Active Copper Cables for SAS-2.x Part Deux

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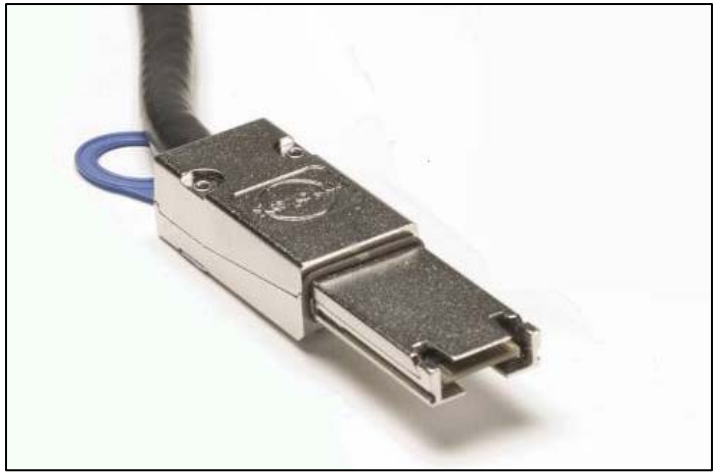
Background

- System designers need the flexibility to implement longer cable interconnects.
- A 20 meter reach is a desired target, allowing to wire a vast majority of connections in a typical datacenter.
- Active cables have proven to be an economical, low-power, low-latency and high-performance option to support longer reaches and thinner wire gauges.
- Growing use by the industry in the InfiniBand, 10GBASE-CX4, PCIe, QSFP and other applications. Several silicon vendors have products.
- Incorporating active cable option (power supply) will also enable optical solutions.
- Consider the active cable option for SAS-2.x

Interconnect Options For Active Cable

- Need power delivery to the plug
- A twin-ax type cable

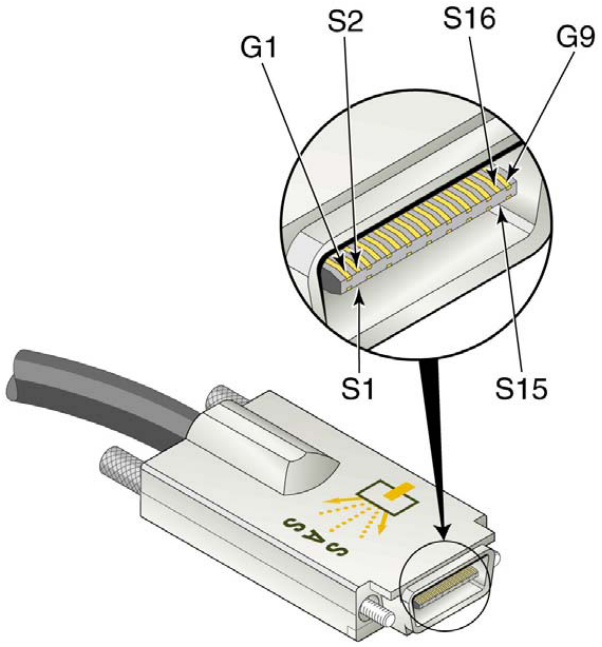
SAS (SFF-8470)



miniSAS (I-Pass)

