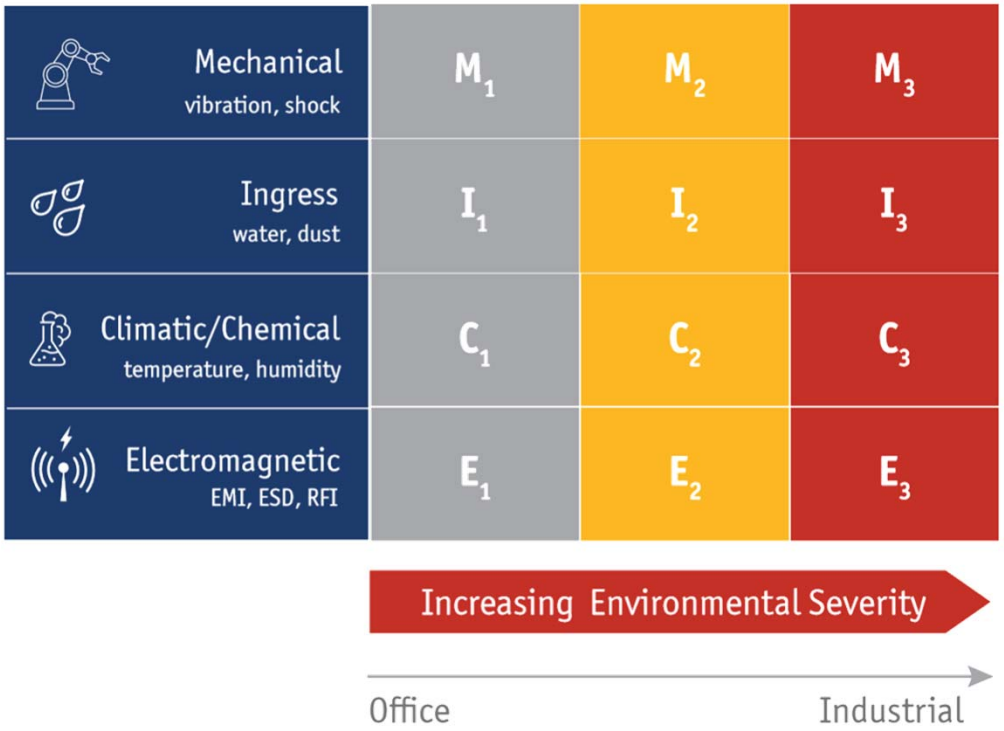




	Worst Case Margin		Worst Case Value	
PASS	MAIN	SR	MAIN	SR

That is nice, but we are in a harsh environment; motors, transformers, arc welders, high temperatures…

