High-Speed Data Center Server and Storage System Cable Assemblies

Application & Product Guide

Delivering Increased Bandwidth and Lower Latency for Emerging IT Technologies

SIEMON™

Connecting Today's Data Center Servers and Storage to a Higher Standard

Adoption of emerging technologies is rapidly increasing as enterprise businesses around the world strive to digitally transform, improve efficiencies, and adapt to changing requirements. The artificial intelligence (AI) market specifically is growing at a rapid annual pace of nearly 20% and is expected to reach more than $500 billion in 2023, giving large enterprise customers valuable insights via measurable ROI. The global machine learning market and edge compute deployments are experiencing similar growth. Simultaneously, the volume of data worldwide is projected to grow to more than 180 zettabytes (Zb) by 2025, which is equivalent to 180 trillion gigabytes (Gb).

Enabled by advancements in transceiver technology and ultra-high-speed switch port uplinks that are reaching speeds of 400 Gigabits per second (Gb/s) or more, servers are advancing to support high-bandwidth, low-latency applications. This means better customer experiences and digital advantages, such as financial institutions being able to process large workloads and support high-frequency trading with the expectation of zero lag, while also offering innovative secure client payment tools. Siemon's high-speed Direct Attach Cable (DAC) and Active Optical Cable (AOC) solutions provide a cost-effective option which deliver the reliability, performance and power consumption that today's cloud and large enterprise data center owners and operators need to cost-effectively adopt these emerging technologies.

This application & product guide will explore the available DAC and AOC options as well as the key considerations and information you need to be aware of to maximize your data center budget.
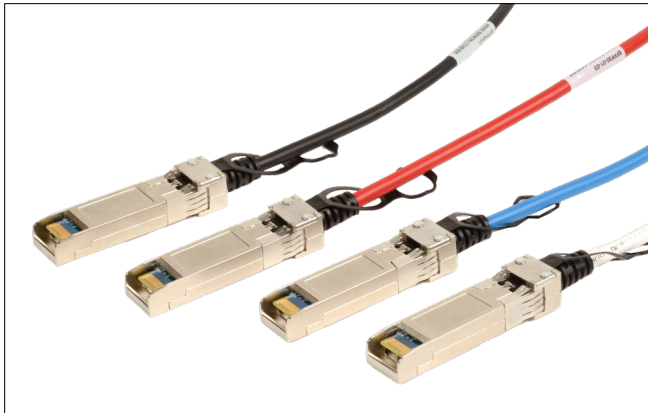
Proven quality and performance backed by dedicated technical support, superior manufacturing capabilities, and supply chain agility for today's advanced server connections.

Emerging Technologies Demanding High-Bandwidth, Low-Latency Network Connections

To keep up with demand for increasing data volumes, rapid content delivery, and compute-intensive real-time applications, increasing bandwidth and lowering latency is now at the very core of data center objectives.

As a refresher, bandwidth is the amount of data that can be transmitted within a given time period and is measured in gigabits per second (Gb/s), while latency is the amount of time it takes for the data signals to reach their intended destination and for th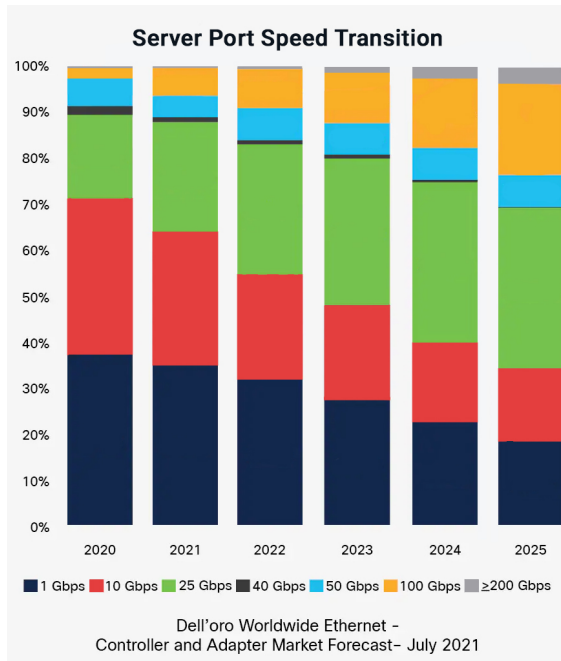e host server to receive and process each request. Measured in milliseconds (ms) and an inevitable phenomenon due to the way data travels across a network, latency varies based on the transmission medium, distance, number of switch hops, and the type of signal encoding.

