2022 ODVA
INDUSTRY CONFERENCE
AND 21ST ANNUAL MEETING

Commissioning cabling infrastructure for OT networks

- including Single Pair Ethernet and Ethernet-APL™

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Storyline

Outline

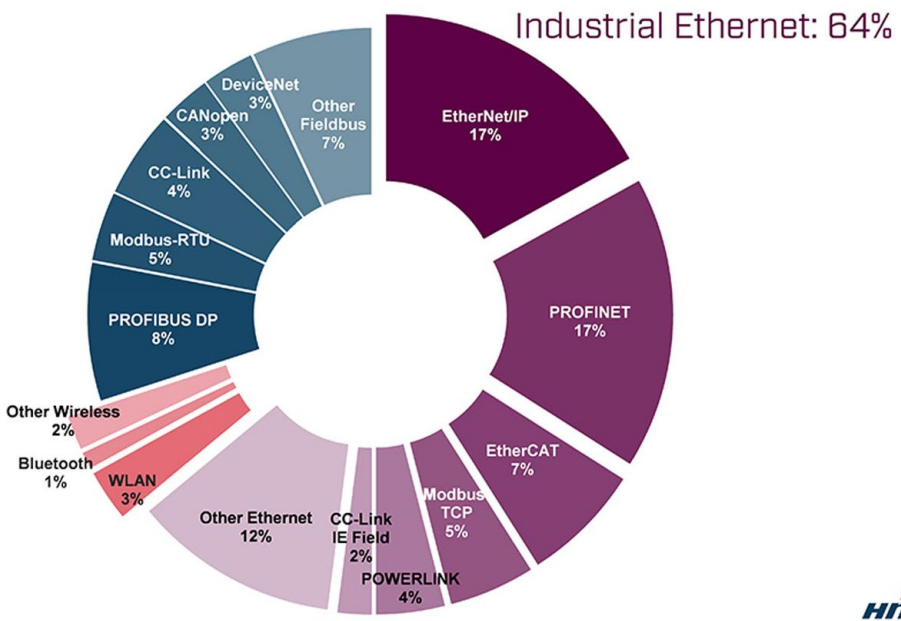
- Standards for specification of OT network wiring systems including power delivery
- Network topologies and wiring practices
- Specific commissioning tests for point-to-point links to identify non-compliant cabling and bad connections, as well as routine workmanship issues
- Measurement properties and associated industry standards for physical infrastructure
- Re-purposing legacy cabling for industrial Ethernet

Storyline

- With the widespread implementation of Ethernet, it's now possible to apply routine best-practices from IT networking to save time and add value in the industrial space.
- One such practice, cable testing, leads to more reliable operations and less trouble-shooting.

Industrial Protocol Market Shares - 2020

- Fieldbuses are in decline, wireless is stable, Industrial Ethernet share at 64%, up from 59% in the previous year
- EtherNet/IP and Profinet are the dominant Industrial Ethernet variants 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

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's *cabling* infrastructure
- 60% of plant floor nodes are on a variant of Ethernet

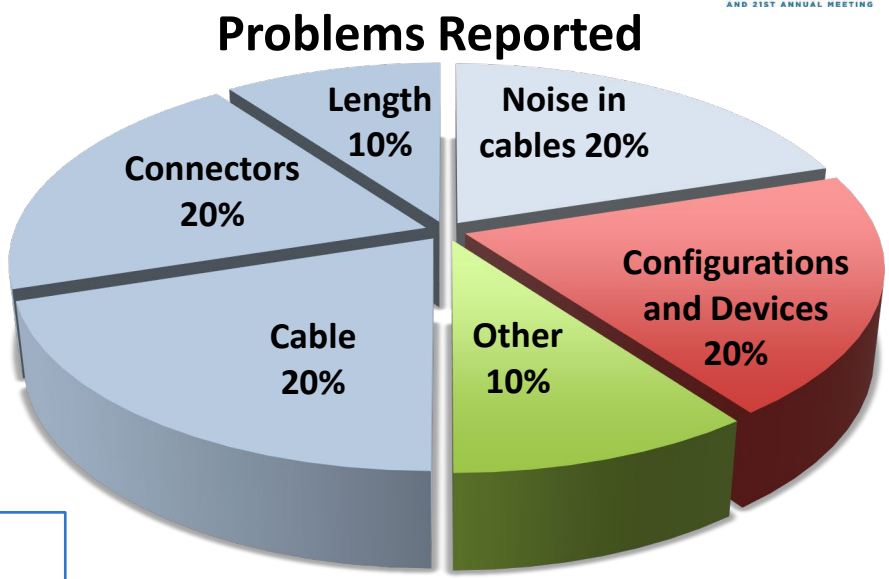
Today's topic: Effective network planning and testing for faster commissioning, increased uptime and improved OEE

*source: ISA

50% of OT Network Problems

Common defects

- Wrong cable for the application
- Re-terminated on-site (too long)
- Damaged during installation or operation
- Wired incorrectly
- Pair separation causing noise ingress
- Poorly connected shields



Environment makes matters worse

- Vibration, Flex, Moisture, Oxidation, Temperature, EMI

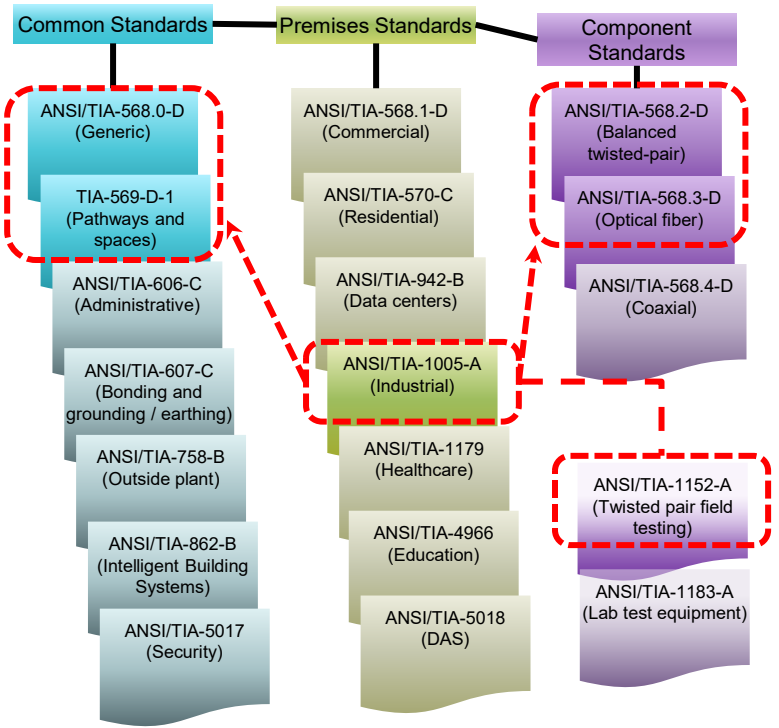
High number of intermittent problems (not repeatable)

- A few lost or damaged frames can stop a machine
- Time consuming to diagnose

Standards applied to OT networks

Applicable Standards

- Information and Communications Technology (ICT)
- TIA/EIA-568 Defines cabling types, distances, connectors, cable system architectures, cable termination, 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
- The ANSI/TIA-1005 industrial standard is explicitly supported by the 568-cabling standard series

