PCIe® Optical Half Cables

Application Note

Revision 1, January 2016

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Patents

Patents: 8588562 and 8588561. Additional Patents pending.

Updated Documentation

Please contact optics@samtec.com to get access to the latest PCIe® documentation including the Optical Cable Assembly User Manual, as well as the PCIe® Over Fiber Guide, and to ensure that you have the latest version of this document.

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Change History

Revision #	Reason	Author	Date
--	Initial Draft	Roger Miller	11/2/2015
01	Release	Roger Miller	1/21/2016

1 PCIe® Optical Cables

Samtec manufactures PCIe® active optical cables (AOCs) that are used to extend the reach of PCIe® links beyond that which can be realized by traditional copper cables. Link distances up to 300 m are supported, as well as data transfer rates as high as PCIe® Gen 3 (8 GT/s). PCIe® link widths of x4 and x8 are currently supported. The cables conform to the PCI Express® External Cabling Specification.

The active opto-electronic circuitry of the cables is implemented on a printed circuit board (PCB) which is housed within a standard PCI Express® External Cabling Specification compliant connector housing. The cable housing is mechanically and electrically compatible with commercially available PCIe® adapter cards and other equipment designed for PCIe® remote connectivity. An edge connector on the cable housing PCB mates with the cable connector on the host or target equipment. In order to fully support PCIe® clocking, sideband and Rx Detect requirements, one end of the cable is designed to interface to the Host PCIe® system, and the other end interfaces to the Target PCIe® system. The cable housings on both cable ends are labelled as either “Host” or “Target”, to assist in proper insertion of the cable.

PCIe® cables from Samtec are available in two versions: A full AOC, or a Half Optical Cable (HOC). A full AOC has cable housings on both the Host and Target ends of the cable. The fiber optic cable is self-contained, and the fiber cannot be disconnected from the cable housings. This effectively makes the cable a closed system. The cables are available in various lengths. See Figure 1.

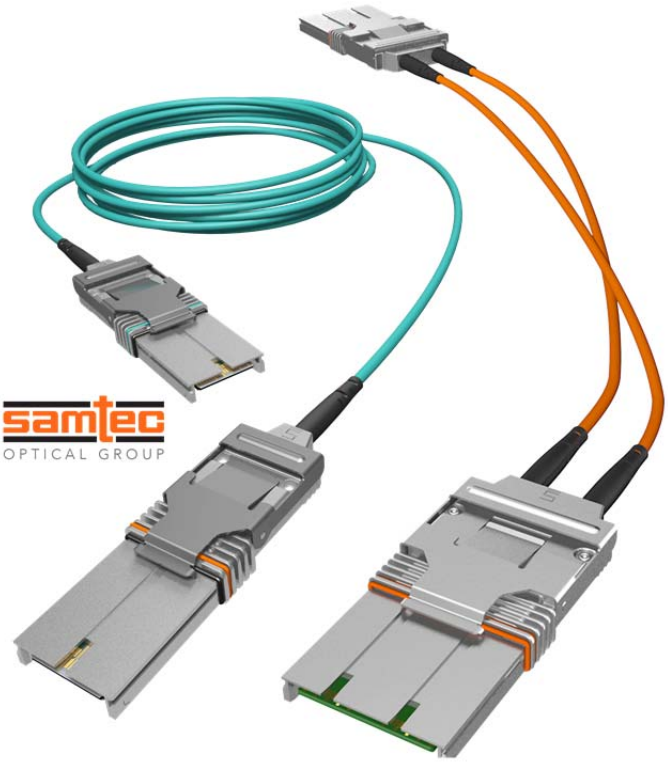


Figure 1: PCIe® Full Active Optical Cables (AOC)

In many optical cabling applications, it may be desirable, or even necessary, to route the fiber interconnect through a chassis bulkhead, or pre-installed structured cabling. In this case, a pair of Half Optical Cables (HOC) is typically used, along with a fiber optic patch cable (FOPC), and bulkhead Optical Panel Adapters (OPA). The HOCs are normally terminated in MPO style multi-channel optical connectors. The MPO connectors are available in 12 or 24 optical channels, and can be configured as male or female. One common brand of MPO connector is the MTP™, made by US Conec.

The MPO end of the host cable is plugged into a bulkhead mounted OPA. The same is done with the target cable at the target equipment bulkhead OPA. A long FOPC is often used to connect between the host and target systems. Figure 2 shows a Half Optical Cable.

