Industrial Ethernet Cable for Industrial Automation Applications

At Schaedler Yesco
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Industrial Ethernet Advantages

• **Industrial Ethernet can allow for better and easier sharing of information over one network**
  – Think “Internet of Things”
  – Faster data transmission rates

• **Cables are specifically designed to function in harsh industrial settings**
  – High EMI “Noisy Environments”
  – Chemical Exposure
  – UV Exposure
  – Less risk of downtime due to cable failure

• **Cables are specifically designed to meet regulatory and performance requirements**
  – Allows for more flexible installation options

• **Ethernet is already established in the premise & commercial world**
Premise Environments and Cable
What is a Premise Environment?

- Commercial building facilities
  - Office buildings, hotels, convention centers, sports arenas, etc.
  - Office side of a manufacturing or industrial facility
  - Data Center
- Education facilities
- Healthcare facilities

Clean and benign cable friendly facilities
Premise Environments for Cable

• Cable is typically installed in concealed locations

• Cables are not exposed to hazardous conditions or foreign chemicals and contaminants

• Very little interaction with cables after installation

Static environments. Install it and forget it!
Premise Ethernet Applications

Typical Applications

• Email, Phone, VoIP, Internet Traffic, Video, PoE (for VoIP, cameras and other smaller devices), Data Centers

Generally, applications in a premise installation are NOT deterministic or “Real Time”

So what does that mean when there is an issue?
Standards for Premise Cables
(For North American Market)

**Safety Codes and Fire Ratings**
National Fire Protection Association (NFPA), the National Electric Code (NEC®), and local jurisdiction having authority (AHJ) are responsible for safety codes and ratings

- NFPA 70 (NEC) and local AHJ
- UL 444 for Communications Cables
  - NFPA 262 for CMP Rated Cable
  - UL1666 for CMR Rated Cable
  - UL1685 for CM Rated Cable
  - VW-1 for CMX Rated Cable

**Transmission Performance Standards**
Largely controlled by the Telecommunications Industry Association (TIA)

- ANSI/TIA 568-C.2
  - Defines structured cabling installation configurations and performance requirements
  - Covers all electrical performance requirements like NEXT, RL, IL, etc.
  - Covers requirements for Cat 3, Cat 5e, Cat 6 and Cat 6A

Safety ratings and transmission performance
Premise Cable Construction

- Primary design focus is fire rating (CMR, CMP, etc.) and electrical performance (Cat 5e, Cat 6, etc.)

- Almost all premise cables are 4 pair
- Majority of cables are Unshielded, UTP type cables
Data Transmission Performance and Applications

- The design of premise cables allows them to have improved data transmission performance over other types of networks.

<table>
<thead>
<tr>
<th>Cable/Property</th>
<th>Cat 3</th>
<th>Cat 5E</th>
<th>Cat 6</th>
<th>DeviceNet™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth (MHz)</td>
<td>16 MHz</td>
<td>100</td>
<td>250</td>
<td>1 MHz</td>
</tr>
<tr>
<td>Speed (MB/s)</td>
<td>10 MB/s</td>
<td>100 MB/s</td>
<td>1 GB/s</td>
<td>≤500 KB/s</td>
</tr>
</tbody>
</table>
Industrial vs. Premise Environments

Why and How Are They Different?
Environment Comparison

Premise Overview

• Typically cable-friendly benign environments with little to no EMI noise
• Less demanding applications
• Standards limited to transmission performance and safety ratings

Industrial Overview

• Harsh environments that expose cable to unfavorable climatic conditions
• Locations with many potential EMI and electrical noise sources
• Operation critical applications like motion control for automation
• Many additional application-specific standards to consider

A lot of things to consider…
Industrial Ethernet – Factory Floor Areas

Image courtesy of Panduit Corp.
Wiring Methods – Structured vs. Point to Point

Structured Cabling
- Adopted from IT in the enterprise down to the manufacturing machine or process equipment
- In use for over 25 years in manufacturing to connect proprietary control networks, and is now migrating to Ethernet connecting devices

Point to Point Cabling
- Copper or fiber cable terminated with connectors
- Connected by patch cords to active equipment
- Copper or fiber cable with field terminated connectors
- Directly connected to device or machine ports

Image courtesy of Panduit Corp.