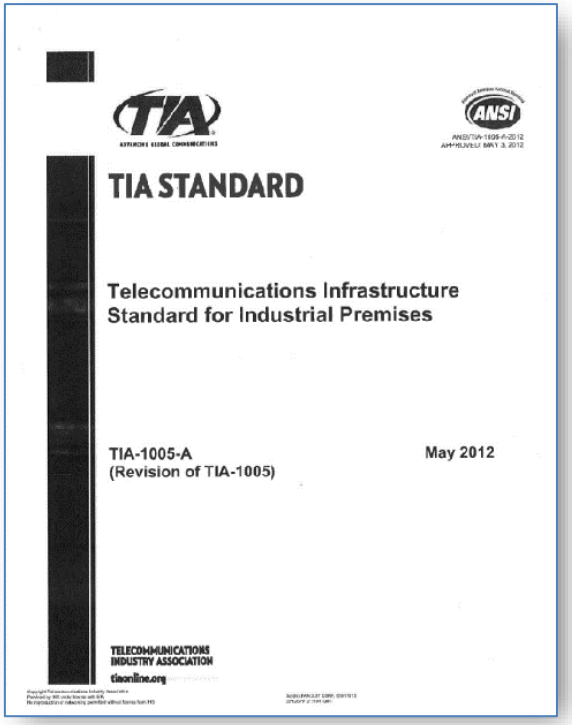


The Telecommunications Industry Association (TIA)

TIA-1005-A adds to the TIA-568 Series

- M12 D-code connector type
- 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

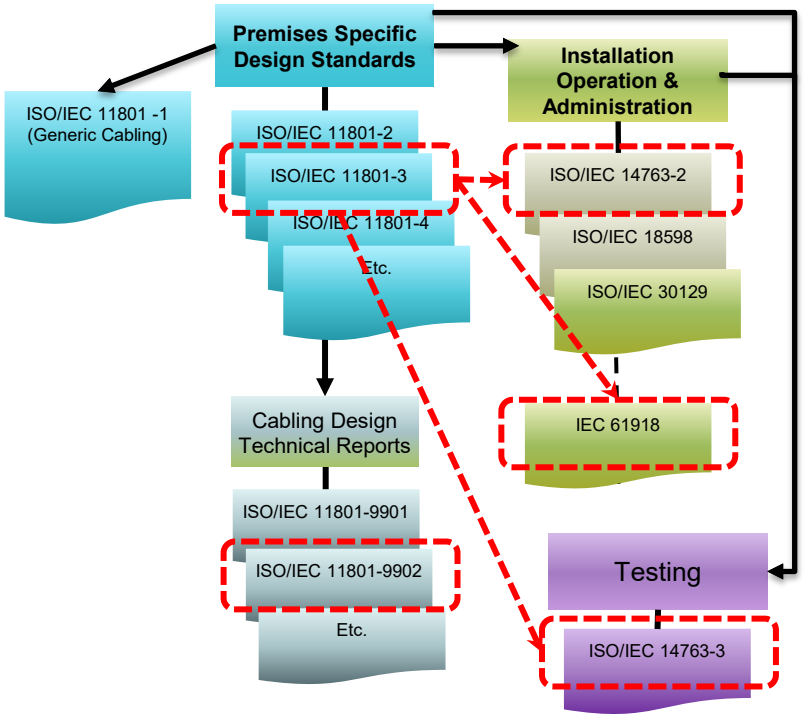


TIA Developments for SPE

- TIA-568.5 cabling and component standard
  - minimum requirements for balanced single twisted-pair cabling channels and components (cable, connectors, connecting hardware, and cords) used in commercial buildings
  - also specifies measurements for all transmission parameters.
- TIA-1005 rev.B premises standard for industrial environments
  - drafted this past year and deferred pending SPE additions
  - includes the new End-to-End link type
- TIA-568.7 new! Industrial Single-Pair Ethernet (SPE) project
  - 1st Committee Ballot circulating soon
  - Includes M.I.C.E. requirements for SPE
- TIA-5071 new! Requirements for SPE Field Test Instruments

Applicable International Standards

- Information and Communications Technology (ICT)
- ISO/IEC 11081 governs all premises types
- ISO/IEC 11081-3 covers the specifics of Industrial premises cabling
- ISO/IEC TR11801-9902 specifies End-to-End link configurations
- ISO/IEC 14763-2 defines planning, installation, and acceptance testing
- ISO/IEC 14763-3 defines Testing of optical fiber cabling
- IEC 61918 Installation of communication networks in industrial premises

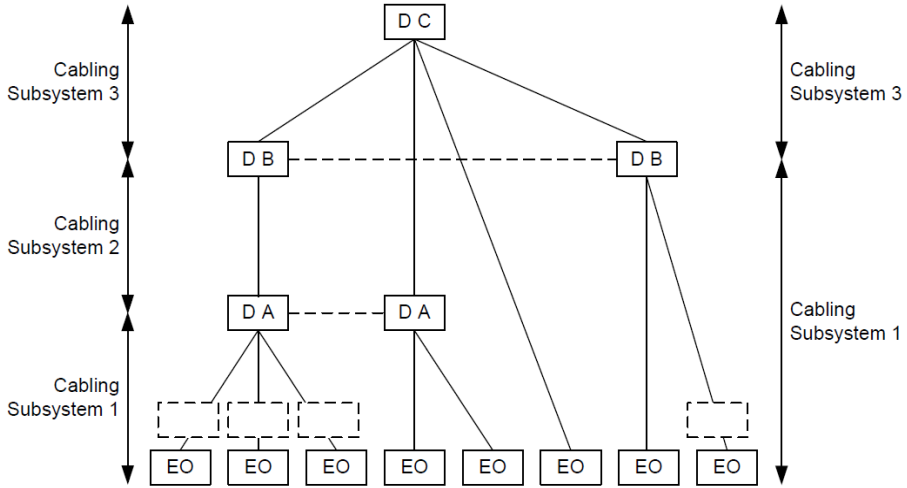


Global Developments for SPE

- ISO/IEC 11081-3 Amd1:2021 Industrial premises cabling
  - Amended to include performance of single-pair Ethernet links
- IEC 61918/AMD1 Installation of communication networks in industrial premises
  - amendment to support all current IEEE BASE-T1 (1000/100/10)
  - forecast publication next year
- IEEE P802.3de Time Synchronization for Point-to-Point Single Pair Ethernet Task Force
- Of particular interest is IEC/IEEE 60802 TSN Profiles for Industrial Automation
  - new project approved Nov-2020, targeting 2023 publication