QSFP

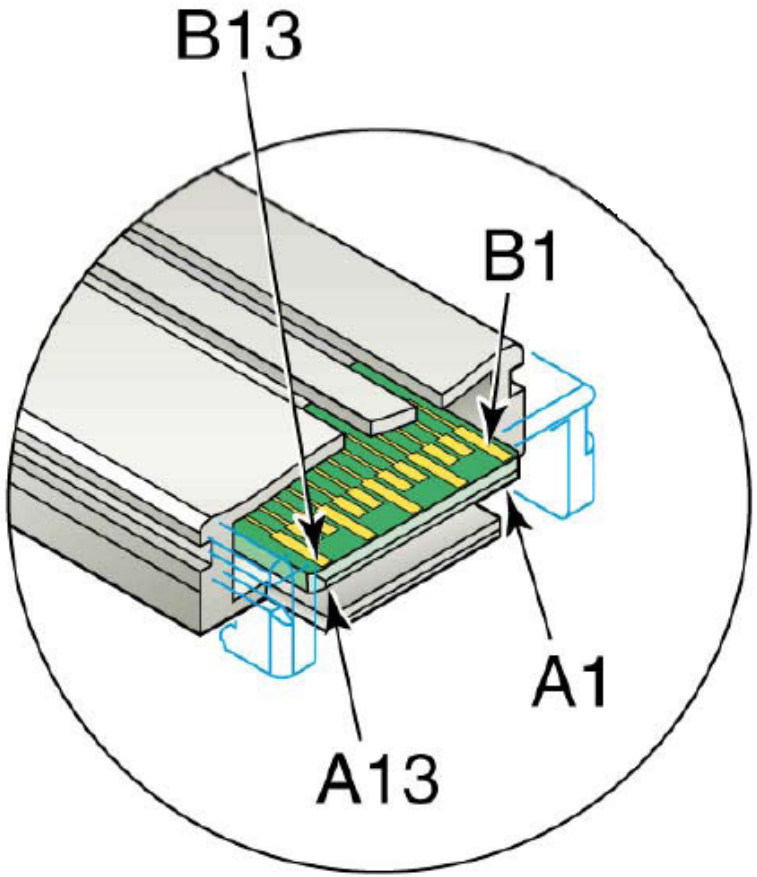
Active Cable with SAS Connectors



- Already done in InfiniBand (and used for 10GBASE-CX4)
- A total of 8 GND tabs
- GND7: Voltage sense pin
- GND8: Power (3.3V)

Signal	Pin
Rx 0+	S1
Rx 0-	S2
Rx 1+	S3
Rx 1-	S4
Rx 2+	S5
Rx 2-	S6
Rx 3+	S7
Rx 3-	S8
Tx 3-	S9
Tx 3+	S10
Tx 2-	S11
Tx 2+	S12
Tx 1-	S13
Tx 1+	S14
Tx 0-	S15
Tx 0+	S16
Sense-3.3V	G7
Vcc	G8
SIGNAL GND	G1 – G6, G9
CHASSIS GND	Housing

Active Cable with mini-SAS Connectors



- There are 10 GND pads on the Mini-SAS cable
- Use any one of the GND pins (e.g. B13) as 3.3V power
- Use another GND pin (e.g. B10) as voltage detection for an active cable
- A/C couple those pins to ground to preserve signal integrity.

Issues We Need to Address

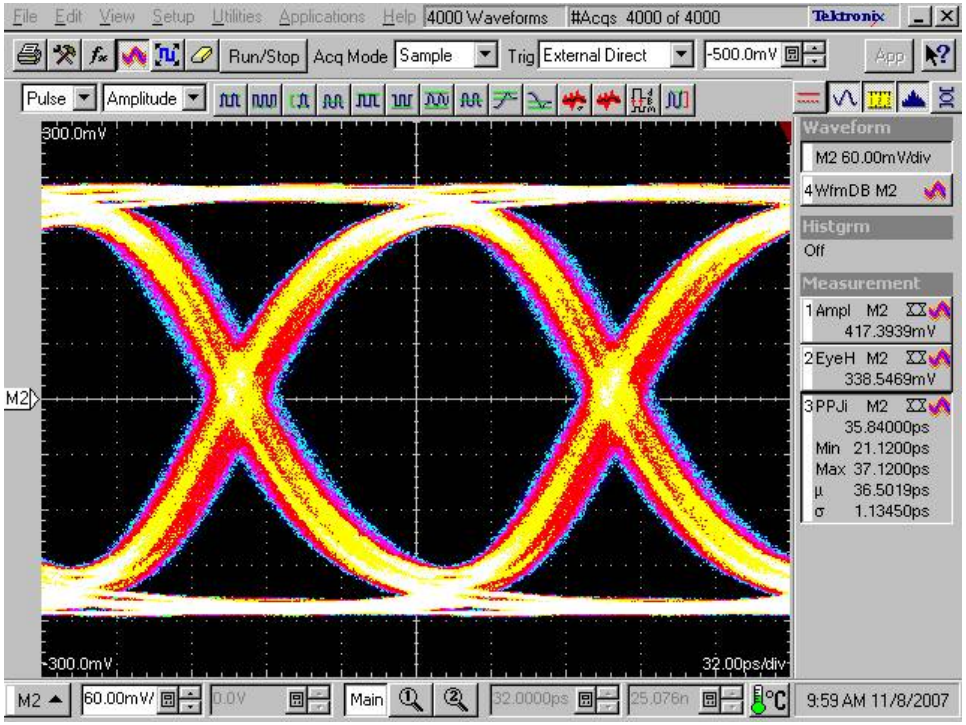
- Performance:
  - Can the 20 meter reach target be achieved with active cables?
  - Can SAS protocol features be supported with active cables?
- Power Delivery:
  - Will using some of the ground pins for power and sense affect signal integrity (crosstalk)?
- Backward Compatibility
  - Will passive cables work on active ports? Active cables on passive ports?
  - Is keying needed?