Structured Cabling

Ring and Bus Topology

Installations- Continued

Typical Premise Wall Plate

Premise Wall Plate on Plant Floor

Lower Images courtesy of Panduit

Panduit IP67 Stainless Sealed Wall Plate and Connector

Panduit M12 D-Code Connector
Standards for Industrial Ethernet Cables
(For North American Market)

Codes and Ratings
• NFPA 70 (NEC) and local JHA
  – Still applies in some applications
  – NEC Article 725
• UL 444 for Communications Cables
  – NFPA 262 for CMP Rated Cable
  – UL1666 for CMR Rated Cable
  – UL1685 for CM Rated Cable
  – VW-1 for CMX Rated Cable
• NFPA 79 for Industrial Machinery
• UL13 for PLTC Cables
• UL508A for premanufactured enclosures

Transmission Performance Standards
Largely still controlled by the TIA as well as some other organizations
• ANSI/TIA 568-C.2
  – Still applies as the base standard
  – Other standards become more stringent than this one and add additional requirements
• ANSI/TIA 1005
• ODVA/EtherNet/IP™
• TIA TSB – 185
• ISO/IEC 24702 (International)
• And standards for several other proprietary networks and applications

More standards for additional hazards and applications
MICE Levels and TIA TSB-185

• MICE stands for *Mechanical, Ingress, Climatic and Electromagnetic* and is used to help classify and quantify the harshness of specific industrial environmental conditions immediately surrounding a cabling channel.

In 2009, TIA wrote the *Technical Service Bulletin (TSB) 185* as a tutorial to help installers and end users better understand MICE levels, how to characterize their applications, and select hardware.

*MICE levels are a helpful tool, but not a standard requirement!*
Industrial Ethernet Applications

- Process, Motion and Automation Control
  - ODVA EtherNet/IP™ and others
- Other “Real-Time” deterministic applications
- Applications in Classified Hazardous Areas
- Building Automation
- General Communications
  - Phones, PC workstations, etc.

A few things could happen…
- Machine malfunction and possible damage
- Increased scrap and material waste
- Machine and line shut down

What happens when there is a network issue and applications crash?

Wasted production time, material, and money!
Industrial Ethernet Cables

Why and how are they different?
Physical Differences in Cables

• Based on the requirements of a given installation, different ratings may be needed in addition to normal UL444 and NEC ratings
  – 600 V AWM, CMX Outdoor – CMR, PLTC, PLTC – ER

• Based on the ratings needed, different thicknesses of cable jackets may be required - abrasion, impact, crush

| UL 444 CMR Cable | 600V AWM, CMR Cable | 600V AWM, UL 13 PLTC-ER, CMR Cable | 600V AWM, UL 13 PLTC, SUN RES, OIL RES DeviceNet™ Cable |

![Cables Comparison](image-url)
Material Comparison

In additional to thicker and tougher jackets, many different materials are also used for a variety of reasons

<table>
<thead>
<tr>
<th>Material/Property</th>
<th>Premise (PVC)</th>
<th>Industrial PVC</th>
<th>FRPE/FRPO LSZH</th>
<th>FEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Tensile Strength (PSI)</td>
<td>2000 - 3100</td>
<td>2000 - 3100</td>
<td>1500 - 2500</td>
<td>3000 - 4000</td>
</tr>
<tr>
<td>Elongation</td>
<td>200 - 350</td>
<td>200 - 350</td>
<td>150 - 200</td>
<td>200 - 500</td>
</tr>
<tr>
<td>Brittle Point (°C)</td>
<td>0 to -20</td>
<td>-20 to -40</td>
<td>-20 to -60</td>
<td>-40 to -20</td>
</tr>
<tr>
<td>Oxygen Index (%)</td>
<td>30 - 50</td>
<td>40 - 50</td>
<td>25 - 45</td>
<td>90+</td>
</tr>
<tr>
<td>Oil Resistance</td>
<td>N/A</td>
<td>OIL RES</td>
<td>OIL RES</td>
<td>Varied</td>
</tr>
<tr>
<td>UV Resistance</td>
<td>N/A</td>
<td>SUN RES</td>
<td>SUN RES</td>
<td>Varied</td>
</tr>
<tr>
<td>Max Temp Rating (°C)</td>
<td>75</td>
<td>105</td>
<td>105</td>
<td>200</td>
</tr>
</tbody>
</table>
Oil Exposure Comparison