Network Infrastructure & Topology

TIA-1005 Model



Structured cabling for industrial premise

Physical infrastructure model for cabling and connectivity design

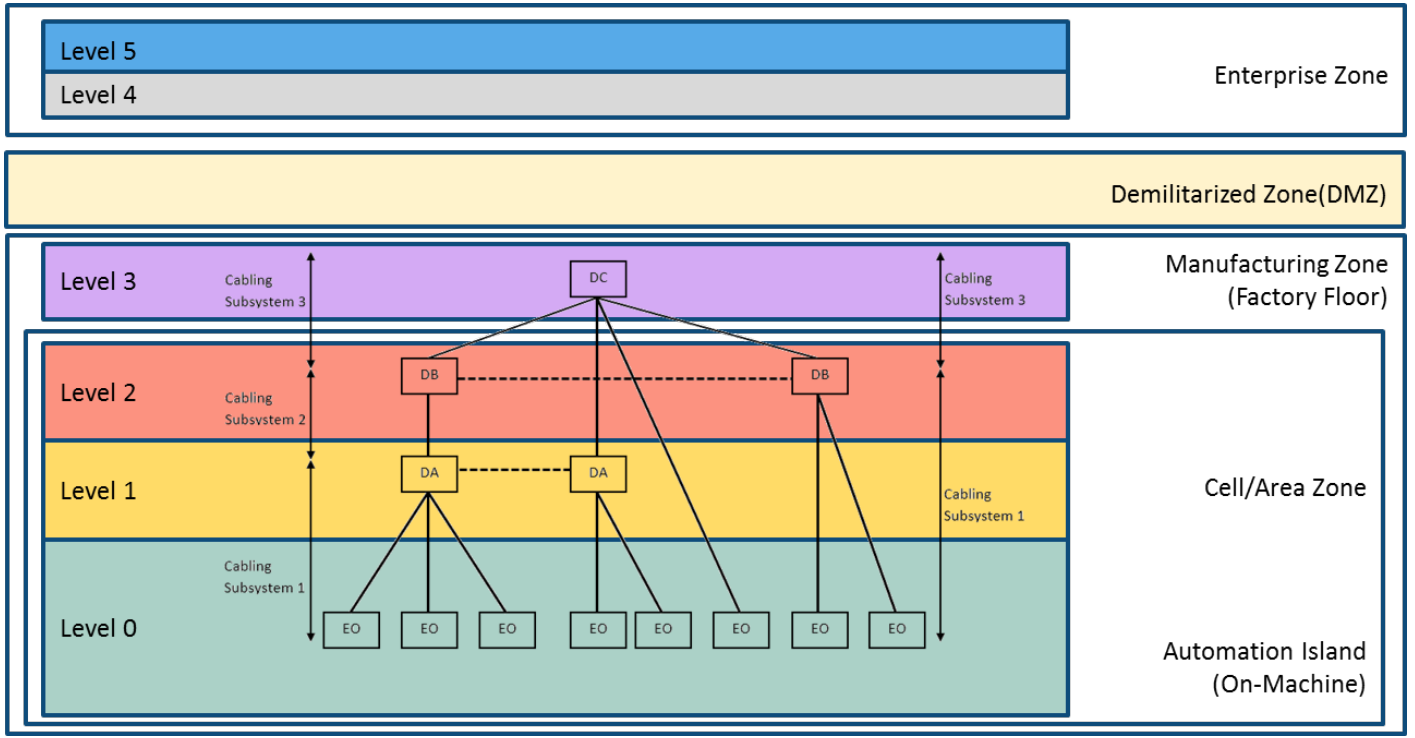
Flexible and scalable

Defines interconnects (to switch) and testable links/channels

D = Distributor (MDF, IDF, Access layer)

EO = Equipment Outlet

Industrial Networks and TIA-1005

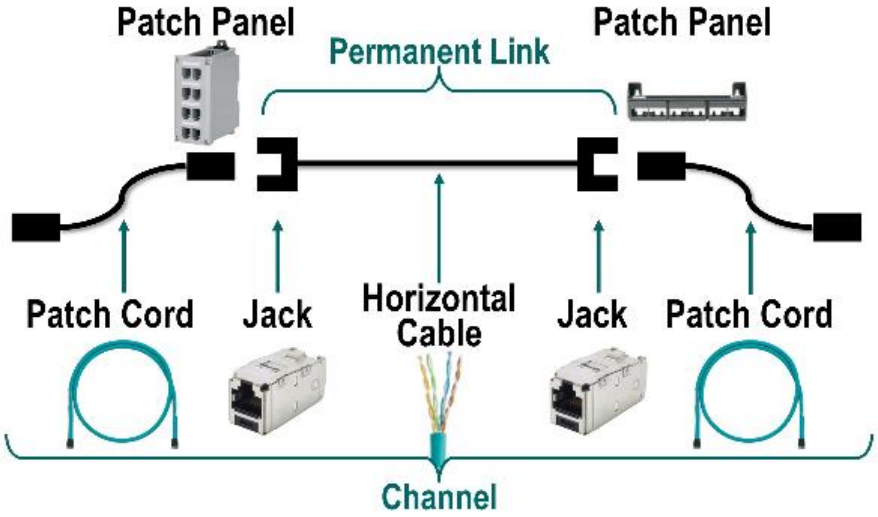


Why Structured Cabling Is a Best Practice

- 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



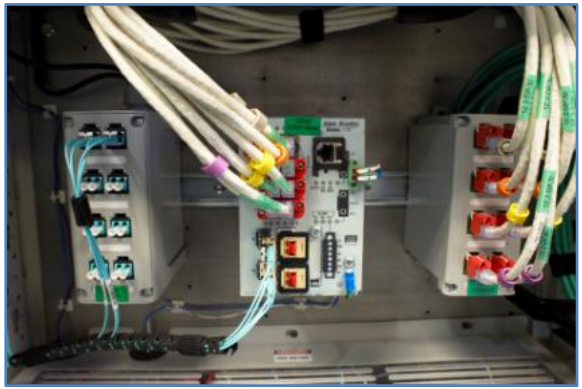
Structured and Point-to-Point Cabling

Point-to-Point Cabling

- Stranded cable field-terminated with plugs
- Infrequently tested
- No standard exists to define the measurement method
- If the lights blink, it's assumed it will work!

Structured Cabling

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



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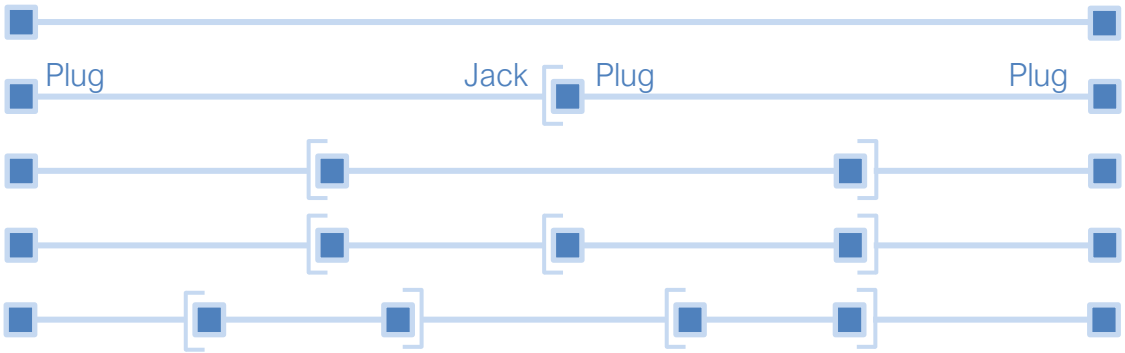
End-to-End link configurations

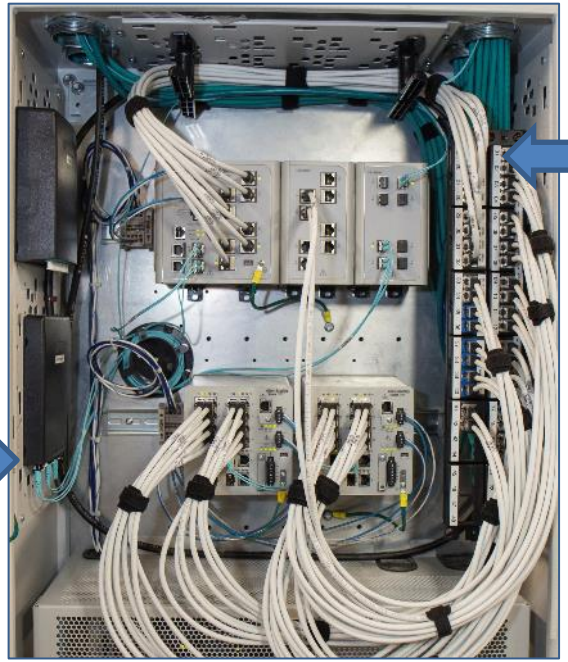
Plug terminated channels



- Specific industrial use
- 2 to 6 connections
- Total cabling channel
- Added with TIA 1005-B and ISO/IEC 11081-3 Amd1; both in 2021