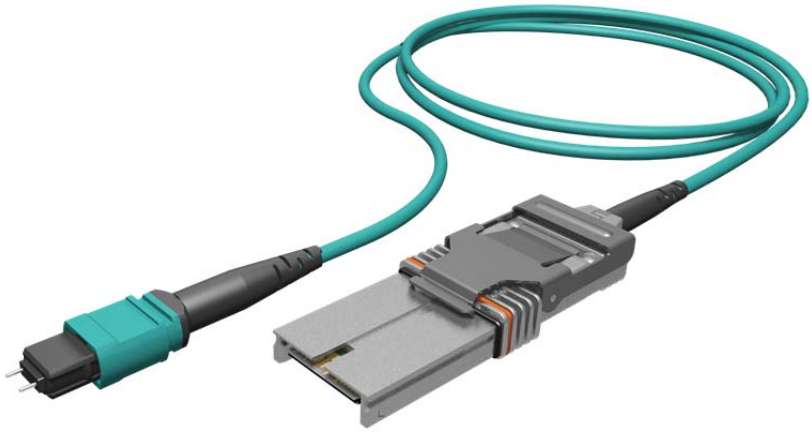


Figure 2: Half Optical Cable (HOC) Terminated in MPO Male Connector

As will be described in detail in the following sections, the MPO bulkhead adapters and the FOPCs are available in different configurations, which affect how the optical signals are mapped onto the connectors. Furthermore, Samtec uses a specific signal mapping between the optical cable of the HOC to the MPO connector. Because of this, it is necessary to use the proper MPO adapter and FOPC configuration. Otherwise, end-to-end connectivity may not be achieved between the Host and Target Transmit (Tx) and Receive (Rx) optical channels. The purpose of this application note is to define the proper configurations to be used with Samtec HOCs, based on the intended PCIe® application.

2 MPO Connectors

MPO connectors are widely used in parallel optical applications. The MPO connector provides a high density optical connectivity solution, together with a mechanical mechanism to provide positive latching. The MPO connectors used in Samtec half optical cables are configured in either 12 or 24 optical channels. A pair of MPO connectors can be mated through a bulkhead mounted MPO adapter, which occupies very little space on the equipment panel.

Figure 3 shows a 12 channel male MPO connector. The MPO connector consists of a MT ferrule, MPO housing, and a latching mechanism. The male MT ferrule contains the 12 optical channels and the guide pins. A female MT ferrule has holes that accept the guide pins from the male MT ferrule. The 12 optical channels are arranged in a single row on the MT ferrule. In a 24 channel MPO connector, the optical channels are arranged in 2 rows of 12 channels each.

The ferrule is installed into the MPO housing. The MPO housing has a guide key, which ensures that the optical channel numbers are oriented properly with respect to the MPO adapter. The MPO housing is enclosed by a spring loaded latching mechanism. When two MPO cables are mated through a MPO bulkhead adapter, the spring loaded latching mechanism keeps the two MT ferrules firmly seated against each other. It is important that the two MT ferrules are firmly seated against each other in order to eliminate any air gap, which minimizes the optical attenuation through the mated connector pair.

Figure 3: 12 Channel Male MPO Connector

3 MPO Bulkhead Adapters as Optical Panel Adapters

The MPO bulkhead adapters are available in 2 different configurations, defined by the relative orientation of the connector keys on each end of the adapter:

- Opposed
- Aligned

Opposed adapters have the connector keys on opposite sides of the adapter (the keys are opposing each other). The result is that the MPO connectors which plug into the adapter will be rotated 180 degrees in relation to each other. Aligned adapters have the connector keys on the same side of the adapter (keys aligned with each other). The result is that the connectors will be aligned in relation to each other. Samtec can supply the MPO adapters, or they can be purchased from other vendors. The MPO adapters will work with either 12 or 24 channel MPO connectors. Figure 4 shows the two types of MPO bulkhead adapters.

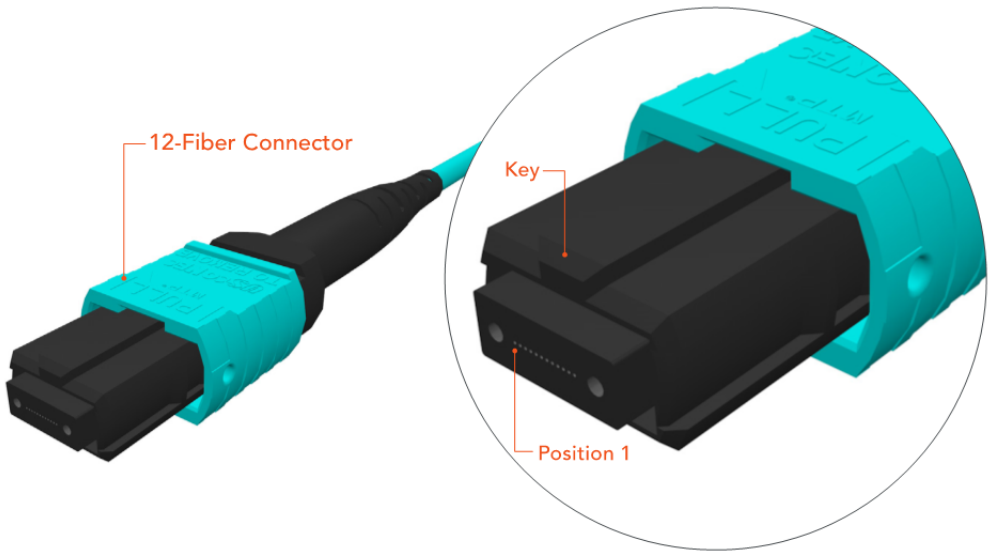
Figure 4: MPO Adapters, Opposed (Left) and Aligned (Right)

4 Fiber Optic Patch Cables

In a Half-Cable application, a Fiber Optic Patch Cables (FOPC) is typically used to connect between the host and target PCIe® equipment, at the MPO bulkhead adapters. The FOPCs are available in various lengths. Samtec can supply the FOPCs, or they can be purchased from various suppliers. Like the MPO connectors, they are available with 12 or 24 optical channels.

