Cable Discharge Event (CDE) Automated Test System Based on TLP Method

Draft V3-2016.03.18
What is CDE Event?
A Cable Discharge Event (CDE) is electrostatic discharge(s) between metal of a cable connector and the mating cable connector or plug. It is very common in daily life.

When CDE happens, transient high current and high voltage pulses are generated into the connector pins and cause potential damage to the system with connector. The pulse characteristic is determined by the cable type, cable length, physical arrangement of the cable and system with connector, and system with connector side circuitry.
Why understanding CDE robustness is important? The discharge processes are complicated due to the number of pins involved and their connections to a system. In addition, the occurrence rate and severity of the static discharge is important to design a robust system.

Basic System Features:
- A well repeatable test setup to reproduce cable discharge events
- Pulse injection level covers different types of cable connections

Additional System Features:
- Automatic computer controlled test for all available connector pins
- Automatic remove DUT residue charge safely after each pulse safely
- Integrate current and voltage probes to monitor CDE events on each pin
## ESDEMC Collected Cable Pins and Practical Passive Cable Length - Page 1

<table>
<thead>
<tr>
<th>Type</th>
<th>Sub Connector Type</th>
<th>Min Pins #</th>
<th>Max Pins #</th>
<th>Practical Passive Cable Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio Connector</td>
<td>TRS connector</td>
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<td>4</td>
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<td></td>
<td>XLR connector</td>
<td>3</td>
<td>7</td>
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<td></td>
<td>RCA connector</td>
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<td>6</td>
<td>20</td>
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<td></td>
<td>BNC connector</td>
<td>2</td>
<td>2</td>
<td>305 (1000 ft)</td>
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<td>Video Connectors</td>
<td>VGA (Video Graphics Array)</td>
<td></td>
<td></td>
<td>15 10 40</td>
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<td></td>
<td>DVI (Digital Visual Interface)</td>
<td></td>
<td></td>
<td>29 15</td>
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<tr>
<td></td>
<td>S-Video (Mini-DIN_connector)</td>
<td>3</td>
<td>9</td>
<td>46 (150 ft)</td>
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<td>Video and Audio</td>
<td>SCART</td>
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<td></td>
<td></td>
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<td></td>
<td>HDMI (High-Definition Multimedia Interface)</td>
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<td></td>
<td>DisplayPort</td>
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<td></td>
<td>IEEE 1394</td>
<td>4</td>
<td>9</td>
<td>4.5</td>
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<td>MHL (Mobile High-Definition Link)</td>
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<td>1.5</td>
<td></td>
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<tr>
<td></td>
<td>Thunderbolt</td>
<td></td>
<td></td>
<td>20 3</td>
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<tr>
<td>SATA</td>
<td>SATA</td>
<td>7 + 15</td>
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<td></td>
<td>eSATA</td>
<td>7</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>eSATA USB Hybrid</td>
<td>4 + 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>eSATAp</td>
<td>4 + 7 + 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Sub Connector Type</td>
<td>Min Pins #</td>
<td>Max Pins #</td>
<td>Practical Passive Cable Length (m)</td>
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<tr>
<td>------------</td>
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<td>-----------------------------------</td>
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<tr>
<td>USB</td>
<td>USB 1.1</td>
<td>4</td>
<td>5</td>
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</tr>
<tr>
<td></td>
<td>USB 2.0</td>
<td>4</td>
<td>5</td>
<td></td>
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<td></td>
<td>USB 3.0</td>
<td>NA</td>
<td>9</td>
<td>3 (practical for AWG26)</td>
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<td></td>
<td>USB 3.1</td>
<td>NA</td>
<td>24</td>
<td>3 (practical for AWG26)</td>
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<td>RS-422</td>
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<td>1500</td>
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<td>RS-423</td>
<td>3</td>
<td>NA</td>
<td>1200</td>
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<td>RS-485</td>
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<td>NA</td>
<td>1200</td>
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<td>Ethernet</td>
<td>RJ45</td>
<td>9</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>D-subminiature</td>
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<td>50</td>
<td>NA</td>
</tr>
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<td></td>
<td>IEEE-488</td>
<td>24</td>
<td>20</td>
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<td></td>
<td>OBD-2</td>
<td>16</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Other Interface</td>
<td>SIM Cards</td>
<td>8</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SDIO</td>
<td>8</td>
<td>9</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Push Button</td>
<td>2</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>
1. In general, maximum pin number for common cables is $<32$