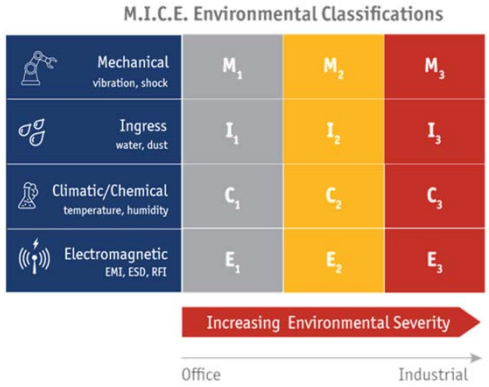
TIA-1005 M.I.C.E. Classifications

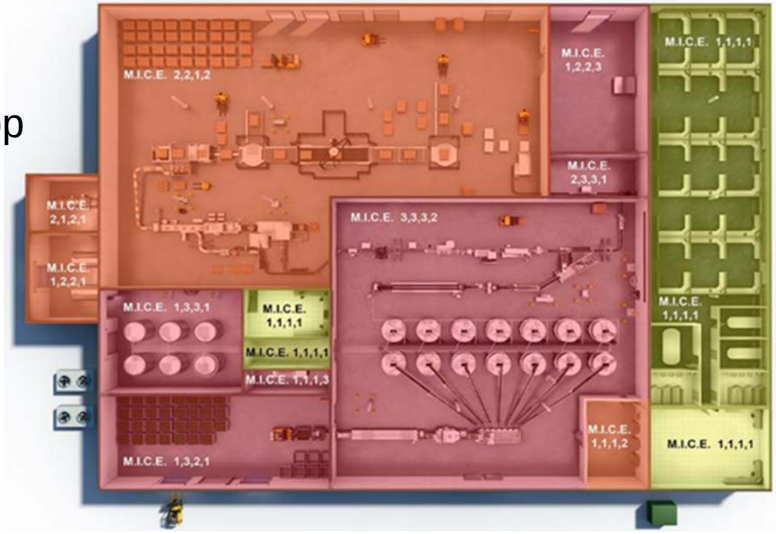


The big concern with E3 environments electromagnetic interference:

Lost packets – CRC/FCS errors

- May cause network latency
- May cause a loss of connection
- A few frame errors can cause machines to stop





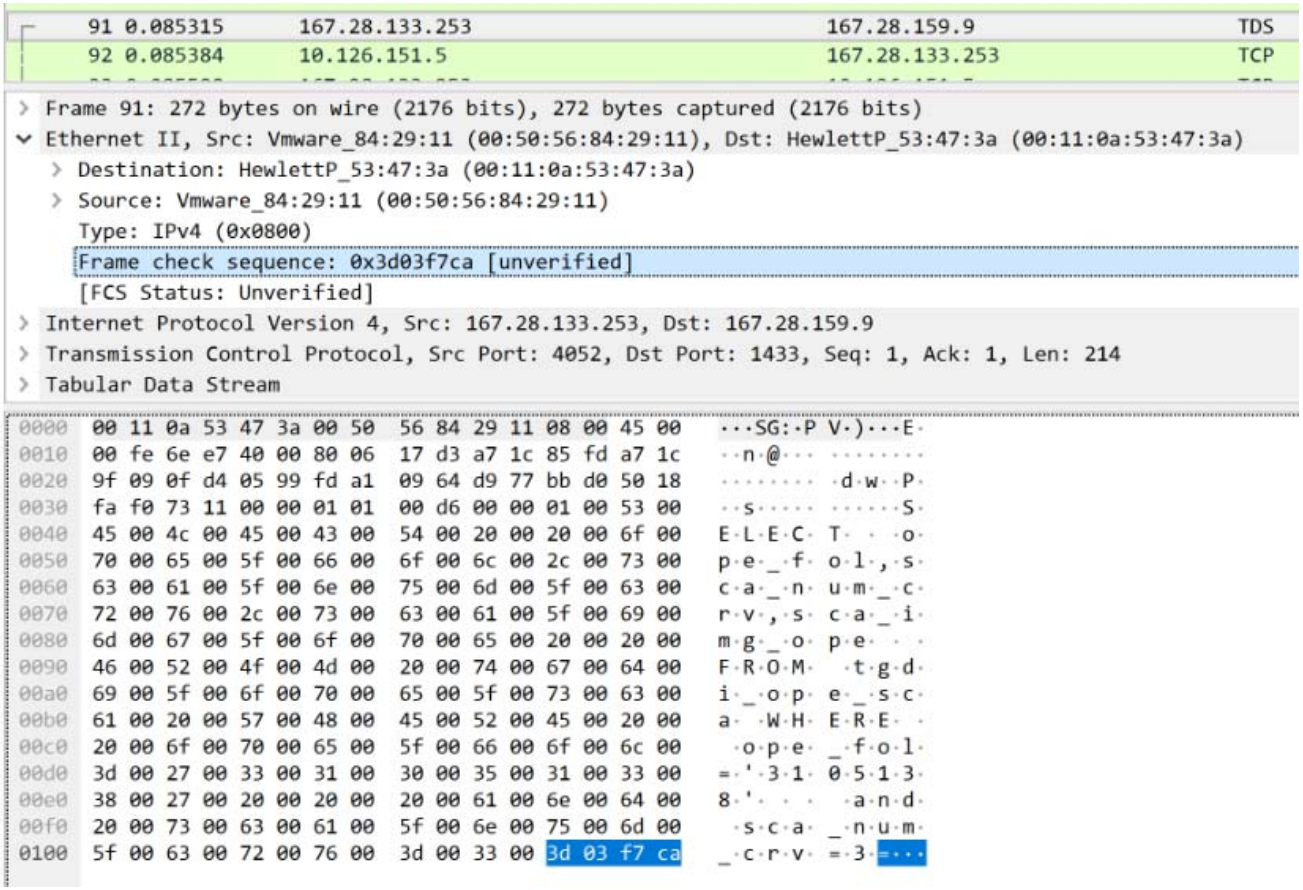
CRC errors can slow down or even crash a network