Patch cables are commonly available in 2 different styles, depending on how the optical fibers are mapped onto the FOPC MPO connector. The mapping scheme is referred to as the polarity of the optical signals.

Figure 5 shows the optical signal mapping for 12 channel generic patch cables, of Type A and Type B. A Type A cable maps pin 1 on one end of the cable to pin 1 on the other end, and pin 2 to pin 2, etc. It is sometimes referred to as a "straight through" cable. A Type B cable flips the channels between ends. In other words, Pin 1 of one end connects to pin 12 on the other end, pin 2 to pin 11, etc. It is sometimes referred to as an "inverted" or "crossover" cable. At this time, Samtec only supplies the Type B FOPC, but it is important to understand the differences between the two cable types.



TYPE A

SIDE A	12 FIBER (A)	SIDE B
MTP POSITION	FIBER COLOR	MTP POSITION
1	BLUE	1
2	ORANGE	2
3	GREEN	3
4	BROWN	4
5	SLATE	5
6	WHITE	6
7	RED	7
8	BLACK	8
9	YELLOW	9
10	VIOLET	10
11	ROSE	11
12	AQUA	12

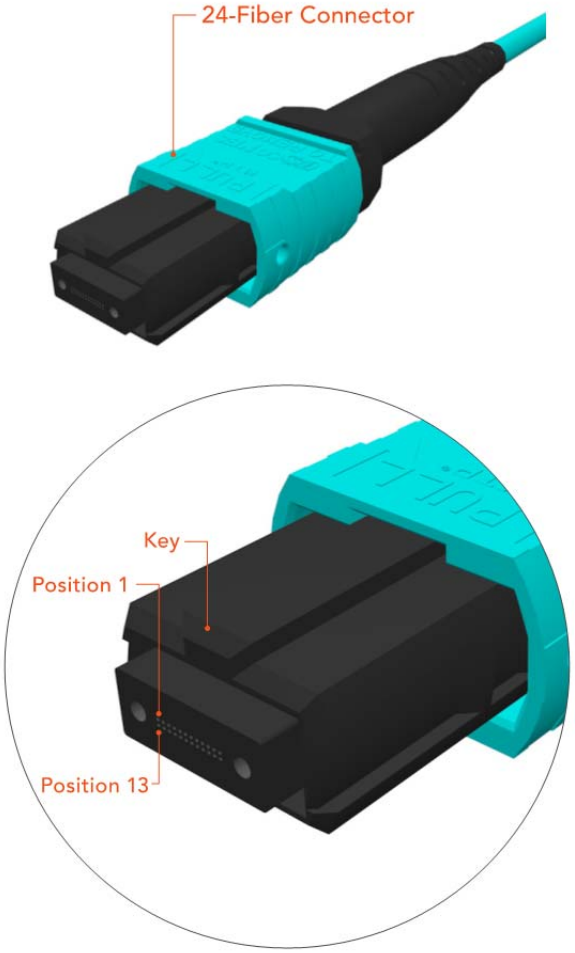
TYPE B

SIDE A	12 FIBER (B)	SIDE B
MTP POSITION	FIBER COLOR	MTP POSITION
1	BLUE	12
2	ORANGE	11
3	GREEN	10
4	BROWN	9
5	SLATE	8
6	WHITE	7
7	RED	6
8	BLACK	5
9	YELLOW	4
10	VIOLET	3
11	ROSE	2
12	AQUA	1

Figure 5: 12-Channel Fiber Optic Patch Cable Signal Mapping

A 24 channel Type C FOPC is required for PCIe® x8 half-cable applications. The 24 channel FOPC is available from Samtec only as a Type C.

Figure 6: shows the optical signal polarity mapping for a Type C FOPC. Position 1 on one end of the cable connects to position 13 on the other end, position 2 connects to position 14, etc. The channels are routed to the opposite row on the far end connector, while maintaining position within the same column.