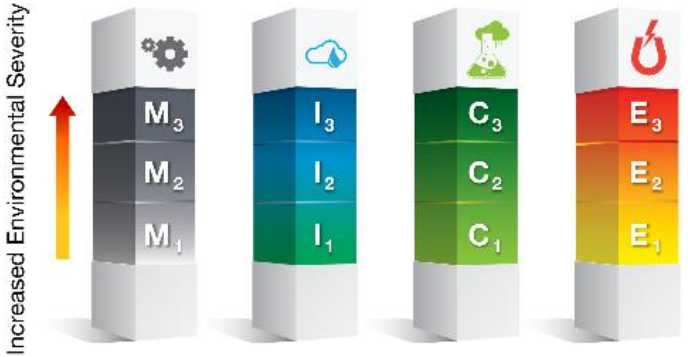
Standardized point-to-point cabling channel for use where outlet jacks are impractical

Structured Cabling within Zone Enclosures



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

- Certified to withstand the severity of the associated M.I.C.E element
- When choosing network cabling systems always consider components rated to withstand the *worst-case* environment for exposure
- Commercial grade network components ($M_1I_1C_1E_1$) can also be considered in applicable areas



TIA-1005-A

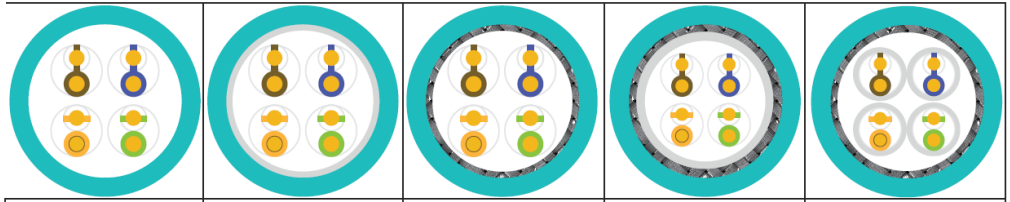
ISO/IEC 11801

IEC 60603-7

Shielded Cable for Industrial Environments

- The better the “electrical balance” of a cable the more protection from EMI
- Shielded cabling provides added layer(s) of protection
- Managing interference is strongly tied to proper design and installation (especially 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)

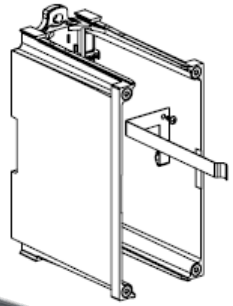
Examples of Shielding Solutions for Ethernet Cabling

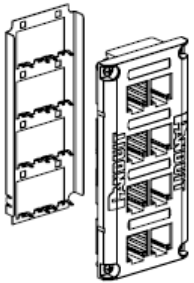
Shielded Wiring Duct

Shielded RJ-45 Jack

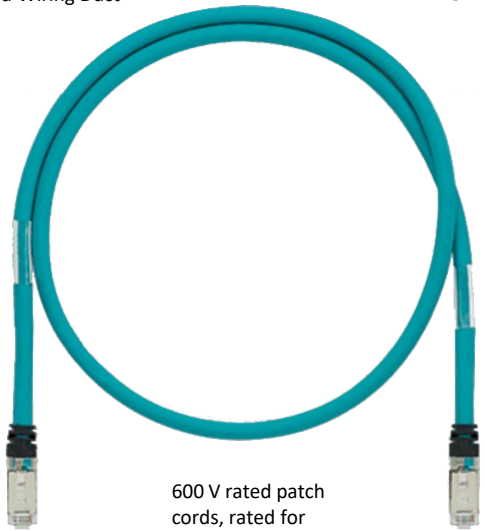
Shielded RJ-45 Field Terminable Plug

M12 X-code Field Terminable Plug

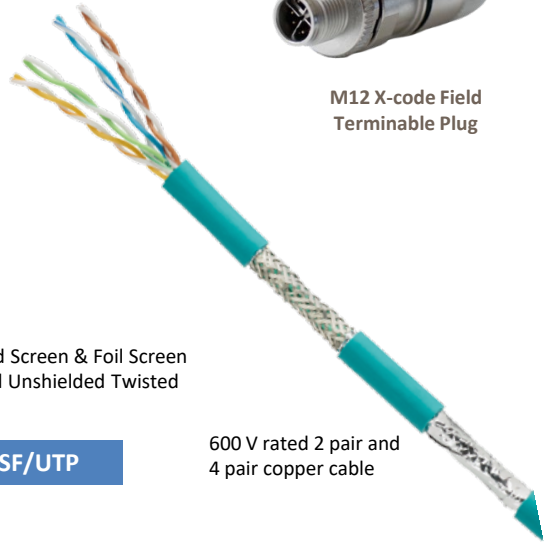




Shielded DIN Rail Copper Patching Solution



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

Section Take-Aways

- Review your internal standards for the network physical layer
  - Specify the latest norms for Industrial Ethernet
  - *Structure* for flexibility, testability and longevity
- Use the M.I.C.E. concept to improve designs and mitigate environmental factors in advance
- Learn and follow controls vendors Industrial Ethernet physical recommendations

Acceptance Tests for Cabling Infrastructure

Why test cabling as part of commissioning?

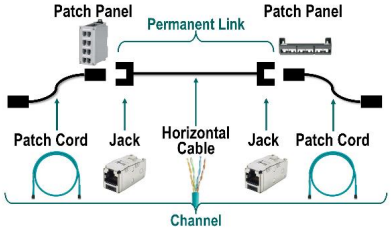
- To be sure that the installed cabling meets the performance you are paying for. An untested cable is a *source of uncertainty*.
  - Cat 6A Jack + Cat 6A Cable + Cat 6A Installer **≠ Cat 6A performance**
- To run faster now *and* support future applications. Experience has shown that tested networks:
  - Reduce CRC/FCS errors that lead to re-transmissions
  - Reduce New Machine Start-up Time
  - Reduce intermittent Production Down Time
  - Have a longer service life
- To get paid for the job (if you are the installer or machine builder)

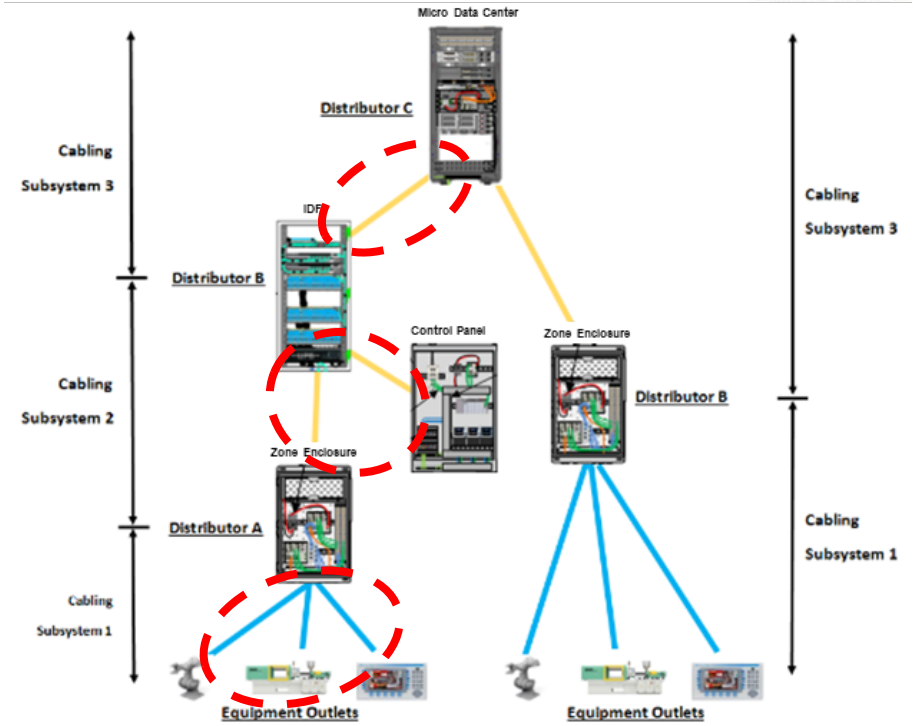
Beware of anyone offering to save $$ on installation by not testing

