Meeting demands of High-Speed and High-Bandwidth Interconnection: PCIe® and Ethernet Standards

3M™ Electrical Materials Solutions Division

2023
Agenda

- Bandwidth Market Trends
- PCIe
- Twin Axial Cable Assemblies
- Ethernet
- Direct Attach Copper Assemblies
Market Trends
Digital Infrastructure

Interconnecting the digital core
Cloud adjacent is the new on-prem

Integrating digital ecosystems
Level the playing field with XaaS and industry ecosystems

Interacting at the digital edge
Bridge the physical and virtual

Technology Trends

<table>
<thead>
<tr>
<th>2000’s</th>
<th>2010’s</th>
<th>2020’s</th>
<th>Evolving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackberry</td>
<td>iPhone</td>
<td>Smartphones universal interface</td>
<td>Quantum computing</td>
</tr>
<tr>
<td>3G Cellular</td>
<td>4G cellular</td>
<td>5G cellular</td>
<td>Virtual collaboration</td>
</tr>
<tr>
<td>Rise of data centres</td>
<td>Cloud computing</td>
<td>Edge/Fog computing</td>
<td>IoT devices</td>
</tr>
<tr>
<td>Many proprietary connectors</td>
<td>Licensed second-sourced</td>
<td>Open components/system</td>
<td>Security</td>
</tr>
<tr>
<td>10GbE</td>
<td>connectors</td>
<td>standard</td>
<td>6G cellular</td>
</tr>
<tr>
<td>Chip feature size 90mm</td>
<td>40/100GbE</td>
<td>200/400GbE</td>
<td>800GbE</td>
</tr>
<tr>
<td></td>
<td>Chip feature size 32mm</td>
<td>Chip feature size 5-10mm</td>
<td>Artificial Intelligence/Machine Learning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Streaming TV</td>
<td>Chip sub 5mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Online gaming</td>
<td>Autonomous vehicles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Social media (Tik Tok – Video)</td>
<td>Factory Automation</td>
</tr>
</tbody>
</table>

Cloud Migration

Types of Cloud Computing:
- Public
- Private
- Hybrid

Causes of accelerated migration:
- COVID-19
- Automation
- Need for agility

Benefits:
- Security
- Cost Savings
- Flexibility and Scalability
- Disaster Recovery
- Sustainability

FedEx to close data centers, retire all mainframes by 2024, saving $400m

Company looking to go all-in on cloud

July 01, 2022  By: Dan Swinhoe  Comment

Artificial Intelligence and Machine Learning

Why AI/ML:
• Pandemic-triggered accelerated digitization
• AI helps achieve sustainability goals
• Business automation

AI Statistics:
• 51% of enterprises have plans to implement AI
• 25% of companies have implemented AI

AI Trends:
• Augmented Business Process and Systems
• Responsible AI (Ethical decisions)
• AI in Cyber security
• Environmental Threats (deep learning)
• Hyper Automation in Healthcare

Global Forecast: Industry

PCIe Standard

Peripheral Component Interconnect Special Interest Group (PCI-SIG): Founded in 1992

Who: Association of 800+ industry companies

Goal: Advancing non-proprietary peripheral component interconnect technology by:
• Defining PCI specification to deliver I/O functionality
• Adapting PCI technology to future applications
• Maintaining backward compatibility with previous specification
• Supporting industry-wide development

Membership: [www.pcisig.com/membership/become-member](http://www.pcisig.com/membership/become-member)

Source: https://pcisig.com/membership
PCI-SIG: organization that defines PCI Express (PCIe) I/O bus specifications and related form factors.


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# PCIe Generations

<table>
<thead>
<tr>
<th>Particulars/Metrics</th>
<th>Gen 1</th>
<th>Gen 2</th>
<th>Gen 3</th>
<th>Gen 4</th>
<th>Gen 5</th>
<th>Gen 6</th>
<th>Gen 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth/lane direction</td>
<td>2.5 GT/s</td>
<td>5 GT/s</td>
<td>8 GT/s</td>
<td>16 GT/s</td>
<td>32 GT/s</td>
<td>64 GT/s</td>
<td>128 GT/s</td>
</tr>
<tr>
<td>Bandwidth Duplex</td>
<td>8 GB/s</td>
<td>16 BG/s</td>
<td>32 GB/s</td>
<td>64 GB/s</td>
<td>128 GB/s</td>
<td>256 GB/s</td>
<td>512 GB/s</td>
</tr>
<tr>
<td>Backward Compatibility</td>
<td>YES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modulation</td>
<td>NRZ (Non-Return to Zero)</td>
<td></td>
<td></td>
<td>PAM4 (Pulse Amplitude Modulation) with FEC (Forward Error Correction)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encoding Type</td>
<td>8b/10b</td>
<td>128b/130b</td>
<td></td>
<td>1b/1b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bits/cycle</td>
<td>1 bit per clock cycle and two amplitude level (0 and 1)</td>
<td></td>
<td></td>
<td>2 bits are transferred per clock cycle and amplitude levels (00, 01, 10, 11)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PCI Express – Initial Target Applications