TYPE C

SIDE A	24 FIBER (C)	SIDE B
MTP POSITION	FIBER COLOR	MTP POSITION
1	BLUE	13
2	ORANGE	14
3	GREEN	15
4	BROWN	16
5	SLATE	17
6	WHITE	18
7	RED	19
8	BLACK	20
9	YELLOW	21
10	VIOLET	22
11	ROSE	23
12	AQUA	24
13	BLUE (+)	1
14	ORANGE (+)	2
15	GREEN (+)	3
16	BROWN (+)	4
17	SLATE (+)	5
18	WHITE (+)	6
19	RED (+)	7
20	BLACK (+)	8
21	YELLOW (+)	9
22	VIOLET (+)	10
23	ROSE (+)	11
24	AQUA (+)	12

Figure 6: 24-Channel Fiber Optic Patch Cable Signal Polarity Mapping (Type C)

5 Half Cable Back-to-Back Operation without Patch Cables

In some instances, it may be desirable to operate two HOCs in a back-to-back configuration. In this application, the MPO ends of the two cables are simply connected together, through an MPO adapter, without using a patch cable.

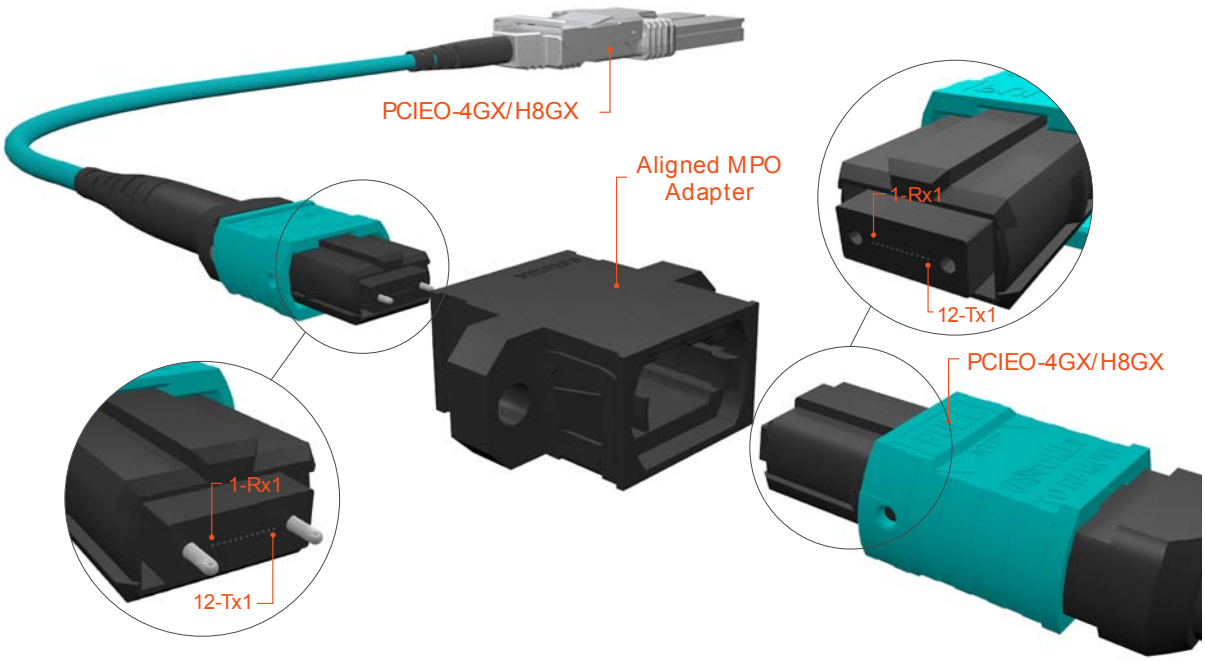
Typical applications are: a quick loopback test, or to evaluate half cable connectivity over various lengths or with multiple host/target combinations.

Care must be taken to use the proper polarity MPO adapter, as will be described later for each of the PCIe® half cables.

6 x4 PCIe® HOC: PCIEO-4GX/H8GX to PCIEO-4GX/H8GX

This section describes the back-to-back configuration for two PCIEO-4GX HOCs, or two PCIEO-H8GX HOCs. A PCIEO-H8GX, referred to as a “Half-8”, has a cable housing constructed in a full x8 form factor, but the cable can support up to a x4 link width. This allows the user the option to upgrade to a full x8 optical cable at a later time.

shows the signal mapping for back-to-back operation of two PCIEO-4GX or PCIEO-H8GX cables (x = 2 or 3, referring to the PCIe® link speed of Gen 2 or Gen 3). Both of these half-cables use a 12 channel MPO connector. Note that an aligned MPO adapter is required. Following the signal flow, Rx1 on the left-hand cable connects to Tx1 on the right-hand cable, and so on, with all Tx channels on one cable being connected to the corresponding Rx channel on the other cable, and vice versa.