Oil and dirt built-up on sensor cables

Close up of cable meeting UL OIL RES I

Close up of cable with poor oil resistance

Cables jackets were aged in oil for 4 days at 100°C
UV Exposure Example

- Many Industrial Ethernet cables are designed to meet UL444 CMX Outdoor and SUN RES requirements
  - This provides the flexibility to install cable outdoors and in UV light

Premise jackets are not intended for UV exposure…
• Standards like ANSI/TIA 1005 and ODVA EtherNet/IP™ have special requirements in addition to ANSI/TIA 568-C.2 built on the “E” portion of the MICE table

  – Performance parameters like Return Loss, Balance and Shielding requirements are enhanced
Industrial Ethernet – Factory Sources of Noise Levels

Identifying Noise Sources helps determine the selection of cables

<table>
<thead>
<tr>
<th>Devices, Noise Source</th>
<th>“E” Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Motors</td>
<td>E₂ - E₃</td>
</tr>
<tr>
<td>Drives/VFDs</td>
<td>E₃</td>
</tr>
<tr>
<td>Welders</td>
<td>E₃</td>
</tr>
<tr>
<td>Heating</td>
<td>E₂ - E₃</td>
</tr>
<tr>
<td>Radio Communications</td>
<td>E₂ - E₃</td>
</tr>
</tbody>
</table>


ANSI/TIA 1005 and ODVA EtherNet/IP™ allow shielded and unshielded cables
Electrical Performance – Unshielded Cables

• Balance
  – Balanced pairs were initially created to help reduce noise coupling to pairs and reduce interference
  – Cables with better balanced pairs are able to have improved noise immunity from external and internal noise sources
  – All Ethernet cables are designed using Balanced Twisted Pairs making Ethernet inherently capable of noise rejection

• ANSI/TIA 1005 and EtherNet/IP™ both have enhanced balance requirements in the form of TCL and ELTCTL for Cat 5e and up

Industrial Ethernet – Factory Transverse Conversion Loss

The Factory Transverse Conversion Loss, or **TCL**, requirements of UTP channels depend on the electromagnetic noise environment. *(Reference MICE/ANSI/TIA-568C.0)*

### TCL Limits for UTP Cables

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency (MHz)</th>
<th>E₁</th>
<th>E₂</th>
<th>E₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>5e</td>
<td>1 ≤ f ≤ 30</td>
<td>53-15log(f)</td>
<td>63-15log(f)</td>
<td>73-15log(f)</td>
</tr>
<tr>
<td></td>
<td>30 &lt; f ≤ 100</td>
<td>60.4 -20log(f)</td>
<td>70.4 -20log(f)</td>
<td>80.4 -20log(f)</td>
</tr>
<tr>
<td>6</td>
<td>1 ≤ f ≤ 30</td>
<td>53-15log(f)</td>
<td>63-15log(f)</td>
<td>73-15log(f)</td>
</tr>
<tr>
<td></td>
<td>30 &lt; f ≤ 250</td>
<td>60.4 -20log(f)</td>
<td>70.4 -20log(f)</td>
<td>80.4 -20log(f)</td>
</tr>
</tbody>
</table>

TCL values greater than 40dB shall revert to the minimum requirement of 40dB.

Premise only has TCL requirements for Cat 6 and no E₂ or E₃ requirements.

Electrical Performance – Shielded Cables

• Coupling Attenuation
  – Used to quantify shielding performance
  – ANSI/TIA1005 and ODVA EtherNet/IP™ have enhanced requirements for $E_2$ and $E_3$ EMI environments

DeviceNet™ Thin Cable

78 Ohm Twinax Data Highway Plus Cable

Cat 5e SF/UTP Cable
Industrial Ethernet – Factory Coupling Attenuation

The Coupling Attenuation requirements of screened twisted-pair cabling channels depend on the electromagnetic noise environment. The local environments are described by MICE classifications, $E_1$, $E_2$ or $E_3$.