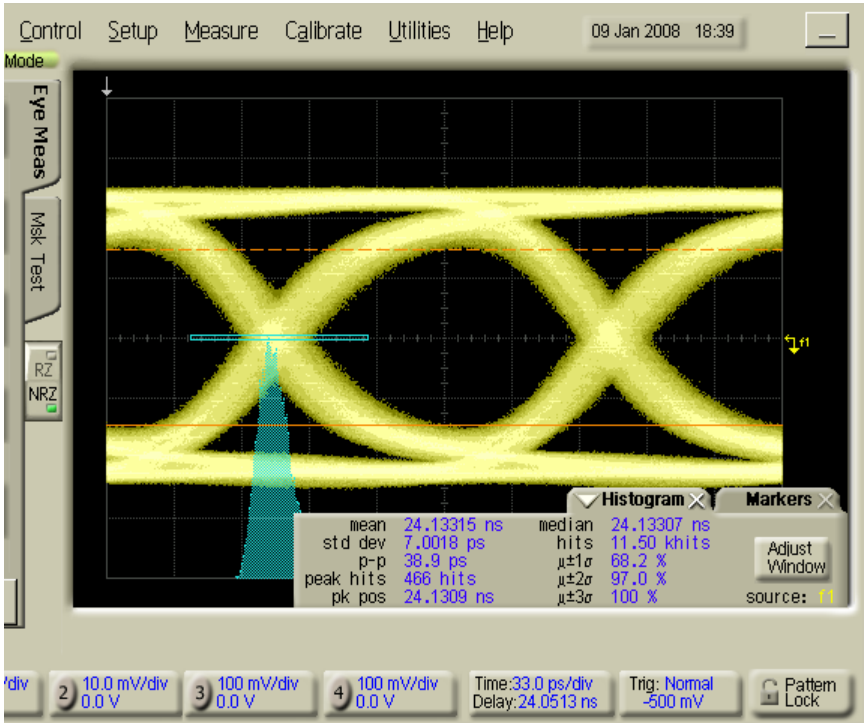
Performance:

For the purposes of this presentation, Quellan's active copper cables with receive-only equalization were used. Other implementations can be used, including adding TX-side EQ for PCB losses, as well as non-copper (optical) solutions. Spec should not restrict implementation.

- Eye diagrams at ~6 Gbps for both SFF-8470 (20m) and I-Pass cables (25 meters are shown). The Output TJ in both cases is better than 0.25 UI (the limit required by other standards that support active cables)

Performance (*continued*):





20m SFF-8470 Cable, 6.25 Gbps

25m I-Pass Cable, 6 Gbps

(graph courtesy of Molex)

Performance (*continued*):

- Active cables can be designed to ensure support for SAS protocol features. OOB signaling is particularly important:
  - OOB signals would require the active cable to support DC idle (muting) with tight constraints on the response time
  - COMWAKE (the tightest OOB signal): 106.6ns duration for both burst and idle; for a minimally compliant receiver, bursts 100 ns or shorter and idles shorter than 101.3 ns may not be detected.
  - So, if an active cable has a difference between idle-to-burst and burst-to-idle response times tighter than 5.3 ns, the OOB features will be supported.
  - Example: Quellan active cables based on the QLx4600 series equalizer are held tighter than 4.5 ns.