PCIEO-4GX/H8GX

HALF CABLE SIGNAL MAPPING

FUNCTION	FIBER COLOR	MTP POSITION
Rx1	BLUE	1
Rx2	ORANGE	2
Rx3	GREEN	3
Rx4	BROWN	4
Dark	SLATE	5
Dark	WHITE	6
Dark	RED	7
Dark	BLACK	8
Tx4	YELLOW	9
Tx3	VIOLET	10
Tx2	ROSE	11
Tx1	AQUA	12

PCIEO-4GX/H8GX

HALF CABLE SIGNAL MAPPING

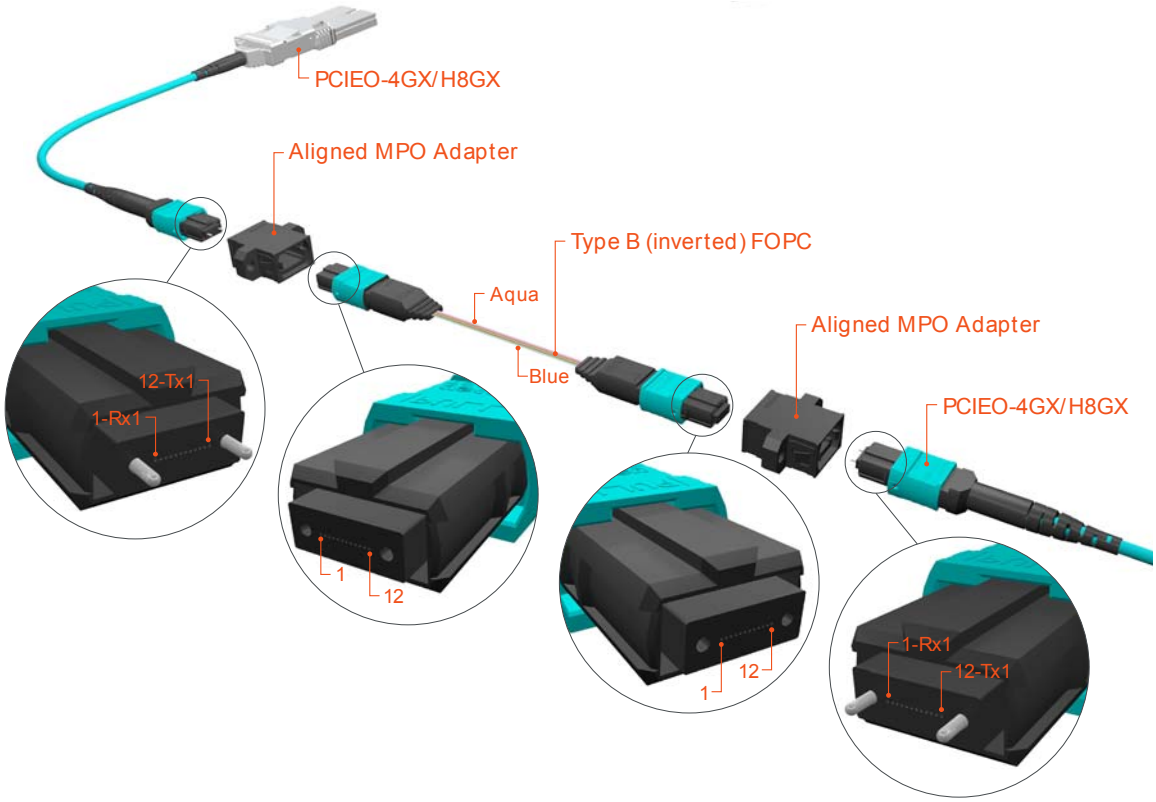
FUNCTION	FIBER COLOR	MTP POSITION
Rx1	BLUE	1
Rx2	ORANGE	2
Rx3	GREEN	3
Rx4	BROWN	4
Dark	SLATE	5
Dark	WHITE	6
Dark	RED	7
Dark	BLACK	8
Tx4	YELLOW	9
Tx3	VIOLET	10
Tx2	ROSE	11
Tx1	AQUA	12

Figure 7 : PCIEO-4GX/H8GX to PCIEO-4GX/H8GX Signal Mapping

7 FOPC App: PCIEO-4GX/H8GX to FOPC to PCIEO-4GX/H8GX

This section describes the configuration when two PCIEO-4GX or PCIEO-H8GX half-cables are joined using a FOPC. These half cables use a 12 channel MPO connector. As was mentioned earlier, this is a common application when the optical link must be passed through a bulkhead at each cable end.

Figure 8 shows the signal mapping for this configuration. Note that aligned MPO adapters are used. A Type B (inverted) FOPC is required. Tracing the signal flow through the diagram, it is seen that all the Tx channels on one cable connect with the corresponding Rx channel on the other cable, and vice versa.



PCIEO-4GX/H8GX

HALF CABLE SIGNAL MAPPING

FUNCTION	FIBER COLOR	MTP POSITION
Rx1	BLUE	1
Rx2	ORANGE	2
Rx3	GREEN	3
Rx4	BROWN	4
Dark	SLATE	5
Dark	WHITE	6
Dark	RED	7
Dark	BLACK	8
Tx4	YELLOW	9
Tx3	VIOLET	10
Tx2	ROSE	11
Tx1	AQUA	12