Just a few extra milliseconds of latency can impact real-time emerging technologies, including:

▶ Artificial Intelligence, machine learning, and advanced data analytics

▶ Virtual and augmented reality

▶ High-resolution video, computer animation, and visual effects

▶ On-line retail, video streaming, and gaming

▶ High-frequency trading and online banking

▶ Work-from-home, telehealth, and dynamic e-learning

▶ Autonomous vehicles and smart traffic systems

▶ Digital twinning, blockchain, and robotics

Network latency can be reduced through advanced server central processing units (CPUs), data center architecture with fewer switch hops, and edge computing strategies that places servers and processing in closer proximity to users, eliminating the time it takes to transmit data back to cloud data centers. Since high-speed server and storage systems needed to support emerging technologies typically run-on multiple servers, increasing bandwidth and reducing latency in these switch-to-server connections within the data center is essential. At the same time, data centers still need to drive down costs and enable scalability to support future technologies, DACs and AOCs are an ideal solution for achieving bandwidth, latency, cost, scalability and power efficiency objectives.

Trends Driving Faster Server Speeds

Server Port Speed Transition

Dell'oro Worldwide Ethernet –
Controller and Adapter Market Forecast– July 2021

Legend: 1 Gbps, 10 Gbps, 25 Gbps, 40 Gbps, 50 Gbps, 100 Gbps, ≥200 Gbps

NRZ vs. PAM4

According to the latest market forecast, trends in digital transformation and the adoption of emerging applications have cloud and large enterprise data centers already deploying next-generation 200 and 400 Gb/s for switch uplinks with 25, 50, and 100 Gb/s server speeds on the rise. For general-purpose servers, 25 Gb/s is expected to surpass 10 Gb/s in 2022.

With 400 Gb/s switch speeds in the initial stages of adoption, 100 Gb/s server speeds are anticipated to gain ground for accelerated server connections in support of emerging technologies. In fact, 200 Gb/s server connections are expected to hit the market in the next few years. These advanced speeds are all made possible via advancements in signal encoding and transceiver technology.

PAM4 Encoding

The ability to support faster transmission speeds has much to do with binary encoding schemes used to convert data into digital signals. The previous non-return-to-zero (NRZ) encoding scheme supports bit rates of 1, 10, and 25 Gb/s per lane in data center links using two different voltage levels. Newer PAM4 encoding offers twice the bit rate per the same signal period of NRZ by using four voltage levels instead of two, supporting 50 and 100 Gb/s per lane without an increase in channel loss.
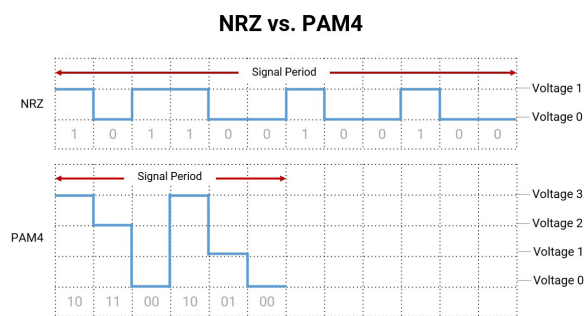
Small Form Factor Advancements

Industry standards for small form-factor pluggable transceivers have advanced alongside signal encoding. Single-lane SFP+ and SFP28 standards support 10 and 25 Gig and are based on NRZ encoding. For higher speeds, four-lane QSFP+ and QSFP28 industry standards support 40 and 100 Gig also based on NRZ, with QSFP+ transceivers at 10 Gb/s per lane and QSFP28 transceivers at 25 Gb/s per lane.