2. The typical passive cable length are: $3, 5, 20\ m$ ($1, 50, 100\ m$ are also possible) which roughly gives $30, 50, 200\ ns$ pulse width

3. The rise-time, depends on cable arrangement, $<10\ ns$ is a good start.

A universal cable discharge system concept based on TLP Pulsed IV-Curve system with automated discharge path control box:

Basic TLP Concept with transient voltage and current monitor:

http://www.infineon.com/dgdl/AN210_v1_3.pdf?fileId=db3a30432cd42ee3012cee8d005b0c19

Semtech Introduction to Transmission Line Pulse (TLP) Testing.ppt
1. **ES620 Transmission Line Pulse (TLP) System**
The transmission line pulse generator is able to generate rise-time < 10ns, pulse width options of 30, 50, 200 ns and voltage level up to 2 kV (for 50 Ohm load). Programmable pulse width switching option and additional pulse width options should be available.

2. **DUT Transient IV Monitor (optional module of ES620 TLP System)**
Monitor the current injected into and voltage applied across the 2 pin DUT.

3. **DUT Failure Monitor (customized module)**
This unit should be customized for each application with specific failure definition.

4. **Automatic DUT Switching Box (optional module of ES620 TLP System)**
This computer controlled module is designed to automatic switching test pins on the same cable, it should also allow user to adapt different cables connectors easily.

**Total cost of such generic CDE test solution would depends on configuration.**
The potential limitation of such generic CDE system

Due to the Generic CDE System design limitation, there are special cases of CDE that may not be covered by such generic design:

1. Ultra-fast rise-time cases
   When the rise time is fast like below 1ns, it exists in real world but such pulse cannot be easily injected and measured by fully automated switching box, the study of such case should be using ES620 system’s vf-TLP setup.

2. Ultra long cable like 1500 meter RS485, 100+ meter Ethernet cable
   When the cable length is so long, the generic CDE system setup may not be able to handle the pulse energy or measure the long duration pulse. Specialized CDE test setup should be developed for those cases, such as ES631 Ethernet Cable Discharge System.

3. Multiple-pins pre-connected configuration
   The current design allows a single cable to be charged and discharge into 1 pin of the DUT, in the real-world, there are possibly multiple pins are pre-connected that creates new discharge current return path. This cannot be simulated with 1 to N automated switching box. A much more complex switching arrays would be needed if multiple-pins pre-connected configuration is a consideration.
Test Setup

- TLP Pulse, rise-time <= 5 ns, Pulse width 100ns
- 70 to 90 % Measurement Window
- Voltage Sweep: 3 to 2550V or to failure as indicated by leakage current change
Pulse Shape Check with different cable length from DUT

The characteristics (length and impedance) of the cable between Multi-Pin Switch Box and DUT could change the pulse shape applied onto the DUT. Several cases have been checked by using different cables:

- M1 – Original TLP pulse before Multi-pin Switch Box
- M2 – Pulse right after the Switch Box (thru with 50Ω coax)
- M3 – Thru 1ft of USB3.0 Cable to Oscilloscope (photos)
- M4 – Thru 3ft of USB2.0 Cable to Oscilloscope

Noticed that the 3 ft USB 2.0 cable has less distortions and reflections than the 1 ft USB 3.0 cable. This is due to the wire impedance to the ground or shield.
TDR Comparison of the previously used 1ft and 3ft cables

- Care must be taken in selection of test cable, as the Line to GND or shielding impedance may not be well matched
- 1ft USB3.0 Cable is around 75Ω, while 3ft USB2.0 Cable is 52Ω
CDE Test and Failure Check Method

The failure is monitored by applying 1 V onto the test pin and measuring the current. If physical damaged occurs, the current value may change.