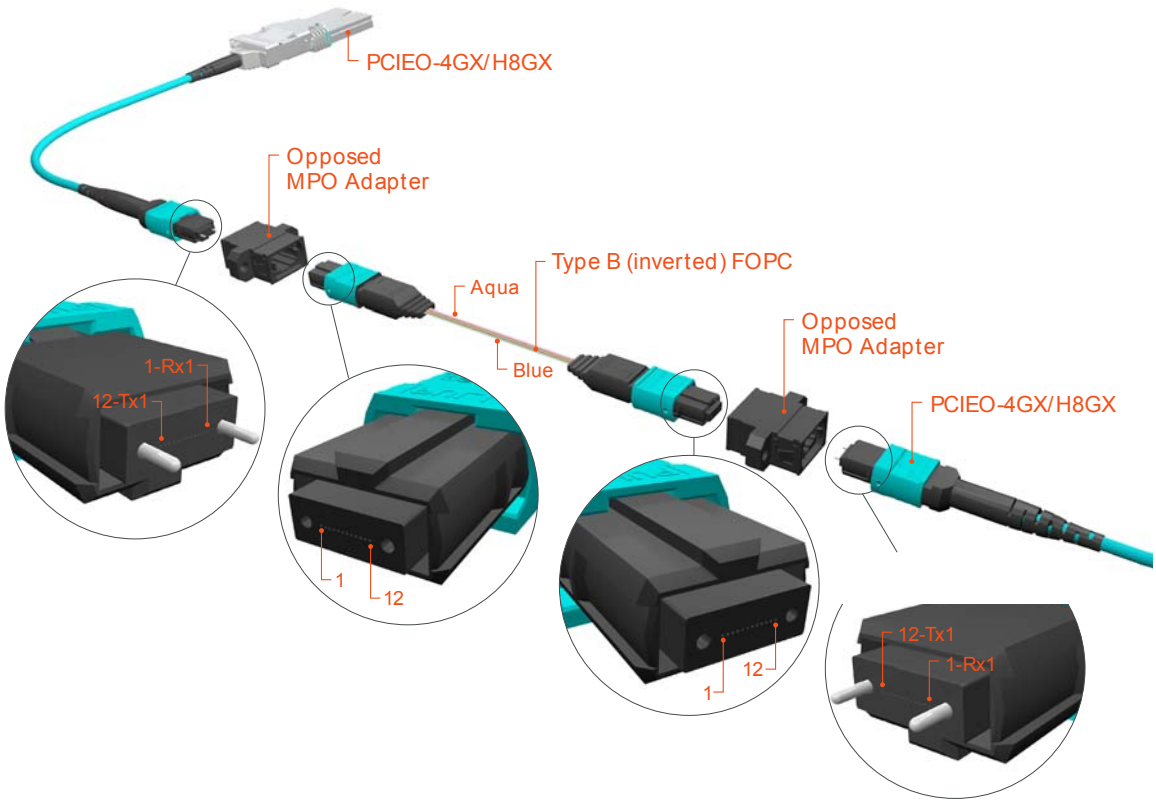
PCIEO-4GX/H8GX

HALF CABLE SIGNAL MAPPING

FUNCTION	FIBER COLOR	MTP POSITION
Rx1	BLUE	1
Rx2	ORANGE	2
Rx3	GREEN	3
Rx4	BROWN	4
Dark	SLATE	5
Dark	WHITE	6
Dark	RED	7
Dark	BLACK	8
Tx4	YELLOW	9
Tx3	VIOLET	10
Tx2	ROSE	11
Tx1	AQUA	12

Figure 8: PCIEO-4GX/H8GX to FOPC to PCIEO-4GX/H8GX Signal Mapping (Aligned Adapters)

It is possible to achieve the same connectivity using Opposed MPO adapters. When using a Type B FOPC, two opposed MPO adapters can be used instead of two aligned adapters. The important point is that the adapters must have the same key alignment type. Figure 9 shows the details of this configuration.



PCIEO-4GX/H8GX

HALF CABLE SIGNAL MAPPING

FUNCTION	FIBER COLOR	MTP POSITION
Rx1	BLUE	1
Rx2	ORANGE	2
Rx3	GREEN	3
Rx4	BROWN	4
Dark	SLATE	5
Dark	WHITE	6
Dark	RED	7
Dark	BLACK	8
Tx4	YELLOW	9
Tx3	VIOLET	10
Tx2	ROSE	11
Tx1	AQUA	12

