Rising Demand for High-Speed and High Bandwidth Interconnection

3M™ Electronics Materials Solutions Division

2022

Agenda

- Market trends
- Twin Axial Internal Cable Assemblies
- Twin Axial External Direct Attach Copper (DAC) Assemblies
- Q & A

Market Trends

Technology trends

PCIe 1.0 @ 2.5GT/s

PCIe 3.0 @ 8GT/s

PCIe 5.0 @ 32GT/s

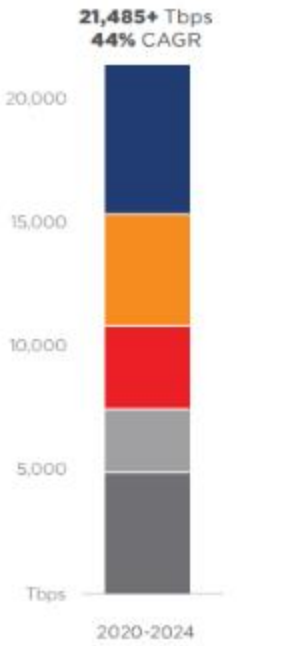
PCIe 6.0 @ 64GT/s

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

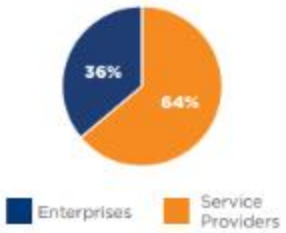
Source: Hult, R. (2021). Top 12 Technology Trends: PCIe Specification Roadmap Evolves in Tandem with Increasing Bandwidths. Connector Supplier™.. https://connectorsupplier.com/pcie-specification-roadmap-evolves-in-tandem-with-increasing-bandwidths/.

Global forecast: industry

Global Growth



Global Mix

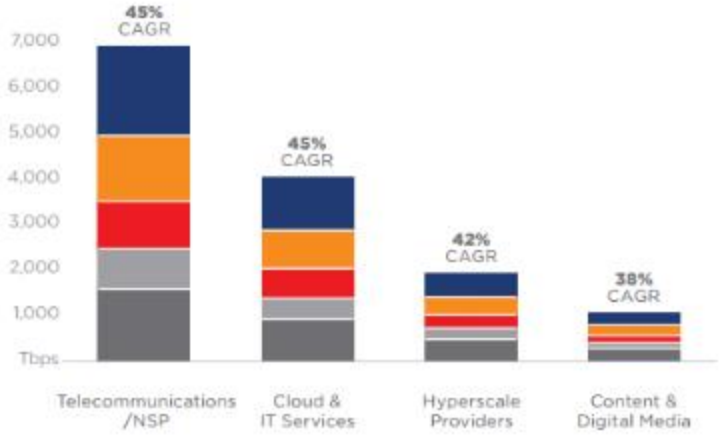


Service Providers

Regional mix
Overall, Service Providers consume 64% of global interconnection bandwidth (13,794 Tbps), with Network Service Providers alone making up 32% of the global mix.

Deployment
Being digitally mature, they deploy on average 16 locations: eight core aggregation points and eight metro edge locations to extend reach.[1]

Growth areas
Providers are also expanding to the edge, with edge infrastructure growth almost double the growth of the core.



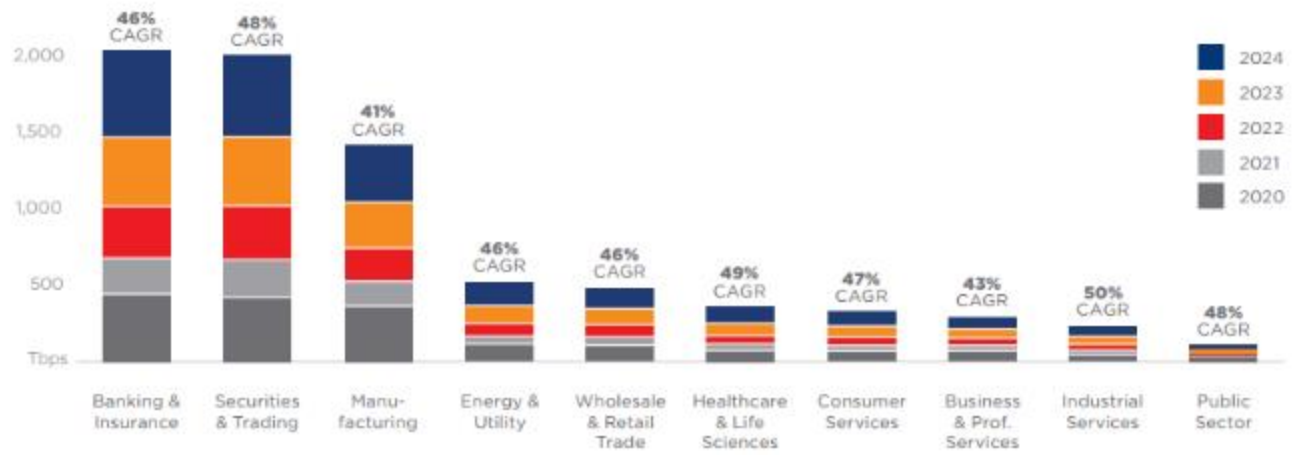
	Core	Edge	Total
Average # of Metros	8	8	16
Average # of DI[2] Cabinets	380	190	570
DI Growth Rate (CAGR)	24%	41%	28%