Single Lane Transceiver			4-Lane Transceiver			8-Lane Transceiver
SFP+	SFP28	SFP56	QSFP+	QSFP28	QSFP56	QSFP-DD/OSFP
10G NRZ	25G NRZ	50G PAM4	40G NRZ	100G NRZ	200G PAM4	400G PAM4

The introduction of PAM4 encoding led to the development of single-lane SFP56 transceivers for 50 Gb/s and four-lane QSFP56 cables for 200 Gb/s. Double-density 8-lane QSFP-DD industry standards with PAM4 50 Gb/s per lane encoding is what enables 400 Gb/s largely being adopted for switch uplinks.

Where do High-Speed Cable Assemblies Fit?

Server speeds above 10 Gb/s can be achieved either directly using point-to-point high-speed cables such as DACs and AOCs, or via optical transceivers with fiber optic structured cabling.

DACs—Factory-terminated, fixed-length passive cables made from twinax copper with small form-factor pluggable transceiver modules that support distances of 0.5 meter to 5 meters, which are ideal for in-cabinet deployments.

AOCs—Factory-terminated, fixed-length active cables made from fiber optics and embedded transceivers to support longer-length server connections across multiple cabinets, typically up to 10 meters.

Structured Cabling—Optical small form-factor pluggable transceivers and connectorized fiber cable that utilize patch panels to create server connections and support much longer distances of 100 meters. Typically used in switch-to-switch applications.

While all three solutions support speeds up to 400 Gb/s due to advancements in signal encoding and transceiver technology, when it comes to selecting a cabling solution, data center topology, cost, and latency are all key considerations. Organizations also need to keep an eye on scalability to support future applications and while there is no one single solution for connecting servers in every data center, high-speed cable assemblies offer several advantages.
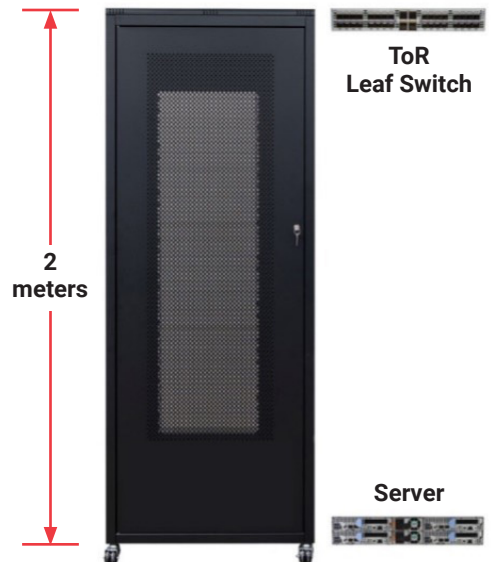
Short-Distance, High-Speed Server and Storage Cluster Deployments

DACs are limited to 5 meters, which makes them well suited for short in-cabinet connections from a Top of Rack (ToR) leaf switch. For longer lengths of 5 to 10 meters, AOCs can be used to connect servers across multiple racks in an End of Row (EoR) or Middle of Row (MoR) topology. Structured cabling is required for longer distances.
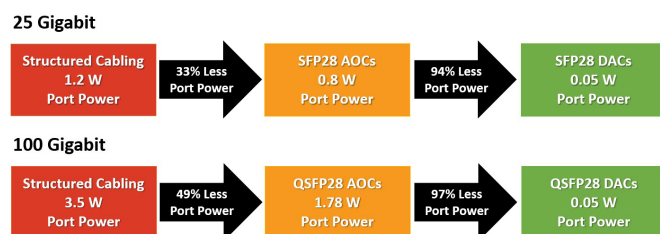
Density also comes into play. For smaller server clusters of 30 or 40 servers, DACs and AOCs offer faster, easier plug-in deployment compared to structured cabling with patch panels.