PCIEO-4GX/H8GX

HALF CABLE SIGNAL MAPPING

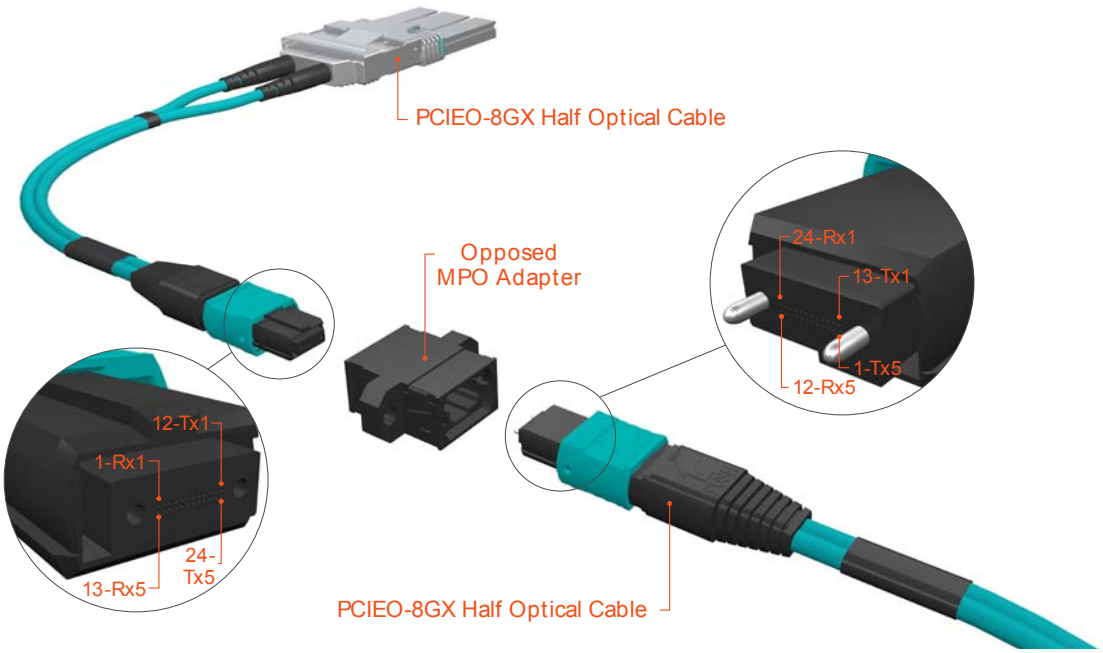
FUNCTION	FIBER COLOR	MTP POSITION
Rx1	BLUE	1
Rx2	ORANGE	2
Rx3	GREEN	3
Rx4	BROWN	4
Dark	SLATE	5
Dark	WHITE	6
Dark	RED	7
Dark	BLACK	8
Tx4	YELLOW	9
Tx3	VIOLET	10
Tx2	ROSE	11
Tx1	AQUA	12

Figure 9: PCIEO-4GX/H8GX to FOPC to PCIEO-4GX/H8GX Signal Mapping (Opposed Adapters)

8 x8 PCIe® HOC: PCIEO-8GX to PCIEO-8GX

This section describes the back-to-back configuration for two PCIEO-8GX HOCs. These cables have a cable housing shell constructed in a full x8 form factor, and will support up to a x8 link width.

shows the signal mapping for back-to-back operation of two PCIEO-8GX cables (x = 2 or 3, referring to the PCIe® link speed of Gen 2 or Gen 3). Due to the increased number of optical channels associated with a x8 PCIe® link, these half-cables use 24 channel MPO connectors. Note that an opposed MPO adapter is required. Following the signal flow, all Tx channels on one cable are connected to the corresponding Rx channel on the other cable, and vice versa.



PCIEO-8G3
HOST SIGNAL MAPPING

	FUNCTION	FIBER COLOR	MTP POSITION
TOP SIDE	Rx1	BLUE	1
	Rx2	ORANGE	2
	Rx3	GREEN	3
	Rx4	BROWN	4
	Tx1	BLACK	12
	Tx2	RED	11
	Tx3	WHITE	10
	Tx4	SLATE	9
BOTTOM SIDE	Rx5	BLUE (+)	13
	Rx6	ORANGE (+)	14
	Rx7	GREEN (+)	15
	Rx8	BROWN (+)	16
	Tx5	BLACK (+)	24
	Tx6	RED (+)	23
	Tx7	WHITE (+)	22
	Tx8	SLATE (+)	21