Enterprises

Regional mix
Enterprises have slightly faster overall growth, with Financial Services making up 50%+ of Enterprise bandwidth or 18% of the global mix. Manufacturing has become the largest non-financial services leader.

Deployment
Enterprise digital leaders deploy in 10 locations: six core locations for a global service fabric that extends into four edge locations.[1] Over time, as preference shifts to aaS models for digital infrastructure, Enterprise growth will likewise be reflected more in Service Provider infrastructure growth.

Growth areas
Close to 30% of Enterprise digital infrastructure is also in edge locations, yet Enterprise edge has a staggering 57% CAGR as it catches up to the "new normal" and re-thinks business operations at the edge.



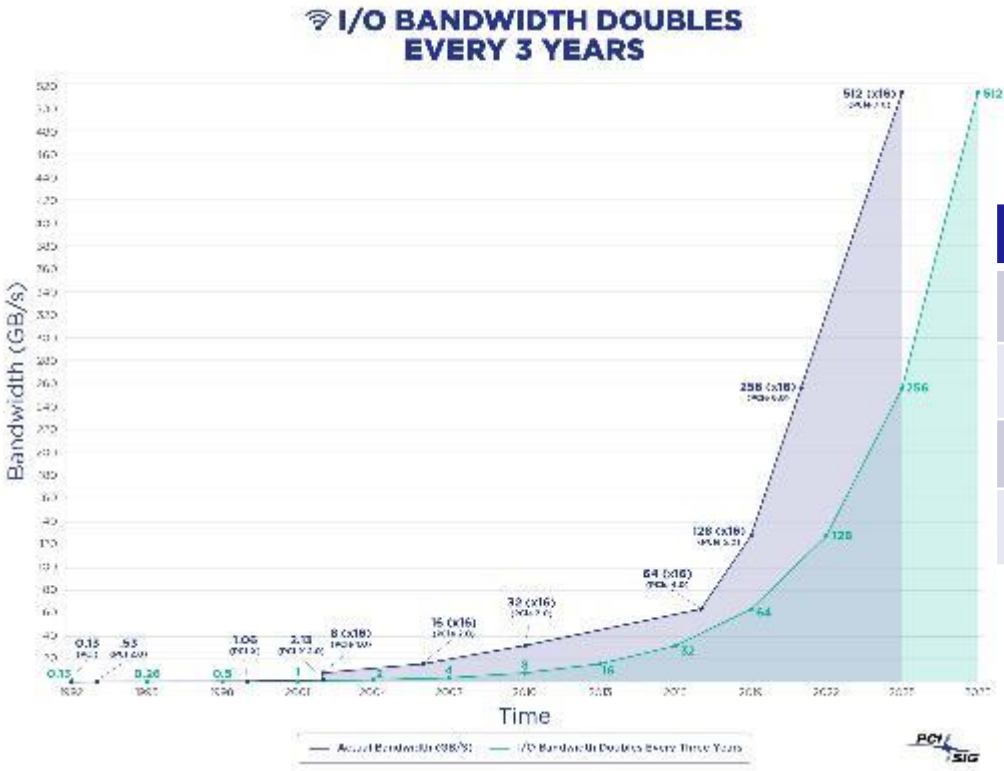
	Core	Edge	Total
Average # of Metros	6	4	10
Average # of DI Cabinets	130	50	180
DI Growth Rate (CAGR)	29%	57%	33%

Source: EQUINIX INC. (2021). Global Interconnection Index: Measuring the Growth of the Global Digital Economy (Vol. 5). EQUINIX Inc.