Power Delivery:

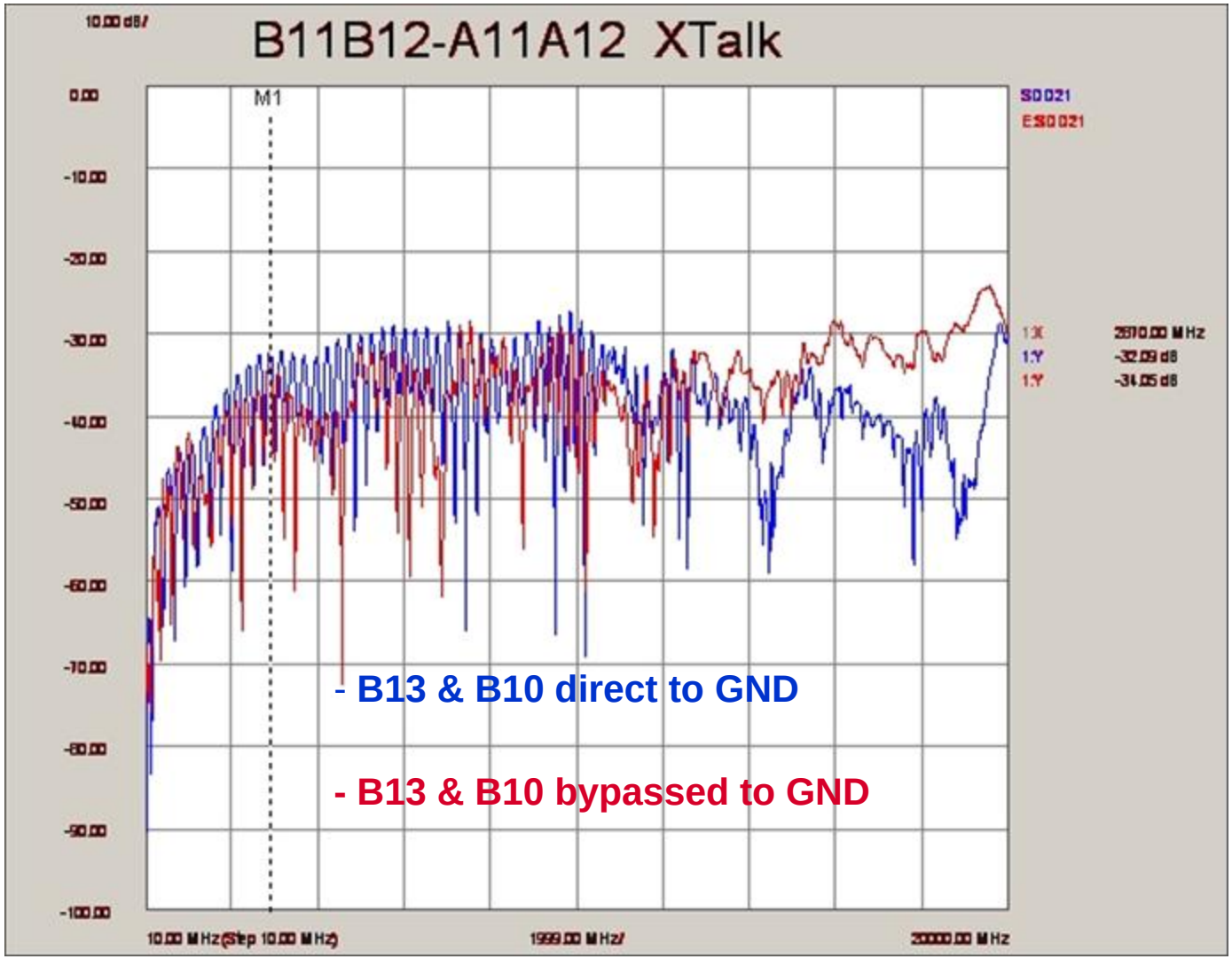
- A concern is sometimes voiced that using ground pins for power may undermine crosstalk performance, in particular when a passive legacy cable is used on an active port.