**PCIe 4.0/5.0**
- Servers
- Workstation/PC/Tablets
- High performance computing (HPC)
- Artificial Intelligence/Machine Learning (AI/ML)
- Gaming
- Storage
- Visual Computing
- Networking

**PCIe 6.0**
- Servers
- AI/ML
- Networking and Storage in Data Intensive Markets
- HPC
- Industrial
- Automotive
- Military/Aerospace

**PCIe 7.0**
- Data Intensive Applications and Markets
- 800 GbE
- AI/ML
- HPC
- Quantum Computing
- Hyperscale Data Centers
- Cloud

Source: [https://pcisig.com/faq](https://pcisig.com/faq)
Choose your Bandwidth

- Five standard PCIe slots and cards: x1, x2, x4, x8 and x16
- Higher generation are backwards compatible (Return bottlenecked to lower version)
- Flexible to meet needs from handheld/client to server/HPC
- 35 Permutations yielding 11 unique bandwidth profiles

<table>
<thead>
<tr>
<th>Specification</th>
<th>x1</th>
<th>x2</th>
<th>x4</th>
<th>x8</th>
<th>X16</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 GT/s (PCIE 1.x +)</td>
<td>500 MB/s</td>
<td>1 GB/s</td>
<td>2 GB/s</td>
<td>4 GB/s</td>
<td>8 GB/s</td>
</tr>
<tr>
<td>5 GT/s (PCle 2.x +)</td>
<td>1 GB/s</td>
<td>2 GB/s</td>
<td>4 GB/s</td>
<td>8 GB/s</td>
<td>16 GB/s</td>
</tr>
<tr>
<td>8.0 GT/s (PCle 3.x +)</td>
<td>2 GB/s</td>
<td>4 GB/s</td>
<td>8 GB/s</td>
<td>16 GB/s</td>
<td>32 GB/s</td>
</tr>
<tr>
<td>16.0 GT/s (PCle 4.x +)</td>
<td>4 GB/s</td>
<td>8 GB/s</td>
<td>16 GB/s</td>
<td>32 GB/s</td>
<td>64 GB/s</td>
</tr>
<tr>
<td>32.0 GT/s (PCle 5.x +)</td>
<td>8 GB/s</td>
<td>16 GB/s</td>
<td>32 GB/s</td>
<td>64 GB/s</td>
<td>128 GB/s</td>
</tr>
<tr>
<td>64.0 GT/s (PCle 6.x +)</td>
<td>16 GB/s</td>
<td>32 GB/s</td>
<td>64 GB/s</td>
<td>128 GB/s</td>
<td>256 GB/s</td>
</tr>
<tr>
<td>128.0 GT/s (PCle 7.x +)</td>
<td>32 GB/s</td>
<td>64 GB/s</td>
<td>128 GB/s</td>
<td>256 GB/s</td>
<td>512 GB/s</td>
</tr>
</tbody>
</table>

“+” = Data rate supported by this and subsequent spec versions

3M™ Twin Axial Cable solutions
3M™ Twin Axial Cable solutions

In general, cables replace PCB traces to help reduce loss and cost

3M™ Twin Axial cables in particular offer:

- Routability enabled by:
  - High cable foldability
  - Low-profile (thin)
- Maintains Signal Integrity performance when folded
- Helps improved cable management
- Helps improved thermal management
  (better airflow in the system)
3M employs a unique precision-formed continuously laminated shield over entire cable, to deliver:

- Precision and control
- Thinness & flexibility
- Tight folding/creasing without loss of performance

Competition uses spiral/longitudinal wrapped shield around individual pairs, optionally further laminated together:

- Thicker, less flexible
- Performance degrades in tight bends
# 3M™ Internal Twin Axial Cable Assembly Portfolio