ToR Leaf Switch

2 meters

Server

Reduced Power Consumption and Cost

If cost is a consideration, the material cost for DACs is less than AOCs with their embedded active optical transmitter and receiver, but both options are far less expensive than the cost of optical transceivers and structured cabling.

Power Consumption Comparison

25 Gigabit

| Structured Cabling 1.2 W Port Power | → 33% Less Port Power | SFP28 AOCs 0.8 W Port Power | → 94% Less Port Power | SFP28 DACs 0.05 W Port Power |

100 Gigabit

| Structured Cabling 3.5 W Port Power | → 49% Less Port Power | QSFP28 AOCs 1.78 W Port Power | → 97% Less Port Power | QSFP28 DACs 0.05 W Port Power |

When it comes to deploying servers in volume, power consumption is also a key factor in cutting energy and cooling costs, as well as supporting sustainability efforts in the data center. Structured cabling is the most power hungry of the three options. That combined with higher material cost can make total system costs for structured cabling anywhere from 30 to 75% higher than DACs and AOCs point-to-point cables.

A Latency Advantage

Direct attached copper cable assemblies offers better latency compared to using fiber structured cabling with transceivers with multiple connection points at patch panels. Recent studies by leading switch vendors using one million samples in short 10 Gb/s server connections demonstrated that DACs offered a slightly better latency over fiber structured cabling of about 400 picoseconds per meter. For higher-speed 25 Gb/s connections using DAC, latency is even better by not needing forward error correction (FEC) in lengths of 3 meters and below which can add up to 409 nS.
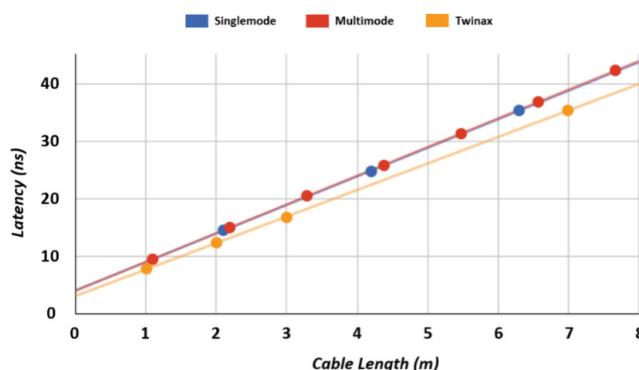
Required for use with PAM4 encoding that is far more susceptible to noise than NRZ, FEC adds redundant data that a receiver can use to correct errors without the need for signal retransmission, depending on network equipment, settings and application FEC can be disabled improving latency in the range of 100 to 500 nS. While low-latency FEC developments are underway to reduce delay, the highest-speed lowest latency option is currently the 4-lane QSFP28 DAC using NRZ encoding with FEC set at disabled supporting speeds of 100 Gb/s up to 3-meters.

Standards-Based Scalability

With advancements in encoding schemes and transceiver technology, application standards for short-reach twinax connections using DACs have continued to evolve, with multiple options for supporting from 10 Gb/s to 400 Gb/s and more on the horizon. There's no doubt that twinax technology will support bandwidth needs for years to come.