A minor change indicates the degrade of the device.

A drastic change indicates the break down of the device.

The waveforms of the current injected into the device and the voltage across the device are monitored at each level and can be used for failure analysis.
## Comparison Strategy

- Measured Dynamic IV & Leakage current, on the Data (-) and Data (+) lines.
  - Measured both **Powered & Unpowered**.
  - **Unpowered Tests**: no connection of the USB hub to a computer during Dynamic IV & Leakage Current measurement.
  - **Powered Tests**: the USB hub was connected to a computer during Dynamic IV & Leakage Current measurement.

- Measured Four (4) Zenhub USB 2.0 hubs with FE1.1s controllers.
  - **Expectation #1**: Same manufacturer and design layout around the FE1.1s controller should provide a consistent measurement result for the CDE Automatic Test System.

- Measured three (3) different USB 2.0 hubs from different manufacturers with FE1.1s controllers.
  - **Expectation #2**: Different manufacturers will have different design layouts around the FE1.1s controller, and some variation could occur.

- Measured two (2) different USB 2.0 hubs from different manufacturers with **FE2.1** controllers.
  - **Expectation #3**: Different USB 2.0 controller could have some variation from the FE1.1s controllers.

- Measured a USB 3.0 hub with RTS5411 controller & a USB 3.0 hub with VL812 controller.
  - **Expectation #4**: USB 3.0 controllers could have some variation from USB 2.0 controllers.

- In the slides to follow, the terms mentioned are defined below:
  - **Failure**: when the leakage currents went to the compliance limit of the SMU. Failure was also verified by connecting a flash drive to the tested port to see if the computer would recognize and allow use through the port.
  - **Degradation**: when the leakage current began to vary from its nominal level.
USB 2.0 Hub Testing: FE1.1s Controller

Asus Zenhub
- FE1.1s Controller
  - [http://www.dx.com/p/asus-zenhub](http://www.dx.com/p/asus-zenhub)

Amazon Basics
- FE1.1s Controller
  - [http://www.amazon.com/AmazonBasics-4-Port-USB-2-0-Ultra-Mini/dp/B003M0NURK](http://www.amazon.com/AmazonBasics-4-Port-USB-2-0-Ultra-Mini/dp/B003M0NURK)

Sabrent
- FE1.1s Controller
  - [https://www.sabrent.com/category/usb-hubs](https://www.sabrent.com/category/usb-hubs)

eLife (Shenzhen Hexing)
- FE1.1s Controller
  - [https://www.sabrent.com/category/usb-hubs](https://www.sabrent.com/category/usb-hubs)
USB 2.0 Hub Testing: FE2.1 Controller

Pisen
• FE2.1 Controller

Moelissa
• FE2.1 Controller
USB 3.0 Hub Testing

Sabrent USB3.0 Hub
• RTS5411 Controller

https://www.sabrent.com/category/usb-hubs

Plugable USB3.0 Hub
• VL812 Controller

http://www.amazon.co.uk/Plugable-SuperSpeed-Adapter-Backwards-Compatibility/dp/B009EX24T4
Zenhub USB 2.0, FE1.1s Controller: Data (-) and Data (+) Lines Comparison

- Compare performance of Data (-) and Data (+) lines in regard to failure points.
  - After each test the Data Lines were physically & permanently damage so could only compare different ports.
    - Unpowered comparison: HubX Port1 Data (-) as compared to HubX Port3 Data(+)
    - Powered comparison: HubX Port2 Data (-) as compared to HubX Port4 Data(+)
- As seen below, the Data (-) and Data (+) lines are very similar.
- Data (-) and Data (+) lines will be combined to obtain average values in proceeding slides.