Commissioning & Performance Validation

Channel Testing with the TIA model

- Channel testing should be done at each cabling subsystem level
- This includes Subsystem 1, and field level 1-0 connections
- Testing is typically be done just prior to commissioning stage in a project
- ANSI/TIA/EIA 568 & 1152-A define testing & field test equipment





TIA 1005 Model shown with Industrial enclosures

Acceptance tests

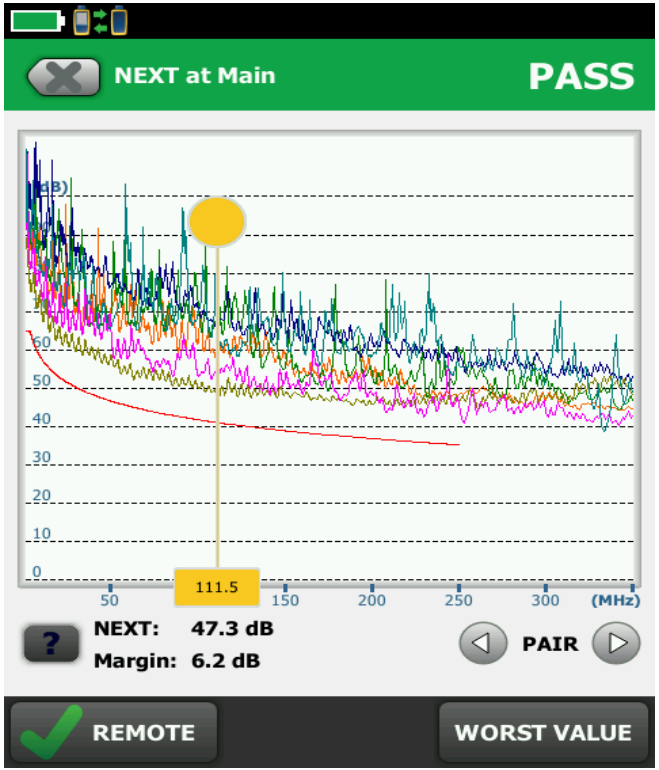
Engineering Guideline Ethernet-APL™ v1.0

- *During the acceptance test the integrity of the cabling should be measured and documented for later use and troubleshooting during the operation of the plant.*

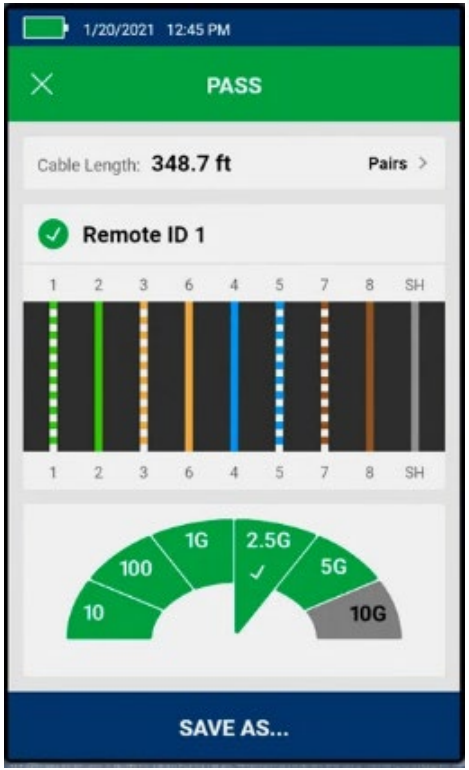
EtherNet/IP Network Infrastructure Guide – ODVA Pub 35

- Testing is easily done with commercially available hand-held network testers. Special adapters may be necessary for sealed connectors. Testing output includes conformance to all electrical requirements including, but not limited to, attenuation, impedance, return loss, cross-talk, and cable segment length measurements.
- Each cabling segment (consisting of cable and connectors) must be tested to confirm that, after installation, the segments all conform to *The EtherNet/IP™ Specification** for performance. (*The CIP Networks Library, Vol. 1 and 2)

Acceptance test results



- Simple pass/fail plus wire-map
- Or complete frequency sweep and guaranteed standards compliance
- Simple operation
- Wireless cloud storage for results and .pdf reports



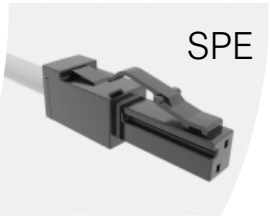
Measurement Properties

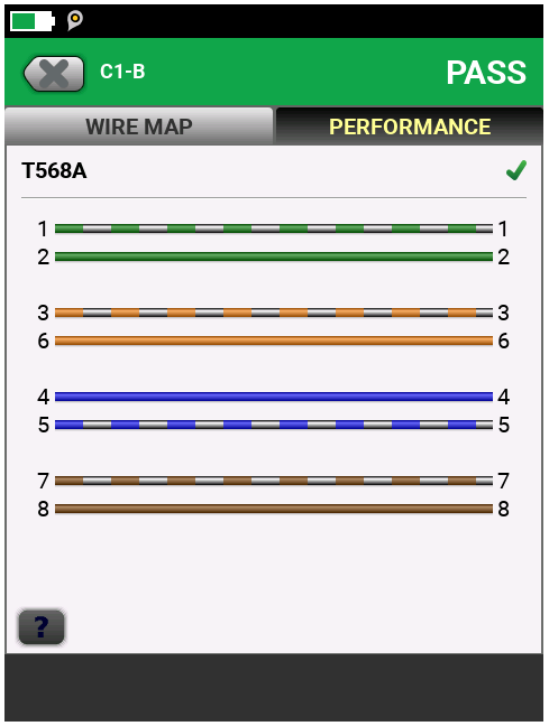
What parameters are measured?