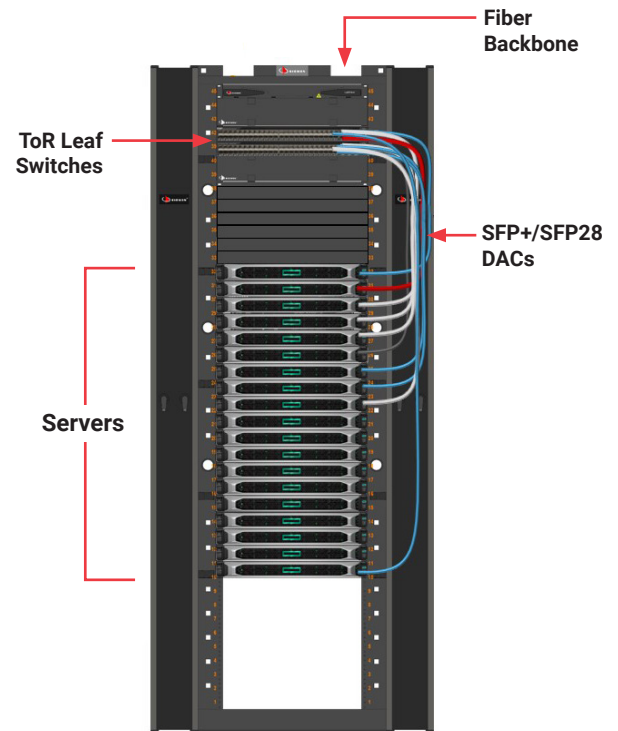| Speed	Form Factor	# of Lanes	Speed per Lane	Cable Type	Max Length	Encoding
10G	SFP+	1	10G	straight-through	7	NRZ
40G	QSFP+	4	10G	straight-through	5	NRZ
40G	QSFP+	4	10G	breakout x 4	5	NRZ
25G	SFP28	1	25G	straight-through	5	NRZ
100G	QSFP28	4	25G	straight-through	5	NRZ
100G	QSFP28	4	25G	breakout x 4	5	NRZ
200G	QSFP56	4	50G	straight-through	3	PAM4
200G	QSFP56	4	50G	breakout x 2, x 4	3	PAM4
400G	OSFP/QSFP-DD	8	50G	straight-through	3	PAM4
400G	OSFP/QSFP-DD	8	50G	breakout x 2, x 4	3	PAM4

Server and Storage Deployment Configurations

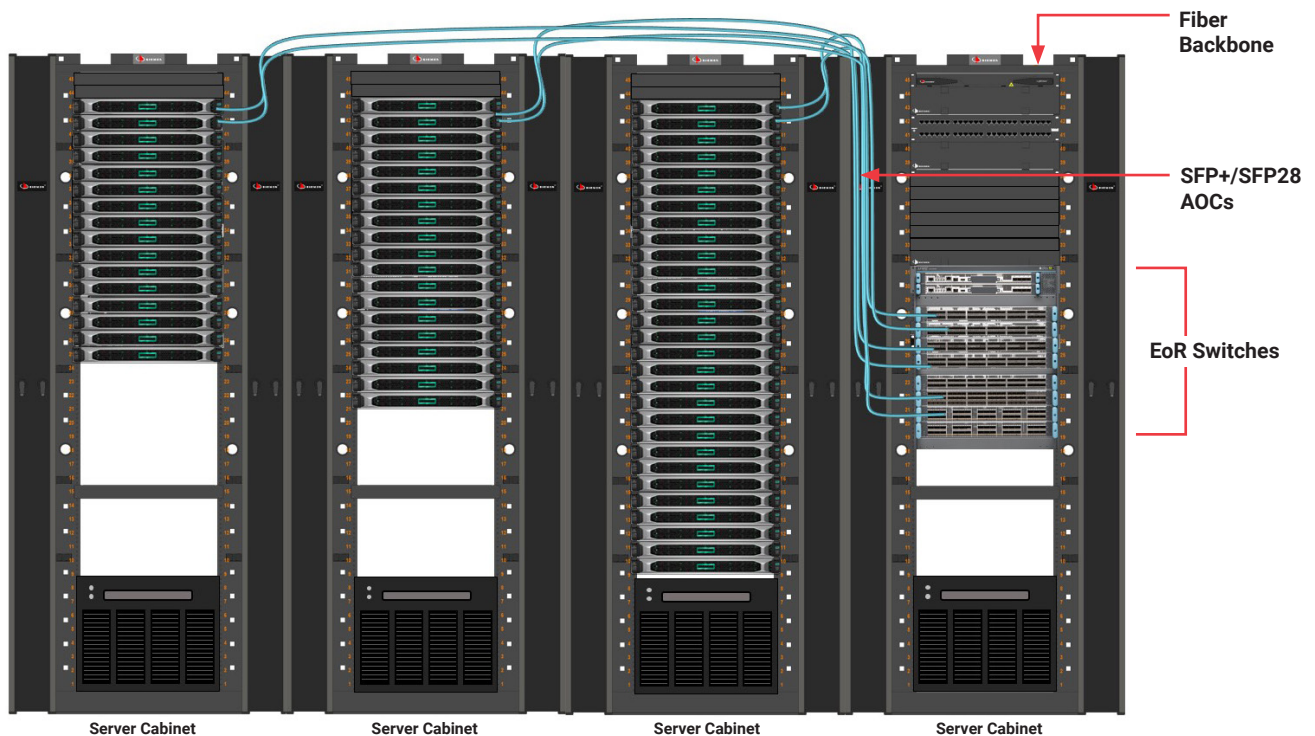## Direct In-Cabinet and Cabinet-to-Cabinet Server Connections