- Caused by the checksum generated by the transmitting device not matching the one generated by the receiving device
- You may not know they are happening
- The Device will ‘throw out’ a defective frame and re-try
- They can be caused by bad cabling or a bad device configurations
- They can be caused by noise, and poor connections

A few bad frames can cause a machine to shut down

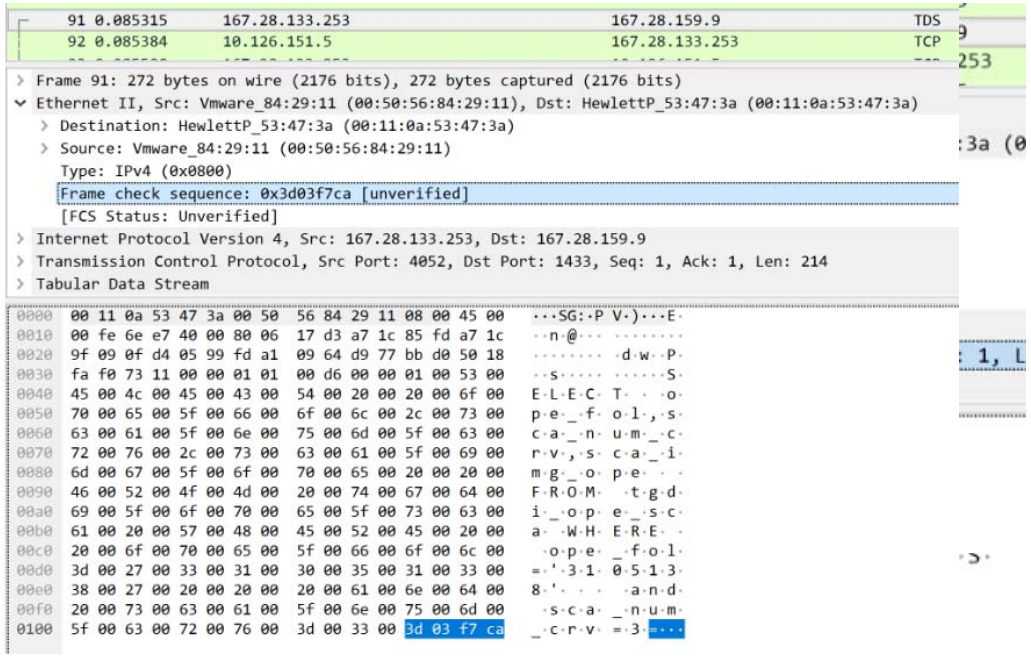
- Especially with high RPIs applications

An Ethernet frame:



EMI and CRC/FCS Errors

Very simplified Ethernet frame:



Destination Address	Source Address	Protocol	Data	

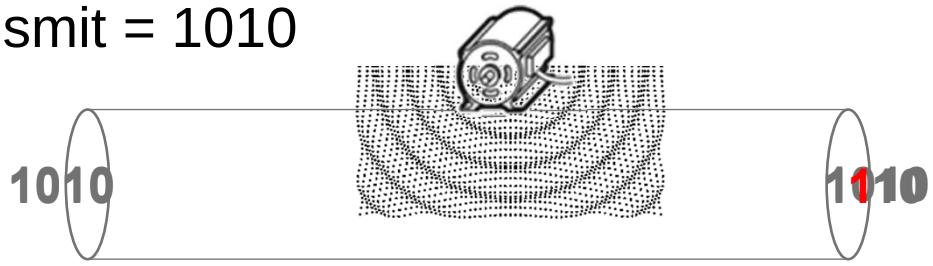
EMI and CRC/FCS Errors

Very simplified Ethernet frame:

Destination Address	Source Address	Protocol	Data	CRC/FCS

Transmit = 1010

Transmit = 1010



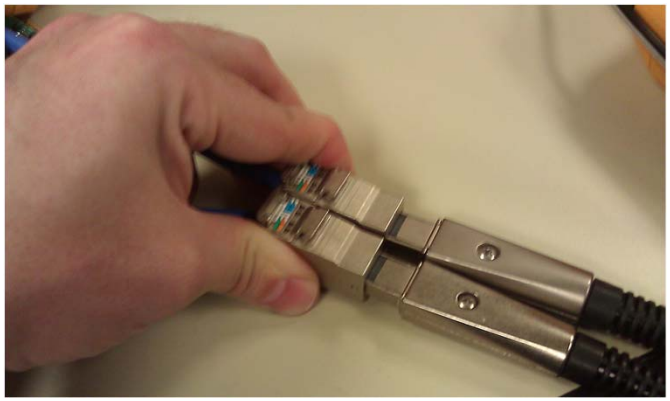
Switch

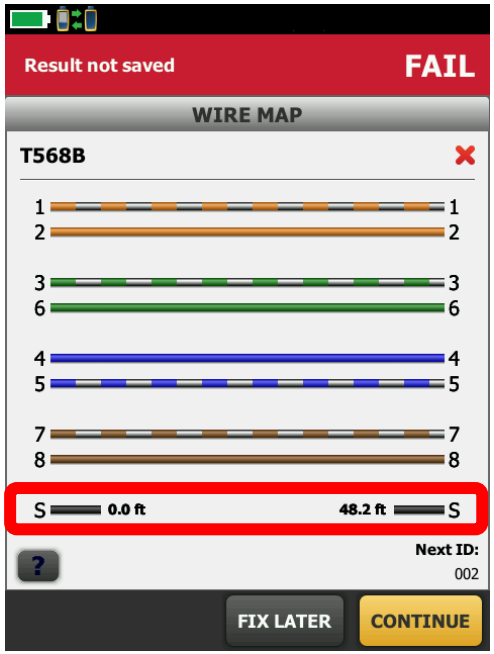
PLC

Two Common Ways to Avoid EMI:
Shielded Cable and/or Well-Balanced Cable

Shield Integrity – Modern Certification tools can determine if the shield follows the path of the cable

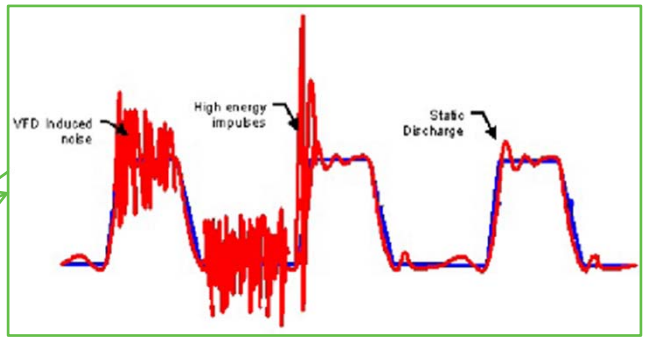
- If the shield does not ***follow the path of the cable*** an open should be reported
- Even when the two connectors are touching