- Experience from other standards suggest that bypassing the ground pins (with ~ 10nF chip capacitors) combined with capacitive coupling of the power planes and the ground planes on the system side relieves this concern.

Power Delivery *(continued):*

- To confirm, the following test has been done:
  - B13 and B10 ground pins were lifted of a mini-SAS SMA test board, then reconnected through 10nF 0603 caps.
  - A 0.5m mini-SAS cable assembly was connected, with another SMA board terminated to 50 Ohm at the far end.
  - Worst-case NEXT (between B11B12 and A11A12 pairs) was measured with an Agilent VNA, before and after the modification.
  - No change other than caused by PCB variations was observed (if anything, bypassing brought the ringing down).

Power Delivery *(continued):*



Backward Compatibility:

shall not operate

shall operate

Keying may be added to allow passive (legacy) cables to plug into an active port, but not the other way round, if the group so desires.

Backward Compatibility (Keying)*:*

Keying Options for Active Mini-SAS:

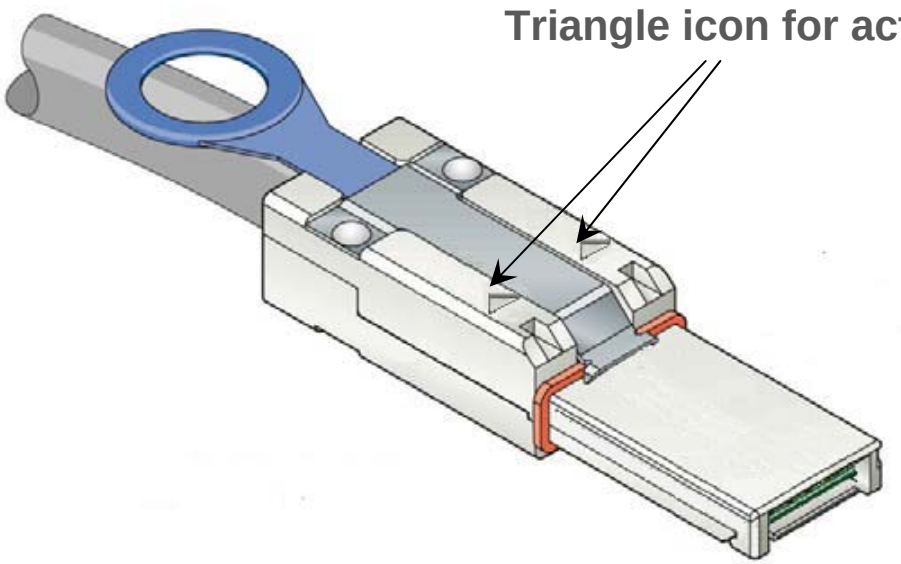
1) Reverse-Gender Key: key on the plug, key slot on the receptacle

- Pros: Allows maximum differentiation
- Cons: Retooling of both plug and receptacle needed, added COST; Impact on EMI unclear; requires resources to develop

3) No Key Slots on the plug, no keys on the receptacle

- Pros: EASY
- Cons: No Table/Substractive Differentiation (may not be necessary, most receptacles moving to universal); not clear what to do distinguish with mini-SATA connectors if SATA also adopts active cable support.

Backward Compatibility (Keying)*:*



Active mini-SAS plug connector

08-052r3

Proposal for SAS 2.x Specification to Enable Support for Active Cables

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March 7, 2008

Introduction

Inclusion of active cable interconnect option into the SAS specification would be beneficial in that it enables active copper and optical interconnects, to support longer reaches, lighter cable, etc.

It is proposed that active cable support may be enabled in the intermediate SAS-2.x specification by making minimum changes to the SAS-2 spec and inserting a section on power supply option.
A proposal for such changes and a stating point for the text of specification is presented.

Changes Since 01/08/2008

- Removed the 1.2V power supply option – the proposal now has a single 3.3V supply.
- Added a section on capacitive coupling.