Top of Rack is a common topology in the data center for switch-to-server connections, where leaf switches, servers, and sometimes storage devices are located in the same rack or cabinet and connected via short-reach DACs. It's especially ideal for server clusters that support a specific application, enabling extremely low-latency communications between servers

Many server connections of 3 meters or below can be made within a cabinet as the distance from the top to the bottom of the cabinet averages 2.5 meters or less. ToR deployments are also popular due to its modular design that makes it easy to expand with additional cabinets when more compute is needed.

For clusters where multiple racks or cabinets house servers with switches placed at the EoR or MoR, AOCs can support longer distances to accommodate cabinet-to-cabinet connections.

Fiber Backbone

ToR Leaf Switches

SFP+/SFP28 DACs

Servers

In-Cabinet Direct Server Connections

Fiber Backbone

SFP+/SFP28 AOCs

EoR Switches

| Server Cabinet | Server Cabinet | Server Cabinet | Server Cabinet |

Cabinet-to-Cabinet Direct Server Connections

Cost-effective Server Breakout Connections

To optimize port utilization and switch density, enterprise data centers often deploy cost-effective breakouts that leverage a single higher-speed switch port to connect multiple lower-speed servers.

Breakouts can be achieved with both DACs and AOCs. While 4 x 10 and 4 x 25 Gb/s breakouts are typical, advancements in transceiver technology will support even higher-speed breakouts.

Breakout examples include:

▶ Connecting a single 40 Gb/s QSFP+ switch port to four 10 Gb/s SFP+ servers/NIC (4 x 10 G/s)

▶ Connecting a single 100 Gb/s QSFP28 switch port to four 25 Gb/s SFP28 servers/NIC (4 x 25 Gb/s)

▶ Connecting a single 400 Gb/s QSFPDD switch port to two 200 Gb/s QSFP56 servers/NIC (2 x 200 Gb/s)

▶ Connecting a single 400 Gb/s QSFPDD switch port to four 100 Gb/s QSFP56 (2-lane) servers/NIC (4 x 100 Gb/s)

NIC—Network Interface Card/Network Interface Adapter Card

Breakout Server Connections
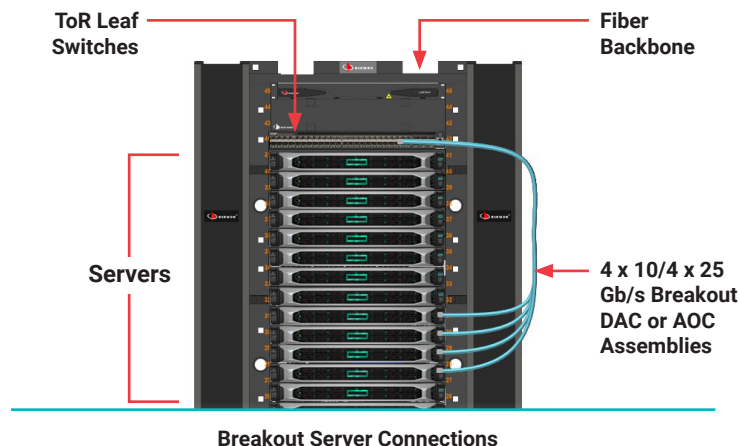
Product Selection Considerations

- Interoperability with active equipment
- Verified performance
- Breadth and availability of product
- Quality and reliability
- Vendor support

are key considerations when it comes to selecting a source for high-speed cables.

