Active Copper Cables for SAS-2.x
(supporting presentation for 08-052r2 proposal)

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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
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)

<table>
<thead>
<tr>
<th>Signal</th>
<th>Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rx 0+</td>
<td>S1</td>
</tr>
<tr>
<td>Rx 0-</td>
<td>S2</td>
</tr>
<tr>
<td>Rx 1+</td>
<td>S3</td>
</tr>
<tr>
<td>Rx 1-</td>
<td>S4</td>
</tr>
<tr>
<td>Rx 2+</td>
<td>S5</td>
</tr>
<tr>
<td>Rx 2-</td>
<td>S6</td>
</tr>
<tr>
<td>Rx 3+</td>
<td>S7</td>
</tr>
<tr>
<td>Rx 3-</td>
<td>S8</td>
</tr>
<tr>
<td>Tx 3-</td>
<td>S9</td>
</tr>
<tr>
<td>Tx 3+</td>
<td>S10</td>
</tr>
<tr>
<td>Tx 2-</td>
<td>S11</td>
</tr>
<tr>
<td>Tx 2+</td>
<td>S12</td>
</tr>
<tr>
<td>Tx 1-</td>
<td>S13</td>
</tr>
<tr>
<td>Tx 1+</td>
<td>S14</td>
</tr>
<tr>
<td>Tx 0-</td>
<td>S15</td>
</tr>
<tr>
<td>Tx 0+</td>
<td>S16</td>
</tr>
<tr>
<td>Sense-3.3V</td>
<td>G7</td>
</tr>
<tr>
<td>Vcc</td>
<td>G8</td>
</tr>
<tr>
<td>SIGNAL GND</td>
<td>G1 – G6, G9</td>
</tr>
<tr>
<td>CHASSIS GND</td>
<td>Housing</td>
</tr>
</tbody>
</table>
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.
• 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.
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):

- B13 & B10 direct to GND
- B13 & B10 bypassed to GND
Backward Compatibility:

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/Subtractive 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
Thank You!