3M™ Twin Axial Cable solutions (Internal)

PCIe standard

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



Particulars/Metrics	Gen 3	Gen 4	Gen 5	Gen 6	Gen 7
Year of Release	2010	2017	2019	2022	Est. 2025
Bandwidth/lane direction	8 GT/s	16 GT/s	32 GT/s	64 GT/s	128 GT/s
Bandwidth Duplex	32 GB/s	64 GB/s	128 GB/s	256 GB/s	512 GB/s
Backward Compatibility					

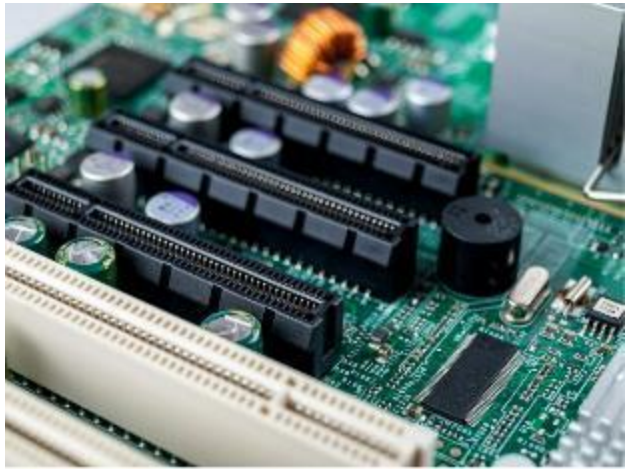
Source: PCI-SIG® DevCon 2022 Update by Al Yanes

PCIe - standard

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

Specification	x1	x2	x4	x8	X16
2.5 GT/s (PCIE 1.x +)	500 MB/s	1GB/s	2GB/s	4 GB/s	8 GB/s
5 GT/s (PCIe 2.x +)	1 GB/s	2 GB/s	4 GB/s	8 GB/s	16 GB/s
8.0 GT/s (PCIe 3.x +)	2 GB/s	4 GB/s	8 GB/s	16 GB/s	32 GB/s
16.0 GT/s (PCIe 4.x +)	4 GB/s	8 GB/s	16 GB/s	32 GB/s	64 GB/s
32.0 GT/s (PCIe 5.x +)	8 GB/s	16 GB/s	32 GB/s	64 GB/s	128 GB/s
64.0 GT/s (PCIe 6.x +)	16 GB/s	32 GB/s	64 GB/s	128 GB/s	256 GB/s
128.0 GT/s (PCIe 7.x +)	32 GB/s	64 GB.s	128 GB/s	256 GB/s	512 GB/s