Changes Since 02/12/2008

- Added a sections, tables and figures for keying of active cable: prevents active cable from plugging into a passive port, while allowing passive cable to plug into an active port.

List of Proposed Modifications to SAS 2.0 to Enable Active Cables

- The title of section 5.2 “Passive Interconnect” shall be changed to read “Interconnect Characteristics”.
- The title of subsection 5.2.4 “Cable assemblies” shall be changed to read “Passive Cable assemblies”.
- The title of subsection 5.2.6 “Cable assembly and backplane specifications” shall be changed to read “Passive cable assembly and backplane specifications”.
- A subsection 5.2.7 titled “Active Cables” shall be inserted with text as per pages 3-7 of this document.
- The table numbering in section 5.3 and onwards shall be changed so that Table 57 becomes Table 61, etc.
- The figure numbering in section 5.3 and onwards shall be changed so that Figure 98 becomes Figure 99, etc.

5.2.7 Active cables

5.2.7.1 Active cable overview

The standard provides support for the cable assemblies which incorporate active circuitry. This includes but is not limited to cables with built-in drivers, repeaters, equalizers, as well as copper cable substitutes which incorporate electro-optical converters and optical transceivers.

In order to enable the operation of devices inside the active cable assemblies, 3.3 V power supply option is made available in the connectors.

The powered ports (receptacles) defined in this standard are required to function when passive cables are plugged into them. This means that they must be able to handle the condition where their power supply pins are shorted to ground for any arbitrary length of time. Therefore, voltage sense pins are used to enable the switching of power in these ports.

Active cable assemblies defined in this standard, when plugged into SAS 2.0 (unpowered) ports will not function.

All active cables defined in this standard are external cable assemblies, and they may be SAS 4x – to – SAS 4x; Mini SAS – to – Mini SAS; and SAS 4x – to – Mini SAS, similarly to passive assemblies defined in 5.2.4.2, except that active connectors defined in 5.2.7.2 with corresponding sense and power pin assignments are used.

Because of a wide range of implementations, technologies and transmission media available for the design of active cables, the specification of high-speed data transmission performance of these cables is beyond the scope of this standard. It is understood that the design of active cables shall be such as to provide operation with the transmitter and receiver defined in section 5.3 of this standard.

5.2.7.2 Active connectors

5.2.7.2.1 SAS 4x active connectors

5.2.7.2.1.1 SAS 4x active plug connector

The SAS 4x active cable plug connector is the same as the passive connector defined in 5.2.3.3.1.1) and shown in figure 74.

5.2.7.2.1.2 SAS 4x active receptacle connector

The SAS 4x active receptacle connector is the same as the passive connector defined in 5.2.3.3.1.1 and shown in figure 75

5.2.7.2.1.3 SAS 4x active connector pin assignments

Table 57 defines the pin assignments for SAS 4x cable plug connectors (see 5.2.7.2.1.1)

and SAS 4x receptacle connectors (see 5.2.7.2.1.2) for applications using one, two, three, or four of the physical links.

Table 57 — SAS 4x active connector pin assignments and physical link usage

Signal	Pin usage based on number of physical links supported by the cable assembly [a]			
	One	Two	Three	Four
Rx 0+	S1	S1	S1	S1
Rx 0-	S2	S2	S2	S2
Rx 1+	N/C	S3	S3	S3
Rx 1-	N/C	S4	S4	S4
Rx 2+	N/C	N/C	S5	S5
Rx 2-	N/C	N/C	S6	S6
Rx 3+	N/C	N/C	N/C	S7
Rx 3-	N/C	N/C	N/C	S8
Tx 3-	N/C	N/C	N/C	S9
Tx 3+	N/C	N/C	N/C	S10
Tx 2-	N/C	N/C	S11	S11
Tx 2+	N/C	N/C	S12	S12
Tx 1-	N/C	S13	S13	S13
Tx 1+	N/C	S14	S14	S14
Tx 0-	S15	S15	S15	S15
Tx 0+	S16	S16	S16	S16
Sense-3.3V	G7			
Vcc	G8			
SIGNAL GROUND	G1 – G6, G9			
CHASSIS GROUND	Housing			

[a] N/C = not connected

SIGNAL GROUND shall not be connected to CHASSIS GROUND in the connector when used in a cable assembly.