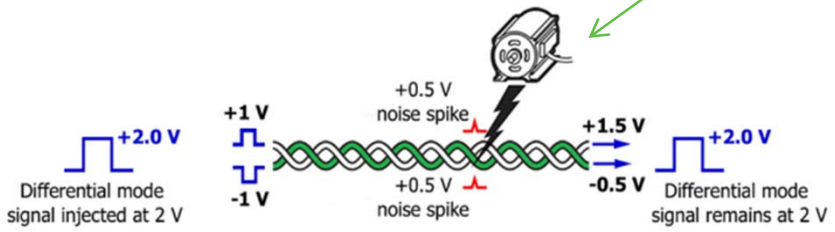




Avoid EMI with Well Balanced Links

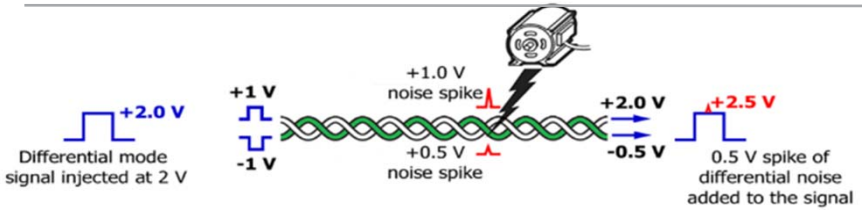
- 480 V VFD EMI: **1000 V,** or higher pulses
- Industrial Ethernet: 2 volt pulses





Good Cable

- Motor or VFD noise is equal across pairs
- Devices still get a 2-volt signal (noise cancelled)
  - Packets get through the 1st time



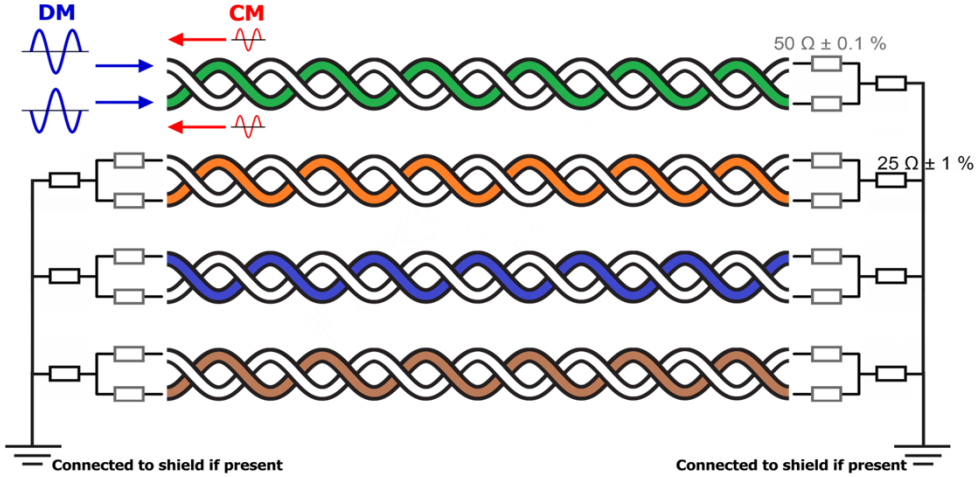
Poor (unbalanced) Cable

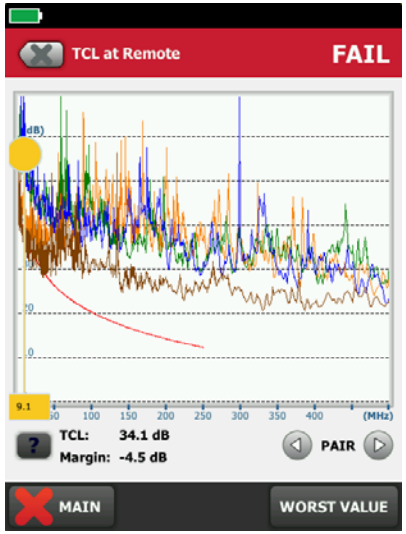
- VFD noise NOT equal across pairs
- Devices **WILL NOT** get a 2-volt signal
  - FCS and CRC errors. Re-tries and latency
  - Usually intermittent

- **Good cables cancel out EMI. Poor cables let EMI reach devices.**
- **TCL and ELTCTL measurements identify resistance to EMI.**

TCL – A measurement of Balance for Cabling

- Transverse Conversion Loss is the ratio (in dB) of a common-mode voltage measured on a wire pair relative to a differential-mode voltage applied to the same end of the pair. The TCL value shows you how well the impedances of the pair's conductors are balanced.