"+" = Data rate supported by this and subsequent spec versions

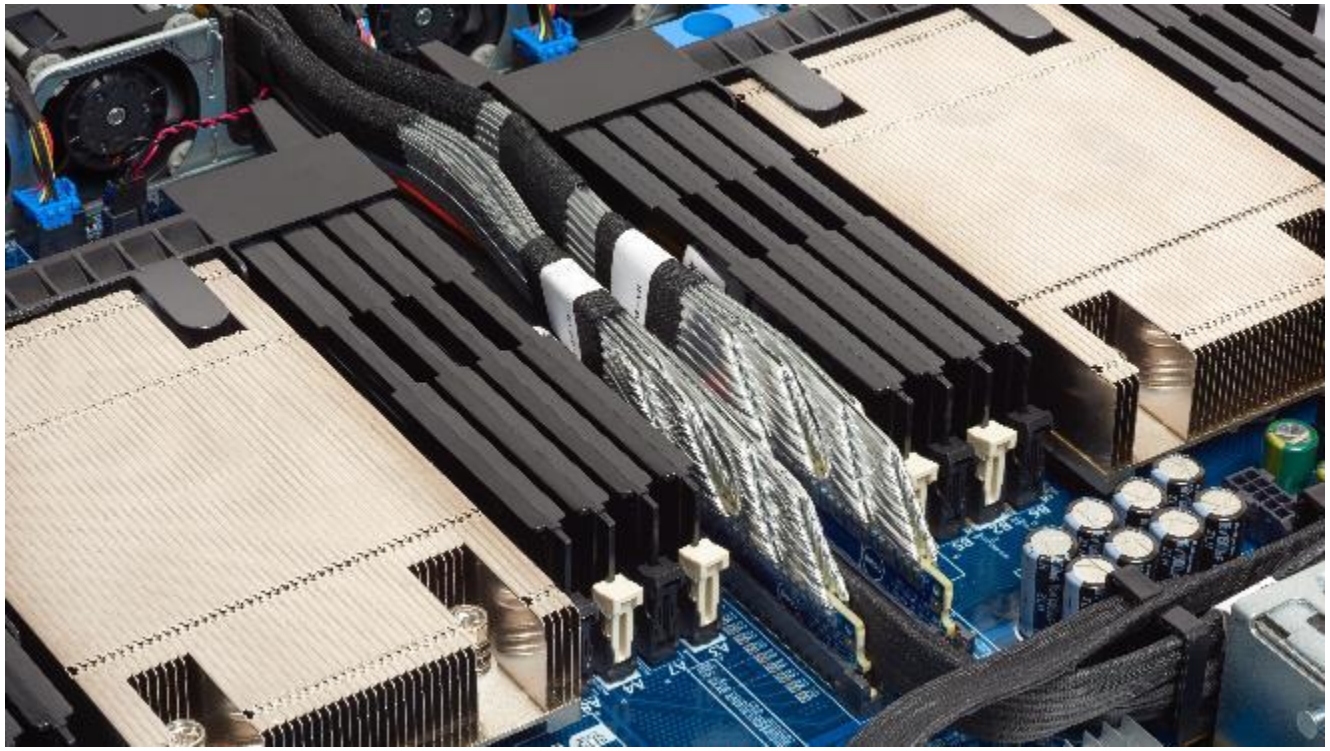
Source: Zea, Meghan. (2022). PCI-SIG® Announces PCI Express® 7.0 Specification to Reach 128 GT/s. Businesswire. https://www.businesswire.com/news/home/20220621005137/en/PCI-SIG%C2%AE-Announces-PCI-Express%C2%AE-7.0-Specification-to-Reach-128-GTs

3M™ Twin Axial Cable solutions

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

3M™ Twin Axial cables in particular offer:

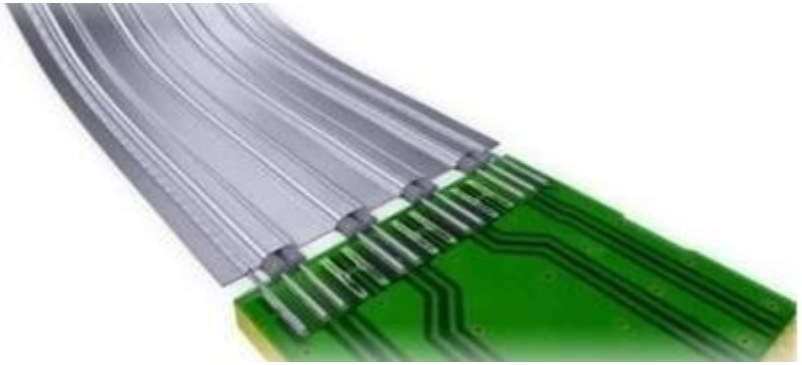
- Routability enabled by:
  - High cable foldability
  - Low-profile (thin)
- Maintains Signal Integrity performance when folded
- Helps improve cable management
- Helps improve thermal management (better airflow in the system)



3M™ Twin Axial Cable overview

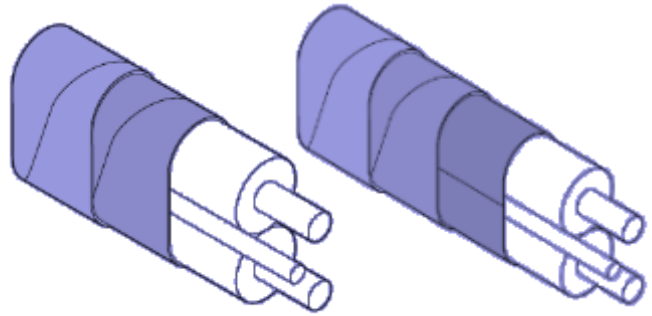
3M employs a unique precision-formed continuously laminated shield over entire cable, to deliver:

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

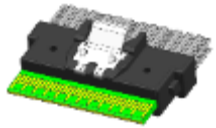
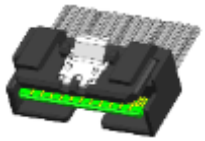
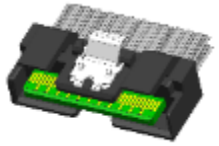


Competition uses spiral/longitudinal wrapped shield around individual pairs, optionally further laminated together:

- Thicker, less flexible
- Performance degrades in tight bends



3M™ Internal Twin Axial Cable Assembly Portfolio offering

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

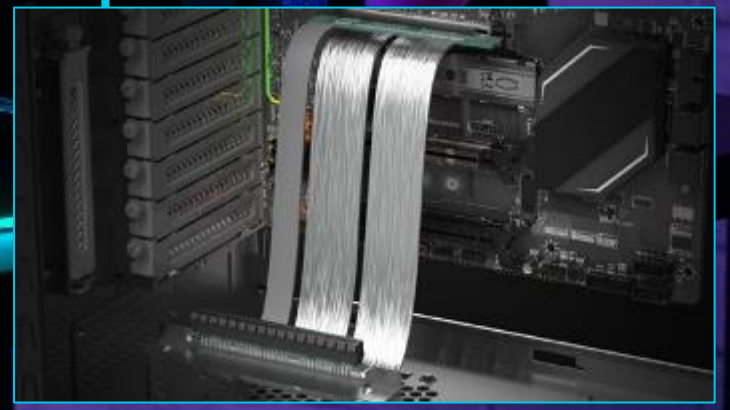
High cable foldability

High speed

PC Gaming

Flexibility and speed.

The demand for bandwidth and speed in today's growing PC gaming market is addressed with **3M™ Twin Axial PCIe x16 Extender Assemblies.**



High speed

High cable foldability

High Speed Test Equipment

Performance matters.

3M™ Twin Axial Cable Assemblies provide high bandwidth, resonance free signal integrity performance. It's extremely tight bend radius facilitates custom folded assembly configurations to fit into your high-density application.

High speed

High cable foldability

High Performance Computing (HPC)

Fold to fit.

High performance computing (HPC) requires the ability to process data and perform complex calculations at high speeds. **3M™ Twin Axial Cable Assemblies** provide high bandwidth, resonance free signal integrity performance. It's extremely tight bend radius facilitates custom folded assembly configurations to fit into your high-density application.