- The capacity of a cable to support high speed data is based on measurements of signal and noise
- Continuity testing, or Wire-Map, is not sufficient assurance for even the slowest Ethernet
- Signal Strength, or loss, is measured as attenuation a.k.a. Insertion Loss
- Noise is measured with two parameters, NEXT and Return Loss
- Putting together these measurements we get a Signal to Noise Ratio
- The greater the frequency where we can maintain a positive SNR, the faster and farther we can communicate

Continuity - RJ45 or M12 D or X (or soon SPE)

RJ45



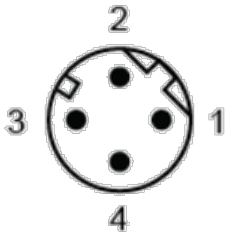


SPE

M12

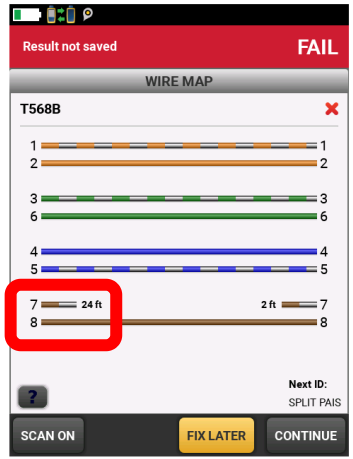
D-coding

Male

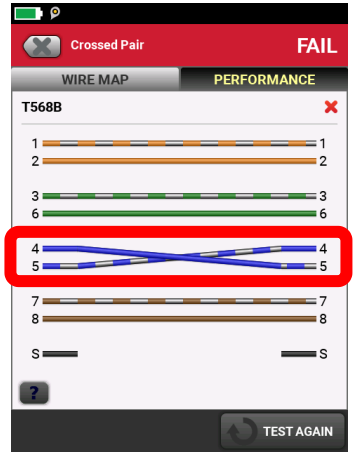


X-coding

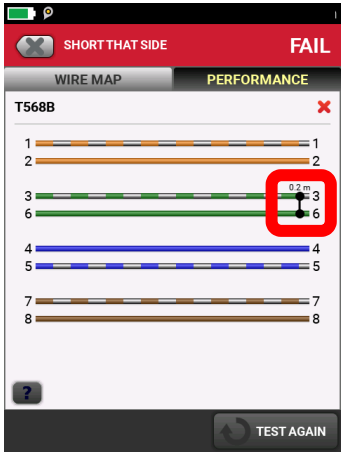
Most Common Problem: Bad Wire Map



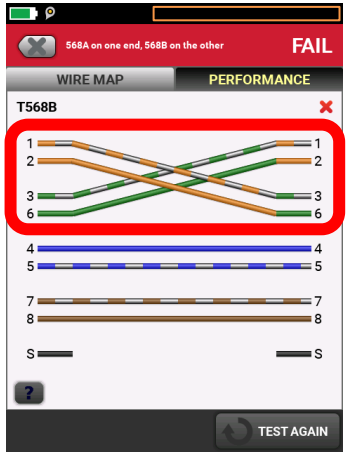
Open Pairs



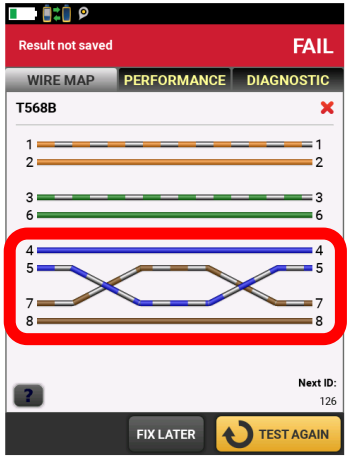
Flipped Pair



Short



Crossed Pairs



Split Pair

Signal Strength – Insertion Loss

Insertion Loss:

- In dB, the signal loss down the cable

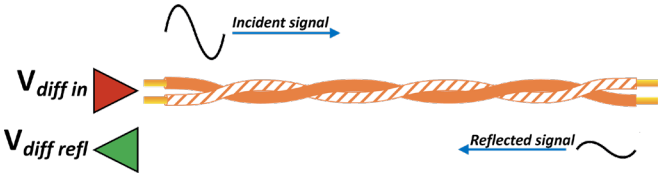
Signal Loss increased with:

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

Noise – Return Loss

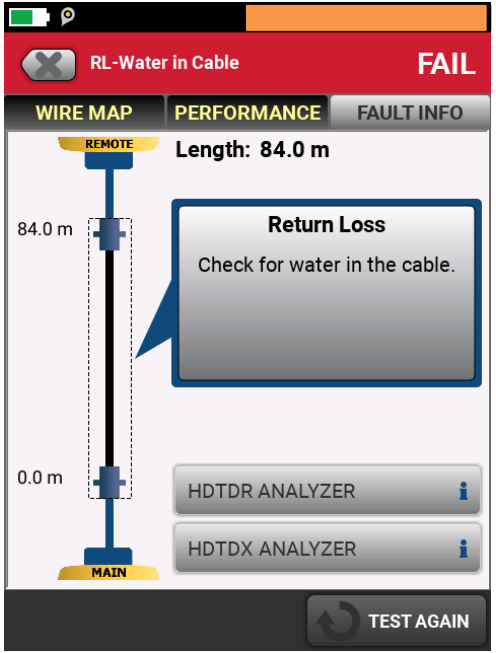
Return Loss:

- In dB, the reflected signal on the same pair



Return Loss increases with:

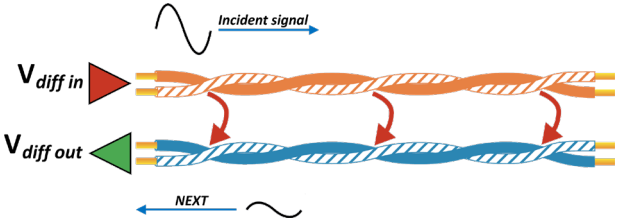
- Defective / damaged cable
- Pairs being separated
- Water in the cable
  - Sometimes the cable isn't bad, it's just the wrong cable for the application



Noise – NEXT (Near-end Crosstalk)

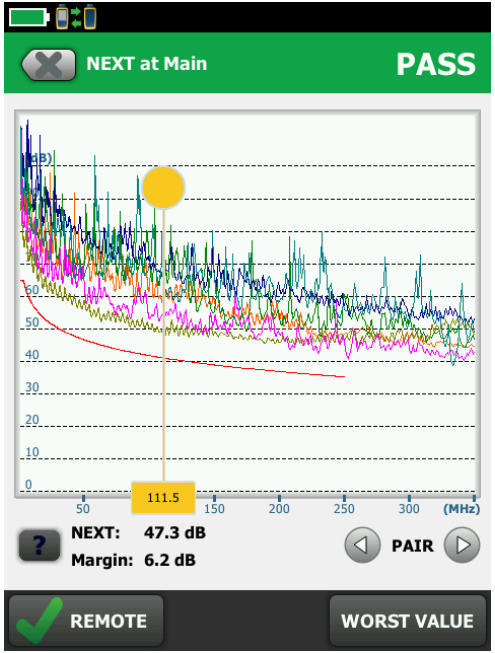
NEXT:

- In dB, the disturbed signal on an adjacent pair



NEXT is increased by:

- Connector geometries and pin configurations
- Defective / damaged cable or connectors
- Untwisting wire-pairs in the connector
- Wrong category of cable or connectors



SNR = ACR (Attenuation Crosstalk Ratio)

Combining I/L and NEXT parameters

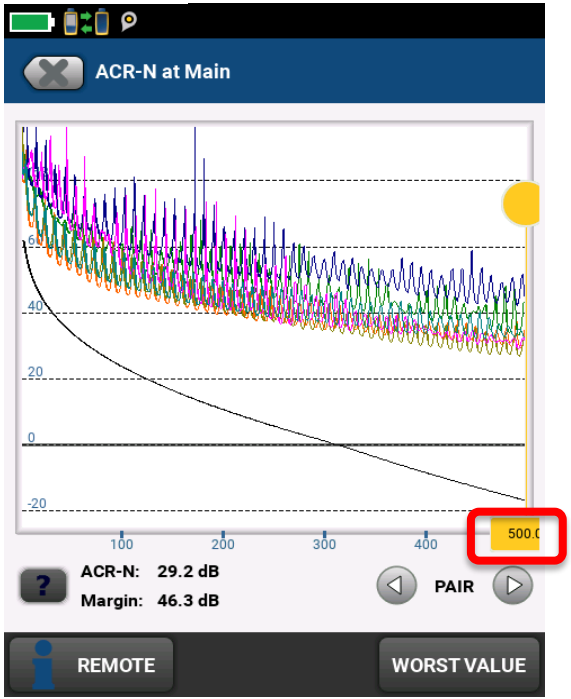
- In dB, signal to noise ratio of a given pair