<table>
<thead>
<tr>
<th></th>
<th>3M SlimLine assembly</th>
<th>3M Mini-SlimLine assembly</th>
<th>3M Compact-SlimLine assembly</th>
<th>3M Low Profile I/O assembly</th>
<th>3M Multi-Channel I/O assembly</th>
<th>3M Scalable High-Speed assembly</th>
<th>3M PCIe Extender assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong># of Lanes</strong></td>
<td>4, 6, 8 or 12</td>
<td>8, 12</td>
<td>8, 12</td>
<td>8, 12</td>
<td>8, 12</td>
<td>4, 8 or 16 (1C, 2C, or 4C)</td>
<td>8, 16</td>
</tr>
<tr>
<td><strong>Protocol</strong></td>
<td>SATA, SAS, PCIe®</td>
<td>SATA, SAS, PCIe®</td>
<td>SATA, SAS, PCIe®</td>
<td>SAS, PCIe®</td>
<td>SAS, PCIe®</td>
<td>SAS, PCIe®</td>
<td>PCIe®</td>
</tr>
<tr>
<td><strong>Speeds</strong></td>
<td>SAS 3.0: 12 Gbps</td>
<td>PCIe® 3.0: 8 Gbps</td>
<td>PCIe® 3.0: 8 Gbps</td>
<td>PCIe® 3.0: 8 Gbps</td>
<td>PCIe® 4.0: 16 Gbps</td>
<td>PCIe® 4.0: 16 Gbps</td>
<td>PCIe® 3.0: 8 Gbps</td>
</tr>
<tr>
<td></td>
<td>SAS 4.0: 24 Gbps</td>
<td>PCIe® 4.0: 16 Gbps</td>
<td>PCIe® 4.0: 16 Gbps</td>
<td>PCIe® 4.0: 16 Gbps</td>
<td>PCIe® 5.0: 32 Gbps</td>
<td>PCIe® 5.0: 32 Gbps</td>
<td>PCIe® 4.0: 16 Gbps</td>
</tr>
<tr>
<td><strong>Types of Application</strong></td>
<td>Motherboard or controller to drive backplane</td>
<td>Motherboard or controller to drive backplane</td>
<td>Motherboard or controller to drive backplane</td>
<td>Motherboard or controller to drive backplane</td>
<td>Motherboard or controller to drive backplane, midboard</td>
<td>Motherboard or controller to drive backplane, midboard</td>
<td>Ext: Flexible “riser” Jmp: Motherboard to motherboard</td>
</tr>
<tr>
<td><strong>Specification</strong></td>
<td>SFF-8654</td>
<td>SFF-8654</td>
<td>SFF-8654</td>
<td>Industry compatible</td>
<td>SFF-TA-1016</td>
<td>SFF-TA-1020</td>
<td>PCIe® -CEM</td>
</tr>
</tbody>
</table>
Ethernet
Ethernet Standard

The Institute for Electrical and Electronics Engineers (IEEE): Founded in 1963

Who: Association of 409,000 members in 160 countries

Goal: Foster Technological innovation and excellence for benefit of humanity
• Enhance public understanding of engineering and technology and pursue standards for their practical application

Ethernet Std: IEEE 802.3-2023

Membership: https://standards.ieee.org/about/membership/
Ethernet – Market forecast by Speed

3M™ Twin Axial External Cable Assembly
3M™ Twin Axial External Cable Assembly

Tight bends at the connector allowing for efficient routing in space constrained applications

3M™ Twin Axial External cables offer:

• Efficient routing of cables
  • No min bend radius
• Maintains Signal Integrity performance when folded
• Helps improved thermal management
  (better airflow in the system)
• Requires less space in front of port
• Improved serviceability
• Space saving
# 3M™ Twin Axial External Cable Assembly Portfolio

<table>
<thead>
<tr>
<th>Status</th>
<th>Form Factor</th>
<th>Aggregate Data Rate</th>
<th>Channel Data Rate</th>
<th>Product Series</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Released</td>
<td>Released</td>
<td>Released</td>
<td>Released</td>
<td>3M™ 400G QSFP-DD DAC Cable Assemblies</td>
<td>OSFP MSA IEEE 802.3ck</td>
</tr>
<tr>
<td>QSFP-DD</td>
<td>QSFP28</td>
<td>QSFP28</td>
<td>25G/channel (4x25)</td>
<td>9V</td>
<td>SFF-8436, 8661, 8665, 8661, 8662 IEEE 802.3bj</td>
</tr>
<tr>
<td>Released</td>
<td>Released</td>
<td>Released</td>
<td>25G/channel (4x25)</td>
<td>9QJ0, 9QH6, 9QN0, 9QM6</td>
<td>IEEE 802.3 cd</td>
</tr>
<tr>
<td>100G</td>
<td>100G</td>
<td>25G/channel (4x25)</td>
<td>25G/channel (4x25)</td>
<td>9SR-Bxx</td>
<td>SFF-8661, 8662, 8665</td>
</tr>
<tr>
<td>100G</td>
<td>100G</td>
<td>25G/channel (4x25)</td>
<td>25G/channel (4x25)</td>
<td>9SR-Axx</td>
<td>SFF-8661-8662, 8665,8431 IEEE 802.3bj</td>
</tr>
<tr>
<td>30 AWG: 0.5 - 2.0m</td>
<td>30 AWG: 0.5 - 2.0m</td>
<td>30 AWG: 0.5 - 2.0m</td>
<td>30 AWG: 0.5 - 2.0m</td>
<td>30 AWG: 0.5 - 2.0m</td>
<td></td>
</tr>
<tr>
<td>26 AWG: 2.25 - 3.25m</td>
<td>26 AWG: 2.0 - 4.0m</td>
<td>26 AWG: 2.0 - 4.0m</td>
<td>26 AWG: 2.0 - 4.0m</td>
<td>26 AWG: 3.0 - 4.0m</td>
<td></td>
</tr>
</tbody>
</table>

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