Interoperability & Performance—High-speed cables are available from a variety of sources, including switch vendors who often provide products that only function with their equipment. Some even program their switches to produce a warning message when a third-party cable assembly is plugged in. To prevent vendor lock-in, it's important to choose high-speed cables that adhere to industry standards and are verified to work with various switch vendors' equipment.

Product Offering & Availability—In addition to being more expensive, high-speed cables from switch vendors are often limited in length and color options, requiring slack management and eliminating color-coding capabilities. Supply chain issues can also often plague vendors that don't have multiple manufacturing and distribution channels, which can mean longer lead times and project delays.

Quality & Reliability—It's important to select cables from reputable vendors that fully factory test their products to meet or exceed industry standards. Cables should also be comprised of the highest-quality materials, adhering to strict quality control throughout the manufacturing process.

Vendor Support—Due to cost and limited options and availability, third-party vendors are an attractive option. While a common concern of using third-party vendors is not receiving switch vendor warranty and support, switch vendors almost always just recommend replacing a cable when there is a failure. It's important to choose high-speed cables from vendors that offer superior customer service and technical support to help you select the right product from the beginning and who will work with you to resolve any cable-related technical issues.

▶▶ The Siemon Advantage

Established in 1903, Siemon's is the trusted go-to industry leader in the manufacturing and innovation of high-quality, high-performance data center solutions for customers around the world. Part of Siemon's Advanced Data Center Solutions recognized for world-class quality, our comprehensive line of DACs and AOCs support reliable, low-latency server connections from 10 to 100 Gb/s.

▶ **Third-party verified for MSA compliance** to ensure compatibility across active equipment from a variety of vendors

▶ **Fully factory tested and proven to meet or exceed industry standards** with ultra-low crosstalk, enhanced shielded for low emissions, and superior bend and strain relief performance

▶ **Manufactured to the highest quality standards** in vertically integrated and automated ISO 9001 and ISO 14001 certified manufacturing facilities

▶ **Available in half-meter lengths and multiple colors at a competitive price** delivered via superior supply chain logistics and customer service

▶ **Reduced downtime and optimized resiliency and scalability** with guidance from Siemon's expert Data Center Design Services team and on-going technical support

▶ **Continually-advancing product line** to meet evolving data center needs, driven by a culture of continuous improvement, significant investment in R&D, and leading participation in industry standards

▶ **Back by global sales and a comprehensive data center partner ecosystem** with leading providers of complimentary products and services for a total value-added approach

▶ **Siemon can offer the full end-to-end solution** in the data center including the fiber & copper structuring cabling