PCIEO-8G3
TARGET SIGNAL MAPPING

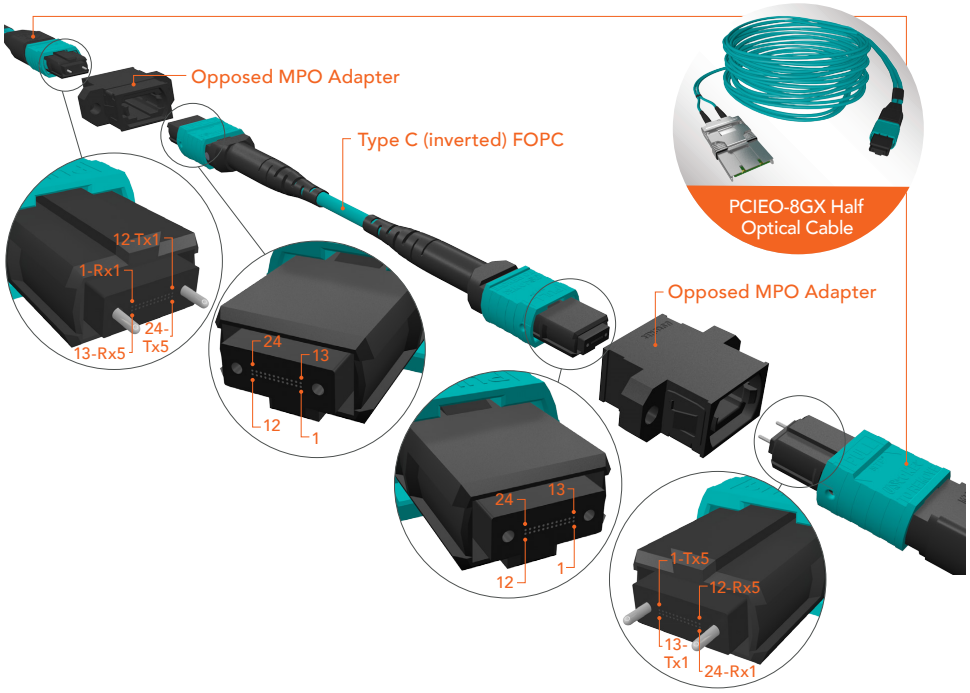
	FUNCTION	FIBER COLOR	MTP POSITION
TOP SIDE	Rx1	BLACK	24
	Rx2	RED	23
	Rx3	WHITE	22
	Rx4	SLATE	21
	Tx1	BLUE	13
	Tx2	ORANGE	14
	Tx3	GREEN	15
	Tx4	BROWN	16
BOTTOM SIDE	Rx5	BLACK (+)	12
	Rx6	RED (+)	11
	Rx7	WHITE (+)	10
	Rx8	SLATE (+)	9
	Tx5	BLUE (+)	1
	Tx6	ORANGE (+)	2
	Tx7	GREEN (+)	3
	Tx8	BROWN (+)	4

Figure 10: PCIEO-8GX to PCIEO-8GX Signal Mapping

9 FOPC App: PCIEO-8GX to FOPC to PCIEO-8GX

This section describes the configuration when two PCIEO-8GX half-cables are joined using a FOPC. These half cables use 24 channel MPO connectors. As was mentioned earlier, this is a common application when the optical link must be passed through a bulkhead at each cable end.

and show the signal mapping for this configuration. Note that aligned MPO adapters are used. A Type C FOPC is required. Tracing the signal flow through the diagram, it is seen that all the Tx channels on one cable connect with the corresponding Rx channel on the other cable, and vice versa.



PCIEO-8G3
HOST SIGNAL MAPPING

	FUNCTION	FIBER COLOR	MTP POSITION
TOP SIDE	Rx1	BLUE	1
	Rx2	ORANGE	2
	Rx3	GREEN	3
	Rx4	BROWN	4
	Tx1	SLATE	12
	Tx2	WHITE	11
	Tx3	RED	10
	Tx4	BLACK	9
BOTTOM SIDE	Rx5	BLUE (+)	13
	Rx6	ORANGE (+)	14
	Rx7	GREEN (+)	15
	Rx8	BROWN (+)	16
	Tx5	SLATE (+)	24
	Tx6	WHITE (+)	23
	Tx7	RED (+)	22
	Tx8	BLACK (+)	21

PCIEO-8G3
TARGET SIGNAL MAPPING

	FUNCTION	FIBER COLOR	MTP POSITION
TOP SIDE	Rx1	BLACK	24
	Rx2	RED	23
	Rx3	WHITE	22
	Rx4	SLATE	21
	Tx1	BLUE	13
	Tx2	ORANGE	14
	Tx3	GREEN	15
	Tx4	BROWN	16
BOTTOM SIDE	Rx5	BLACK (+)	12
	Rx6	RED (+)	11
	Rx7	WHITE (+)	10
	Rx8	SLATE (+)	9
	Tx5	BLUE (+)	1
	Tx6	ORANGE (+)	2
	Tx7	GREEN (+)	3
	Tx8	BROWN (+)	4

Figure 11: PCIEO-8GX to FOPC PCIEO-8GX Signal Mapping on Host and Target Cable Ends

TYPE C

SIDE A	24 FIBER (C)	SIDE B
MTP POSITION	FIBER COLOR	MTP POSITION
1	BLUE	13
2	ORANGE	14
3	GREEN	15
4	BROWN	16
5	SLATE	17
6	WHITE	18
7	RED	19
8	BLACK	20
9	YELLOW	21
10	VIOLET	22
11	ROSE	23
12	AQUA	24
13	BLUE (+)	1
14	ORANGE (+)	2
15	GREEN (+)	3
16	BROWN (+)	4
17	SLATE (+)	5
18	WHITE (+)	6
19	RED (+)	7
20	BLACK (+)	8
21	YELLOW (+)	9
22	VIOLET (+)	10
23	ROSE (+)	11
24	AQUA (+)	12

Figure 12: PCIEO-8GX to FOPC to PCIEO-8GX Signal Mapping on Type C MPO Adapter Sides

10 References

[1] https://www.samtec.com/active-optics/active-optical-cable/PCIe.aspx

[2] Samtec: PCIe® Active Optical Cable Assembly User Manual

[3] Samtec: PCIe® Over Fiber Guide

[4] PCI Express® External Cabling Specification, Revision 2.0

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