5.2.7.2.2 Mini SAS 4x active connectors

5.2.7.2.2.1 Mini SAS 4x active cable plug connector

The Mini SAS 4x active cable plug connector is the same as the passive connector: the free (plug) 26-circuit Shielded Compact Multilane connector defined in SFF-8088.

In order to ensure that active cables cannot be plugged into legacy (passive) ports, differentiating keying shall be provided by removing all the key slots from the plug connector and all the keys on the receptacle connector. In addition, two triangle icons on each side on the plug connector will be added to the plug connector to distinguish an active cable assembly (Figure 98).

Table 58 defines the icons that shall be placed on or near Mini SAS 4x cable plug connectors and the key slot positions (see SFF-8088) that shall be used by Mini SAS 4x cable plug connectors.

Table 58 — Mini SAS 4x active cable plug connector icons and key slot positions

Use	Icon	Key slot positions	Reference
End of a SAS external cable that attaches to an end device, or an enclosure universal port	2 Triangles	None	Figure 98

Figure 98 shows an active mini SAS 4x cable plug connector that attaches to an enclosure universal port:

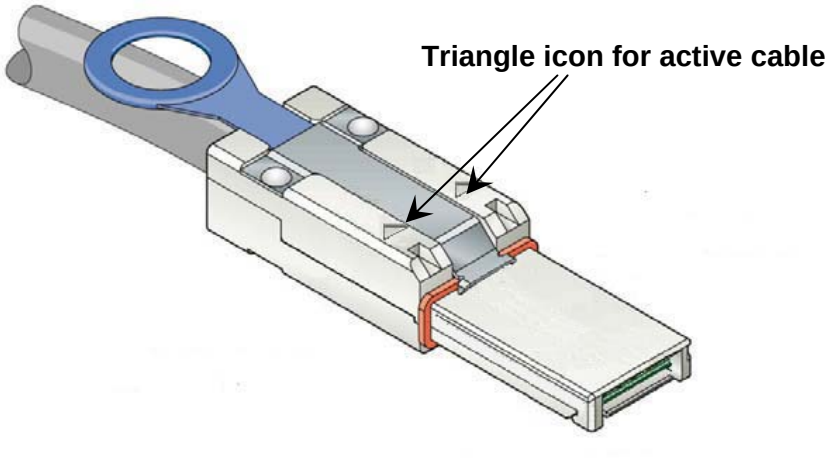

Figure 98 — Mini SAS 4x cable plug connector that attaches to an enclosure universal port

5.2.7.2.2.2 Mini SAS 4x active receptacle connector

The Mini SAS 4x active receptacle connector is the fixed (receptacle) 26-circuit Shielded Compact Multilane connector defined in SFF-8088 and shown in figure 79.

In order to ensure that active cables cannot be plugged into legacy (passive) ports, differentiating keying shall be provided by removing all the key slots from the plug connector and all the keys on the receptacle connector. In addition, two triangle icons shall be placed near the receptacle to identify active receptacle connectors.

Table 59 defines the icons that shall be placed on or near Mini SAS 4x receptacle connectors and the key positions (see SFF-8088) that shall be used by active Mini SAS 4x receptacle connectors.

Table 59 — Mini SAS 4x active cable receptacle connector icons and key slot positions

Use	Icon	Key positions
End device or enclosure universal port	2 Triangles	None

5.2.7.2.2.3 Mini SAS 4x active connector pin assignments

Table 60 defines the pin assignments for Mini SAS 4x cable plug connectors (see 5.2.7.2.2.1) and Mini SAS 4x receptacle connectors (see 5.2.7.2.2.2) for applications using one, two, three, or four of the physical links.