Direct Attach Cable (DAC) Assemblies

10 Gb/s SFP+ DACs

go.siemon.com/SFPPlus
go.siemon.com/SFPPlusCisco

25 Gb/s SFP28 DACs

go.siemon.com/SFP28
go.siemon.com/SFP28Cisco

**40G QSFP+ and 100G
QSFP28 DACs**

go.siemon.com/QSFPPlus
go.siemon.com/QSFP28
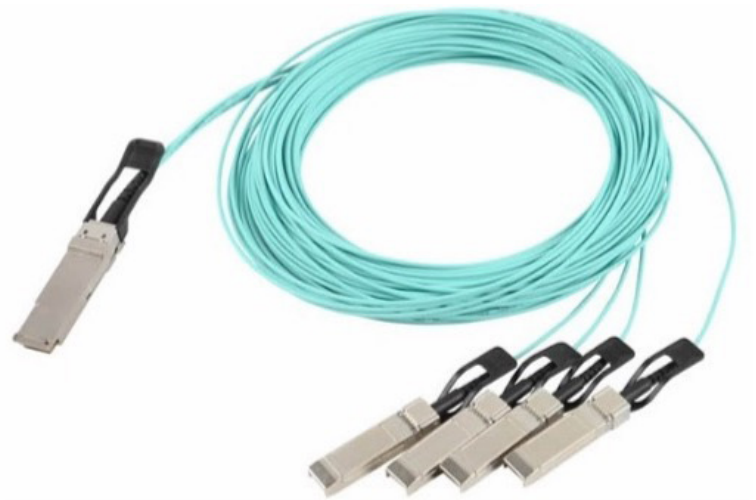
**4 x 10 Gb/s and 4 x 25 Gb/s
Breakout DACs**

go.siemon.com/QSFPPlusBreakout
go.siemon.com/QSFP28Breakout

Not all products are available in every region. Visit www.siemon.com for availability in our eCatalog.

Active Optical Cable (AOC) Assemblies
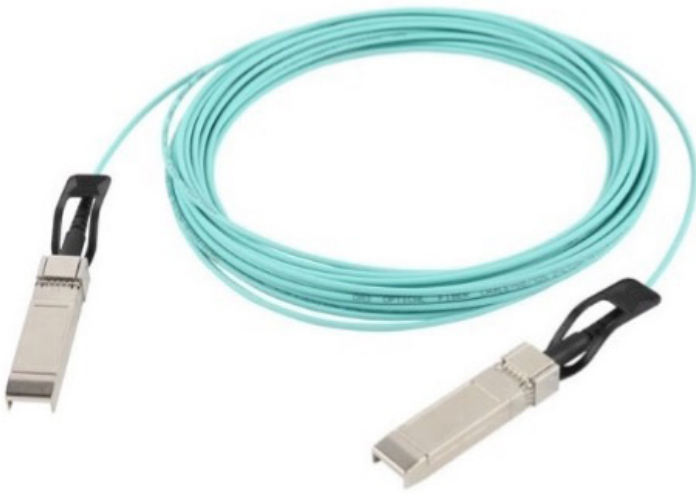
10 Gb/s SFP+ AOCs

go.siemon.com/SFPPlusAOC
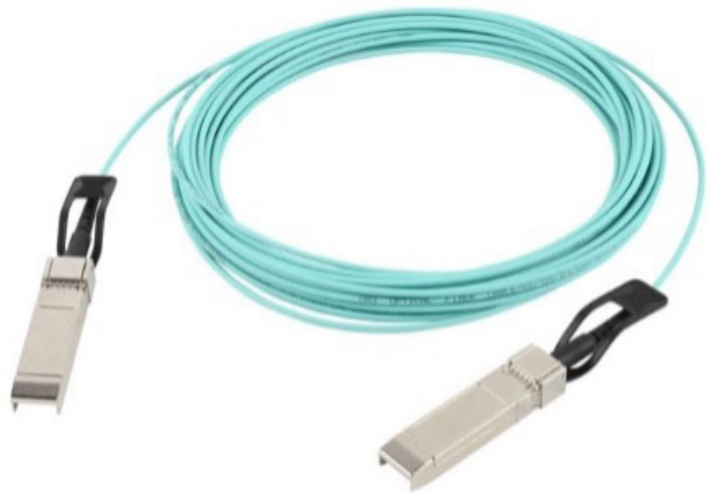
25 Gb/s SFP28 AOCs

go.siemon.com/SFP28AOC

**40G QSFP+ and 100G
QSFP28 AOCs**

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**4 x 10 Gb/s and 4 x 25 Gb/s
Breakout AOCs**

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Want to Learn More About our High-Speed Solutions?

Contact us to today to see how Siemon can help you support high-bandwidth, low-latency server connections and all your data center cabling infrastructure needs.

For more information visit:
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