ACR is a derived parameter

- NEXT minus Insertion Loss across frequency

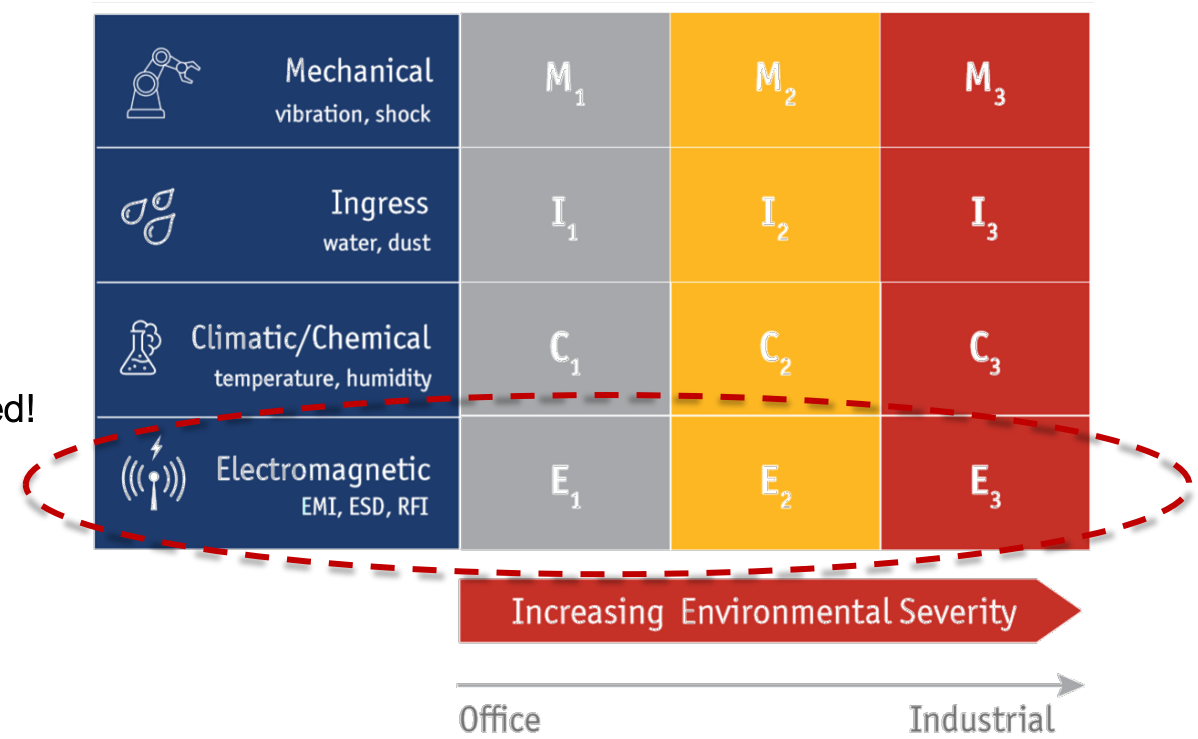
Better ACR, faster communications

- 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



Reminder: ISO & TIA M.I.C.E. Classifications

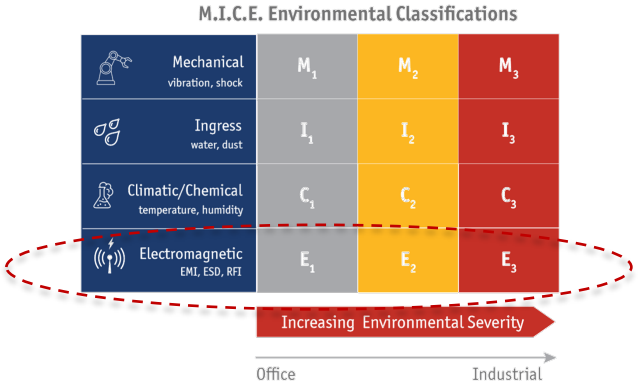
These can be tested!

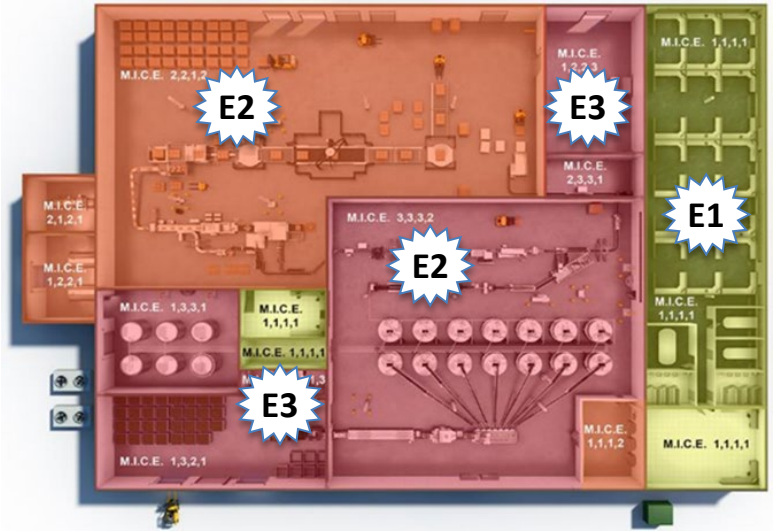


Electromagnetic interference:

Lost packets – CRC/FCS errors

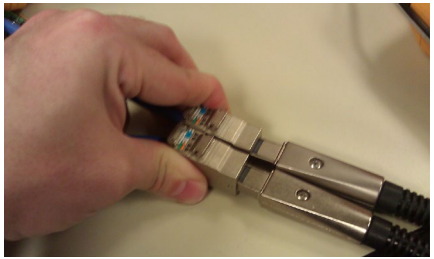
- May cause excess network latency
- May cause retry/loss of connection
- A few frame errors can cause machines to stop

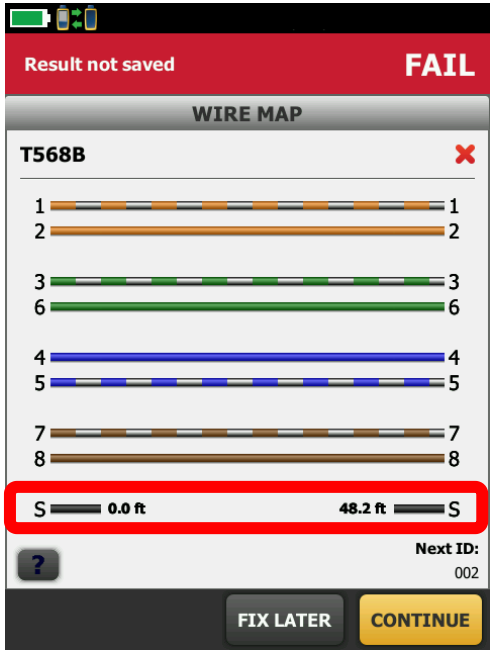




Shield Integrity –

- Modern test tools can determine if the shield continuously follows the path of the cable
- If the shield does not *follow the path of the cable* an open shield will be reported (shown on the right)
- Even when both ends are grounded (shown here)