### Coupling Attenuation Limits for ScTP (F/UTP) Cables

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency (MHz)</th>
<th>Minimum (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$E_1$</td>
</tr>
<tr>
<td>5e</td>
<td>$30 \leq f \leq 100$</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>$30 \leq f \leq 250$</td>
<td>$80 - 20 \log(f)$ (Max 40 dB)</td>
</tr>
</tbody>
</table>

**NOTE:** For EMC purposes, coupling attenuation is normally measured up to 1 GHz.
Electrical Performance – Return Loss

- Return loss and impedance variations can cause BER and signal loss

- ODVA EtherNet/IP™ has enhanced return loss specs compared to standard Cat 5e and Cat 6 cables

- Industrial Ethernet cables are specifically designed and manufactured to have improved RL performance

So What Cable is Needed?
Industrial Ethernet Advantages

• Cables are specifically designed to meet different codes, regulatory and performance requirements
  – NEC, UL444, TIA 1005, TIA 568 – C.2, NFPA 79, UL508A, UL 13, ODVA EtherNet/IP™, UL 600 V AWM and more
  – Allows for more installation options

• Cables are specifically designed and enhanced to function in harsh environments
  – EMI “Noisy Environments”
  – Chemical Exposure
  – Temperature
  – UV Exposure
  – Less risk of downtime due to cable failure

• Many different cable options are available to provide the best solution for a specific environment without being cost prohibitive

<table>
<thead>
<tr>
<th>Category/Options</th>
<th>UTP</th>
<th>Shielded</th>
<th>Armored</th>
<th>Hi-Temp</th>
<th>CCW Armor</th>
<th>Hi – Flex</th>
<th>Jacket Options</th>
</tr>
</thead>
</table>
Industrial Ethernet Examples

- **Enhanced Category 5e Electrical Performance**
  - Better RL and Balance for TIA 1005, Ethernet/IP™, and other demanding applications
- **CMX Outdoor and CMR Rated**
- **Thick Oil and UV/Sun-Resistant PVC Jacket**
  - Also allows for 600 V AWM rating

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**Cat 5e SF/UTP Cable**

**Cat 5e 2 Pair F/UTP Cable**
## Industrial Ethernet – GCC Cables

<table>
<thead>
<tr>
<th>General Cable Part</th>
<th>Category</th>
<th>Shielded</th>
<th>Conductor Type</th>
<th>Jacket Grade</th>
<th>Oil and UV Sunlight Resistant</th>
<th>600V CMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCR1402</td>
<td>5e- UTP, 2 pr.</td>
<td></td>
<td>Solid</td>
<td>Industrial PVC</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GCR1403</td>
<td>5e- F/UTP, 2 pr.</td>
<td>✓</td>
<td>Solid</td>
<td>Industrial PVC</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GCR1404</td>
<td>5e- UTP</td>
<td></td>
<td>Solid</td>
<td>Industrial PVC</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GCR1408</td>
<td>5e- 22 AWG PLTC</td>
<td></td>
<td>Solid</td>
<td>Industrial PVC</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GCR1410</td>
<td>5e- UTP</td>
<td></td>
<td>Solid</td>
<td>Industrial- Interlocking Armored</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GCR1419</td>
<td>5e- F/UTP</td>
<td>✓</td>
<td>Solid</td>
<td>Industrial PVC</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GCR1405</td>
<td>5e- F/UTP, Enhanced</td>
<td>✓</td>
<td>Solid</td>
<td>Industrial PVC</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GCR1407</td>
<td>5e- SF/UTP</td>
<td>✓</td>
<td>Solid</td>
<td>Industrial PVC</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>5136100</td>
<td>5e- OSP, Gel-Filled</td>
<td></td>
<td>Solid</td>
<td>OSP- Halogen Free</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>GCR1440</td>
<td>6- UTP</td>
<td></td>
<td>Solid</td>
<td>Industrial PVC</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GCR1450</td>
<td>6- UTP, Enhanced</td>
<td></td>
<td>Solid</td>
<td>Industrial PVC</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GCR1452</td>
<td>6- F/UTP</td>
<td>✓</td>
<td>Solid</td>
<td>Industrial PVC</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>7136100</td>
<td>6- OSP, Gel-Filled</td>
<td></td>
<td>Solid</td>
<td>OSP- Halogen Free</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
Thank You for Your Time!

Questions?