The Basic TIA-1005 Limit has no TCL Test

TIA 1005 Cat 6 Channel

		Unbalance	Pair to Pair	Length	Delay	Delay Skew	Freq.	Insertion Loss	NEXT	RL	ACR-N	ACR-F	PS NEXT	PS ACR-N	PS ACR	TCL	ELTCTL	CDNEXT	CMRL	TCTL
1,2 - 1,2	Ω	Ω or %	Ω or %	Max.	nS	nS	MHz	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB
3,6 - 3,6	i			100	555	50	1	3.0	65.0	19.0	62.0	63.3	62.0	59.0	60.3					
4,5 - 4,5							4	4.0	63.0	19.0	59.0	51.2	60.5	56.5	48.2					
7,8 - 7,8							8	5.7	58.2	19.0	52.5	45.2	55.6	49.9	42.2					
							10	6.3	56.6	19.0	50.2	43.3	54.0	47.7	40.3					
i	Informational measurement only, no limit available						16	8.0	53.2	18.0	45.2	39.2	50.6	42.6	36.2					
	10% length rule - will fail when length > 110 m						20	9.0	51.6	17.5	42.6	37.2	49.0	39.9	34.2					
	Not evaluated against the test limit						25	10.1	50.0	17.0	39.9	35.3	47.3	37.2	32.3					
	If Insertion Loss < 3 dB, not evaluated against the test limit						31	11.4	48.4	16.5	37.0	33.4	45.7	34.3	30.4					
	If FEXT is < 70 dB, not evaluated against the test limit						63	16.5	43.4	14.0	26.9	27.3	40.6	24.1	24.3					
							100	21.3	39.9	12.0	18.6	23.3	37.1	15.8	20.3					
							200	31.5	34.8	9.0	3.3	17.2	31.9	0.3	14.2					
							250	35.9	33.1	8.0	-2.8	15.3	30.2	-5.8	12.3					
							350	i	i	i	i	i	i	i	i					

The E1 (+ALL) test includes TCL Limits

and ELTCTL – TCL on the far end

TIA 1005 Cat 6 Channel E1 (+All)

		Resistance		Length	Delay	Delay Skew	Freq.	Insertion Loss	NEXT	RL	ACR-N	ACR-F	PS NEXT	PS ACR-N	PS ACR	TCL	ELTCTL	TCDNEXT	CMRL	TCTL
		Unbalance	Pair to Pair																	
1,2 - 1,2	Ω	Ω or %	Ω or %	Max.	nS	nS	MHz	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB
3,6 - 3,6	25	0.2 or 3.0	0.2 or 7.0	100	555	50	1	3.0	65.0	19.0	62.0	63.3	62.0	59.0	60.3	40	30	i	i	i
4,5 - 4,5							4	4.0	63.0	19.0	59.0	51.2	60.5	56.5	48.2	40	18	i	i	i
7,8 - 7,8							8	5.7	58.2	19.0	52.5	45.2	55.6	49.9	42.2	40	12	i	i	i
							10	6.3	56.6	19.0	50.2	43.3	54.0	47.7	40.3	38	10	i	i	i
i	Informational measurement only, no limit available						16	8.0	53.2	18.0	45.2	39.2	50.6	42.6	36.2	35	6	i	i	i
	10% length rule - will fail when length > 110 m						20	9.0	51.6	17.5	42.6	37.2	49.0	39.9	34.2	34	4	i	i	i
	Not evaluated against the test limit						25	10.1	50.0	17.0	39.9	35.3	47.3	37.2	32.3	32	2	i	i	i
	If Insertion Loss < 3 dB, not evaluated against the test limit						31	11.4	48.4	16.5	37.0	33.4	45.7	34.3	30.4	31	i	i	i	i
	If FEXT is < 70 dB, not evaluated against the test limit						63	16.5	43.4	14.0	26.9	27.3	40.6	24.1	24.3	25	i	i	i	i
							100	21.3	39.9	12.0	18.6	23.3	37.1	15.8	20.3	20	i	i	i	i
							200	31.5	34.8	9.0	3.3	17.2	31.9	0.3	14.2	14	i	i	i	i
							250	35.9	33.1	8.0	-2.8	15.3	30.2	-5.8	12.3	12	i	i	i	i
							350	i	i	i	i	i	i	i	i	i	i	i	i	i