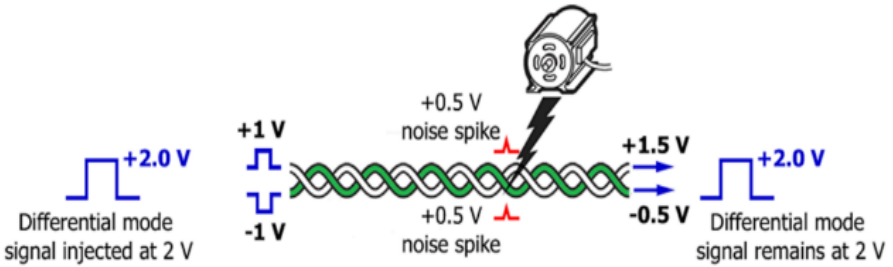




Reject EMI with Well Balanced Links

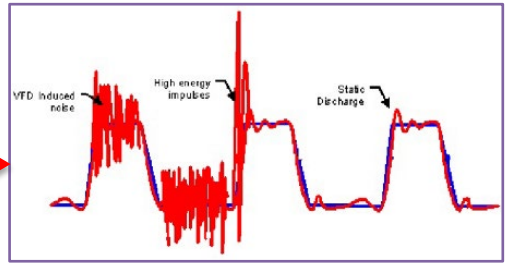
Balanced Cable

- Motor or VFD noise is equal across pairs
- Noise is rejected, devices get proper logic levels
  - Packets get through the 1st time



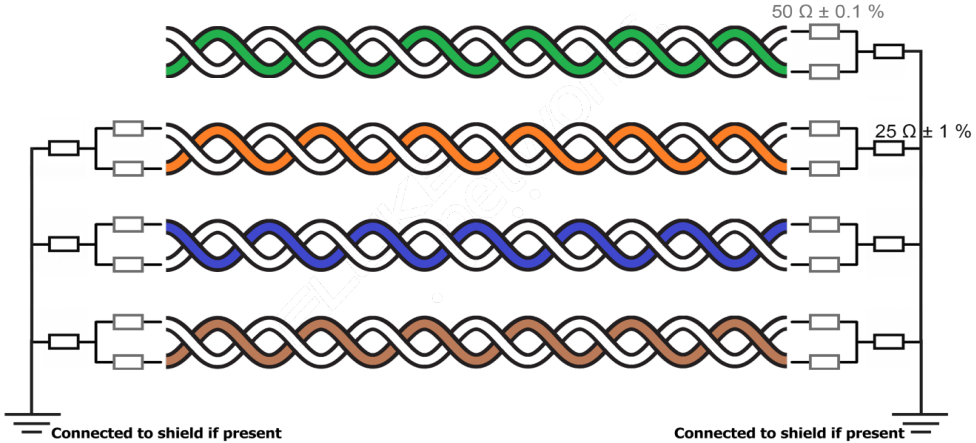
Unbalanced Cable

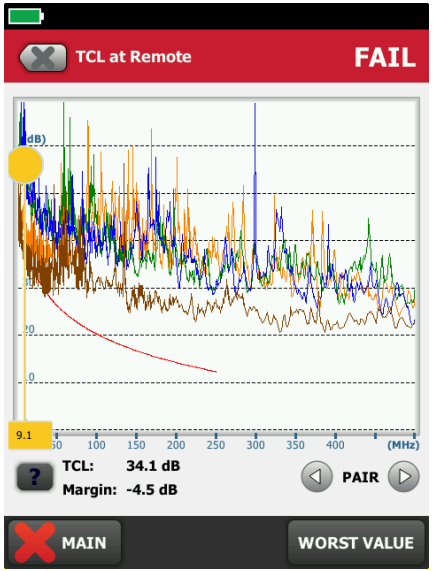
- VFD noise NOT equal across pairs
- Devices **WILL NOT** get proper logic levels
  - FCS and CRC errors. Re-tries and latency
  - Usually intermittent



TCL – Balance measurement 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.





Re-purposing legacy control cabling

- Extend the cabling assets you already have

Cable Reuse?

- Potential for high quality, recent vintage, control cabling to perform well for SPE traffic
- Quickest and most certain way to tell is to *test it*
  - Certification tests – high accuracy, total parametric coverage, highest level of assurance
  - Verification tests – less parameters, slightly reduced accuracy, *reasonable* assurance
- Doesn't mean you have to test every link
  - **Statistical sampling** is recommended for reuse of large populations

* Given the supplier and age is fairly uniform

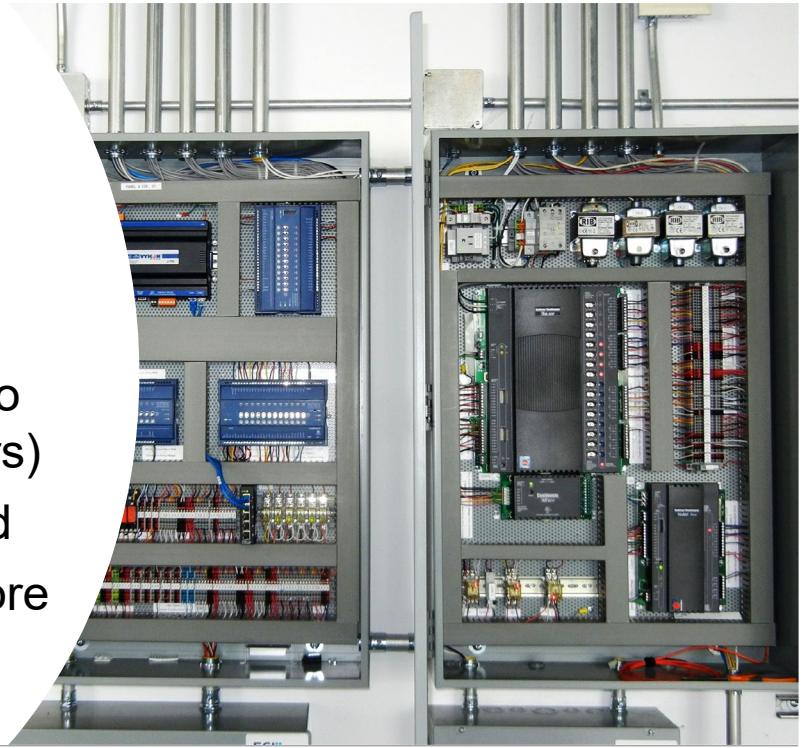
Statistical sampling methods

- ISO/IEC 14763-2 Cabling planning and installation standard
- Test to an equivalent acceptance quality level (AQL) of 0.4% as defined for link populations up to 500,000, per ISO 2859-1

Installation size (No. of total links)	Sample size (No. of links to test)
3 – 33	100%
34 – 3,200	33
3,201 – 35,000	126
35,001 – 150,000	201
150,001 – 500,000	315

Topology reuse

- SPE doesn't change the way you install
  - Homerun wiring
  - Fieldbus wiring
- SPE will improve on the fieldbus trend of replacing control boxes with switches and addressing the end-nodes (IP)
- Small field switches can connect directly to edge devices (sensors, actuators, counters)
- Design your wiring on CAD, not in the field
- Faster and easier commissioning - therefore faster project completion



Recap

- Summary of key take-aways

Quick Recap

- Fieldbuses are in decline; Industrial Ethernet is now more than 60% and SPE/APL are here to wire the remainder
- Review your internal standards for the network physical layer and specify the latest norms for Industrial Ethernet
- Use the MICE concept to improve designs and mitigate environmental factors in advance
- Greater than 50% of problems operating industrial ethernet can be traced to cabling problems
- Assessment tests are a recommended best-practice that can catch most common defects and provide the greatest assurance over the lifetime of the network

THANK YOU

It has been a great pleasure

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