Table 59 — SAS 4x active connector pin assignments and physical link usage

Signal	Pin usage based on number of physical links supported by the cable assembly [a]				Mating level
	One	Two	Three	Four	
Rx 0+	A2	A2	A2	A2	Third
Rx 0-	A3	A3	A3	A3	
Rx 1+	N/C	A5	A5	A5	
Rx 1-	N/C	A6	A6	A6	
Rx 2+	N/C	N/C	A8	A8	
Rx 2-	N/C	N/C	A9	A9	
Rx 3+	N/C	N/C	N/C	A11	
Rx 3-	N/C	N/C	N/C	A12	
Tx 0+	B2	B2	B2	B2	
Tx 0-	B3	B3	B3	B3	
Tx 1+	N/C	B5	B5	B5	
Tx 1-	N/C	B6	B6	B6	
Tx 2+	N/C	N/C	B8	B8	
Tx 2-	N/C	N/C	B9	B9	
Tx 3+	N/C	N/C	N/C	B11	
Tx 3-	N/C	N/C	N/C	B12	
Sense 3.3 V	B10				First
Vcc	B13				
SIGNAL GROUND	A1, A4, A7, A10, A13, B1, B4, B7				
CHASSIS GROUND	Housing				
[a] N/C = not connected					N/A

SIGNAL GROUND shall not be connected to CHASSIS GROUND in the connector when used in a cable assembly.

5.2.7.3 Active cable power requirements

5.2.7.3.1 Active cable power overview

Active SAS 4x and Mini SAS 4x cables may contain integrated active devices such as drivers, repeaters, equalizers, as well as electro-optical converters and optical transceivers for fiber-optic assemblies. In order to enable the operation of these devices, 3.3 V power supply is provided.

Because active SAS 4x and Mini SAS 4x receptacle connectors must be intermateable with legacy passive cables, there will be times when the power supply pins will be shorted to ground. Sense pins are therefore defined (see Tables 57 and 58) in order to enable the power circuitry to supply power only when an active cable assembly is plugged in, and to remain in the default “off” state when a passive cable or no cable is plugged in.

5.2.7.3.2 Power consumption

The voltage and current requirements are such as to enable support for active cable assemblies with power consumption at 3.3 V of up to 2 W per an interface with four functioning links.

5.2.7.3.3 Voltage

The active cable 3.3 V voltage shall be a minimum of 3.13 V at maximum current and a maximum of 3.47 V at any current, measured at the Vcc pin of the receptacle connector.

5.2.7.3.4 Current

The active cable power interface shall be capable of supplying a minimum of 639 mA of current at 3.13 V and per an interface with four functioning links.

Each end of an active cable assembly with four functioning links operating with the 3.3 V power supply option shall consume a maximum of 639 mA.

5.2.7.3.5 Voltage Sense

The active cable assembly shall provide a connection of the Sense pin to ground via a 5 kOhm (±5%) resistor.

The active cable power supply circuitry shall enable power to the receptacle connector only when the presence of the Sense resistor is detected, and it shall be disabled if the Sense pin is open (no cable plugged in) or shorted to ground (passive cable).

5.2.7.3.6 Short Circuit Protection

The active cable power supply shall have protection against the connection of its pins to ground, and shall limit short circuit current to below 50 mA when equivalent load resistance is less than 1 Ohm.

5.2.7.3.7 Hot-pluggable operation

In order to support hot plugging, the active cable power supply circuitry shall be able to detect the Sense resistor value and provide full current within 50 milliseconds of cable connection.

5.2.7.3.8 Bypassing

The active cable power pins (Vcc and Sense) shall be coupled to ground via bypass capacitors in such a way as to have low impedance to ground from 100 MHz to 1.5 times the fundamental frequency of the maximum baud rate supported by the port. These bypassing shall be present both in the receptacle and the plug.

5.2.7.3.9 Capacitive coupling

In addition to bypassing, the system designers shall ensure that the power planes of the system (on the receptacle side) are sufficiently coupled to ground.

5.2.7.3.10 Voltage Converters (DC-to-DC)

In specific implementations where the active circuitry in the cable requires voltages other than the provided 3.3 V, local voltage regulators may be used. These regulators shall be located within the active cable assembly.

Thank You!