The E1 (+ALL) test includes TCL Limits

and ELTCTL – TCL on the far end

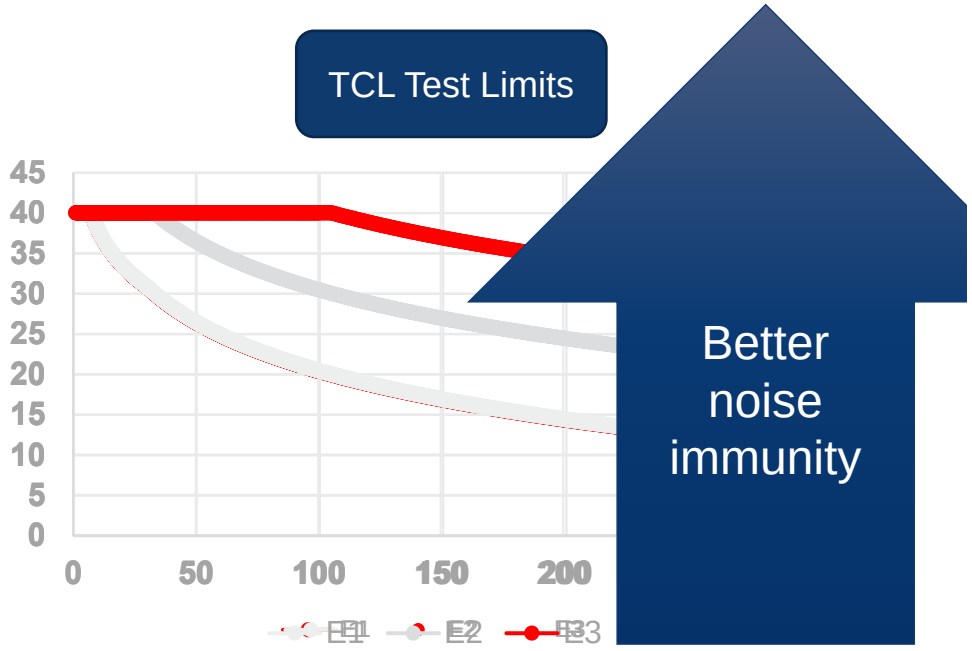
TIA 1005 Cat 6 Channel E1 (+All)

		Resistance		Length	Delay	Delay Skew	Freq	Insertion Loss	NEXT	RL	ACR-N	ACR-F	PS NEXT	PS ACR-N	PS ACR	TCL	ELTCTL	TCDNEXT	CMRL	TCTL
		Unbalance	Pair to Pair																	
1,2 - 1,2	Ω	Ω or %	Ω or %	Max.	nS	nS	MH	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB	dB
3,6 - 3,6	25	0.2 or 3.0	0.2 or 7.0	100	555	50	1	3.0	65.0	19.0	62.0	63.3	62.0	59.0	60.3	40	30	i	i	i
4,5 - 4,5							4	4.0	63.0	19.0	59.0	51.2	60.5	56.5	48.2	40	18	i	i	i
7,8 - 7,8							8	5.7	58.2	19.0	52.5	45.2	55.6	49.9	42.2	40	12	i	i	i
							10	6.3	56.6	19.0	50.2	43.3	54.0	47.7	40.3	38	10	i	i	i
i	Informational measurement only, no limit available						16	8.0	53.2	18.0	45.2	39.2	50.6	42.6	36.2	35	6	i	i	i
	10% length rule - will fail when length > 110 m						20	9.0	51.6	17.5	42.6	37.2	49.0	39.9	34.2	34	4	i	i	i
	Not evaluated against the test limit						25	10.1	50.0	17.0	39.9	35.3	47.3	37.2	32.3	32	2	i	i	i
	If Insertion Loss < 3 dB, not evaluated against the test limit						31	11.4	48.4	16.5	37.0	33.4	45.7	34.3	30.4	31	i	i	i	i
	If FEXT is < 70 dB, not evaluated against the test limit						63	16.5	43.4	14.0	26.9	27.3	40.6	24.1	24.3	25	i	i	i	i
							100	21.3	39.9	12.0	18.6	23.3	37.1	15.8	20.3	20	i	i	i	i
							200	31.5	34.8	9.0	3.3	17.2	31.9	0.3	14.2	14	i	i	i	i
							250	35.9	33.1	8.0	-2.8	15.3	30.2	-5.8	12.3	12	i	i	i	i
							350	i	i	i	i	i	i	i	i	i	i	i	i	i