High Density

Thin/low profile

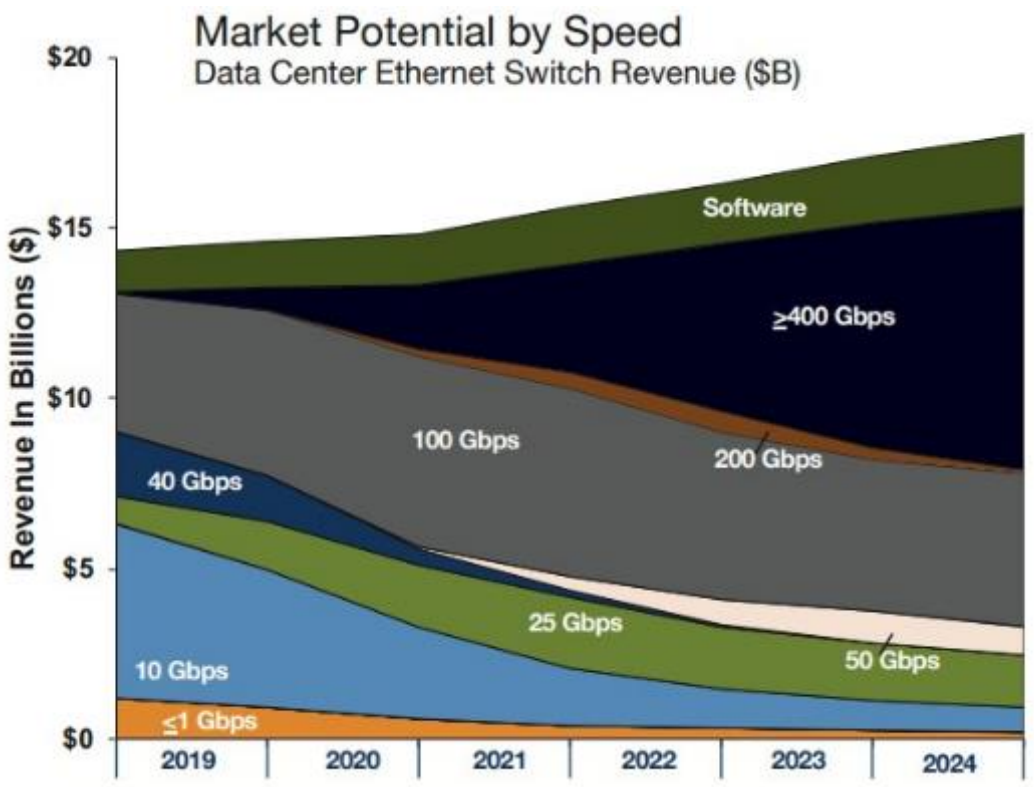
NVMe Drive Backplane

Solid connections for solid state.

Connect NVMe drive backplanes with ease using **3M™ SlimLine Twin Axial Cable Assemblies, 3M™ Low Profile I/O Twin Axial Cables Assemblies or 3M™ Multi-Channel I/O Twin Axial Cable Assemblies**. Thin and foldable is critical since NVMe drives increase the number of cables required to connect to your backplane. Standard or custom cables configurations with the form factor you require.

3M™ Twin Axial External Cable Assembly

Ethernet – Market forecast by speed



	IEEE 802.3ba	IEEE 802.3bj	IEEE 802.3cd	IEEE 802.3ck
Speed	40 Gbps	100 Gbps	400 Gbps	800 Gbps
Commercialized (Year)	2015	2016	2019	2022/23

Source: Morgan, T. P. (2020, May 14). *This Switcheroo Doesn't Get Old*. The Next Platform. https://www.nextplatform.com/2020/05/07/this-switcheroo-doesnt-get-old/

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
  - Virtually no min bend radius
- Maintains Signal Integrity performance when folded
- Helps improve 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 offering

	TDB	3M™ 400G QSFP-DD Direct Attach Copper Cable Assemblies	3M™ 100G QSFP28 Direct Attach Copper Cable Assemblies	3M™ 100G QSFP28 Direct Attach Copper Cable Assemblies	3M™ 100G QSFP28 Direct Attach Copper Cable Assemblies	3M™ Twin Axial Cable Assemblies for QSFP+ Applications, 40GbE
	Under Development					
Form Factor	QSFP-DD	QSFP-DD	QSFP28 Q28-Q28[1]	QSFP28 Q28-1Q28[2]	QSFP28 Q28-4SFP28[2]	QSFP+
Aggregate Data Rate	800G	400G	100G	100G	100G	40G
Channel Data Rate	100G/channel (8X100)	56G/channel (8x50)	25G/channel (4x25)	25G/channel (4x25)	25G/channel (4x25)	10G/channel (4x10)
Lengths	TBD	30 AWG: 0.50 - 2.0 m 26 AWG[3]: 2.25 - 3.50 m	30 AWG: 0.5 to 2.0m 26 AWG: 2.0 to 4.0m	30 AWG: 0.5 to 2.0m 26 AWG: 2 to 4.0m	30 AWG: 0.5 to 2.0m 26 AWG: 3.0 to 4.0m	30 AWG: 0.25 to 3.0m
Series	TBD	9V	9QJ0, 9QH6, 9QN0, 9QM6	9SR-Bxx	9SR-Axx	9QA0
Standards	QSFP-DD MSA IEEE 802.3ck	QSFP-DD MSA IEEE 802.3 cd	SFF-8436, 8661 8665, 8661, 8662 IEEE 802.3bj	SFF-8661, 8662, 8665 IEEE 802.3bj	SFF-8661- 8662,8665,8431 IEEE 802.3bj	SFF-8436 IEEE 802.3ba

1: Q28-Q28 cable assembly - Cable and PCB are halogen free
2: Q-2Q and Q-4S - Cable is halogen free, PCB is not halogen free, CL2 Flame Rated
3: QSFP-DD - 3.25meter meets 802.3cd,3.50meter does not meet 802.3cd standard, however, passes COM

Additional products available in:
- 25G, 10G and miniSAS

High cable routability

Thin/low profile

Server to Switch.

Space saving.

Thin, flexible and easily routed, **3M™ Twin Axial External Direct Attached Copper (DAC) cable assemblies** help customers maintain signal integrity when bent or folded sharply. Improve cable and thermal management along with serviceability in your high-density, high bandwidth application.

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Thank you