As we move from E1 to E2 to E3 limits, the standard signal and noise limits do not change, only TCL gets more stringent

E1 vs E2 vs E3 – These are all Category 6

Freq.	TCL E1	TCL E2	TCL E3
MHz	dB	dB	dB
1	40	40	40
4	40	40	40
8	40	40	40
10	38	40	40
16	35	40	40
20	34	40	40
25	32	40	40
31	31	40	40
63	25	35	40
100	20	30	40
200	14	24	34
250	12	22	32
350			

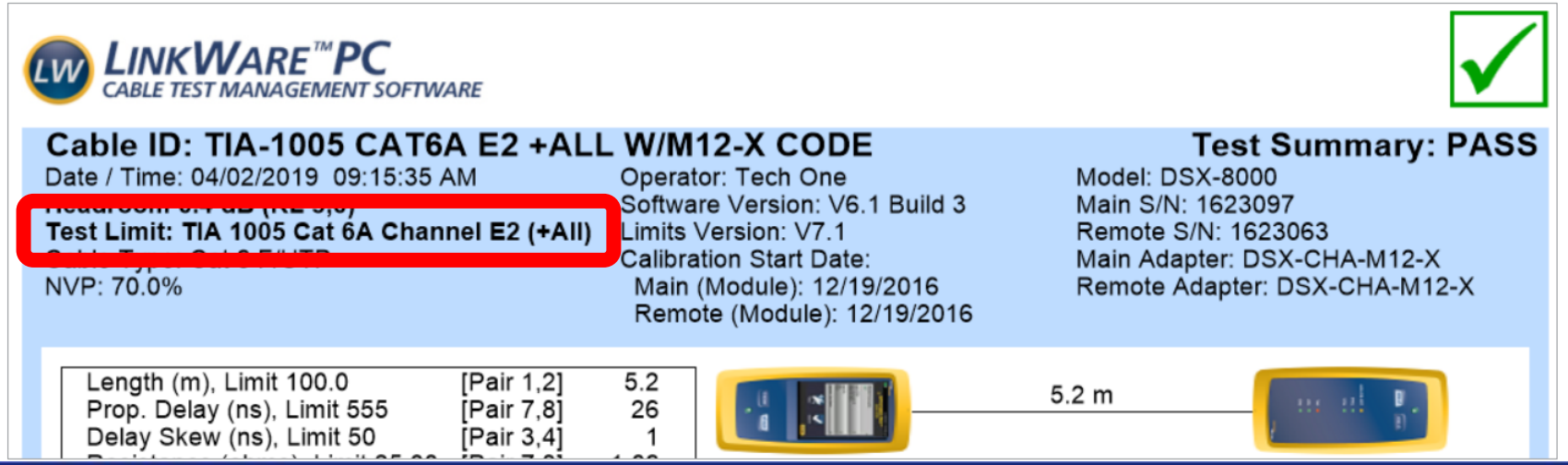


What Test Limit Should I Specify in my Bid Document / Contract?

- Ask your Consultant/Architect/Engineer
- What is the performance of the components you are using?
- What applications are you planning to support?
- What is the M,I,C,E rating of the environment?
- One Cell of an Excel file specification:
  - Links shall be tested to ANSI/TIA-568.2-D limits for Category X (5e, 6, 6A)
  - “TIA 1005 Cat 5e Channel E1 (+ALL)” is a good starting point
  - TIA-1005 is the Premise Standard for industrial environments of the TIA-568 specification

In Summary, to avoid start up delays and minimize downtime

- Certify your installed cabling to ANSI/TIA-568 limits to make sure it meets your performance requirements
- Check the limit on your test reports



Thank you
Gracias
Obrigado

Jim Davis, Fluke Networks

Jim.Davis2@flukenetworks.com

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