### Unpowered Pulse Voltage at Failure

<table>
<thead>
<tr>
<th>Hub and Port Numbers</th>
<th>Data (-)</th>
<th>Data (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hub1 P1 &amp; P3</td>
<td>510</td>
<td>530</td>
</tr>
<tr>
<td>Hub2 P1 &amp; P3</td>
<td>510</td>
<td>530</td>
</tr>
<tr>
<td>Hub3 P1 &amp; P3</td>
<td>510</td>
<td>530</td>
</tr>
<tr>
<td>Hub4 P1 &amp; P3</td>
<td>510</td>
<td>530</td>
</tr>
</tbody>
</table>

### Unpowered DUT Current at Failure

<table>
<thead>
<tr>
<th>Hub and Port Numbers</th>
<th>Data (-)</th>
<th>Data (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hub1 P1 &amp; P3</td>
<td>8</td>
<td>8.5</td>
</tr>
<tr>
<td>Hub2 P1 &amp; P3</td>
<td>8</td>
<td>8.5</td>
</tr>
<tr>
<td>Hub3 P1 &amp; P3</td>
<td>8</td>
<td>8.5</td>
</tr>
<tr>
<td>Hub4 P1 &amp; P3</td>
<td>8</td>
<td>8.5</td>
</tr>
</tbody>
</table>

### Powered Pulse Voltage at Failure

<table>
<thead>
<tr>
<th>Hub and Port Numbers</th>
<th>Data (-)</th>
<th>Data (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hub1 P2 &amp; P4</td>
<td>490</td>
<td>470</td>
</tr>
<tr>
<td>Hub2 P2 &amp; P4</td>
<td>490</td>
<td>470</td>
</tr>
<tr>
<td>Hub3 P2 &amp; P4</td>
<td>490</td>
<td>470</td>
</tr>
<tr>
<td>Hub4 P2 &amp; P4</td>
<td>490</td>
<td>470</td>
</tr>
</tbody>
</table>

### Powered DUT Current at Failure

<table>
<thead>
<tr>
<th>Hub and Port Numbers</th>
<th>Data (-)</th>
<th>Data (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hub1 P2 &amp; P4</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Hub2 P2 &amp; P4</td>
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<td>9.5</td>
</tr>
<tr>
<td>Hub3 P2 &amp; P4</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Hub4 P2 &amp; P4</td>
<td>9.5</td>
<td>9.5</td>
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</tbody>
</table>
Four Zenhub USB 2.0 Hubs with FE1.1s Controller

Error bars indicate standard deviation
• Unpowered – 11.7
• Powered – 11.1

X-Axis Labeling Examples:
H1P1DM – Hub1, Port1, Data (-)
H1P2DP – Hub1, Port2, Data (+)

<table>
<thead>
<tr>
<th></th>
<th>Unpowered</th>
<th>Powered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Pulse Voltage at Failure</td>
<td>560.0</td>
<td>11.5</td>
</tr>
<tr>
<td>Avg. DUT Current at Failure</td>
<td>460.0</td>
<td>9.4</td>
</tr>
<tr>
<td>Hub #1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hub #2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hub #3</td>
<td>535.0</td>
<td>10.9</td>
</tr>
<tr>
<td>Hub #4</td>
<td>550.0</td>
<td>10.8</td>
</tr>
<tr>
<td>All</td>
<td>551.3</td>
<td>11.0</td>
</tr>
<tr>
<td>Avg. Pulse Voltage at Failure</td>
<td>466.3</td>
<td>9.3</td>
</tr>
<tr>
<td>Avg. DUT Current at Failure</td>
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<td></td>
</tr>
</tbody>
</table>

DUT Current at Failure

Error bars indicate standard deviation
• Unpowered – 0.3
• Powered – 0.1
Four Zenhub comparison to Three Other USB 2.0 Hubs with FE1.1s Controllers

<table>
<thead>
<tr>
<th></th>
<th>Unpowered</th>
<th></th>
<th>Powered</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg. Pulse Voltage at Failure</td>
<td>Avg. DUT Current at Failure</td>
<td>Avg. Pulse Voltage at Failure</td>
<td>Avg. DUT Current at Failure</td>
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<td>4 Zenhub Avg.</td>
<td>551.3</td>
<td>11.0</td>
<td>466.3</td>
<td>9.3</td>
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<tr>
<td>Sabrent</td>
<td>510.0</td>
<td>10.2</td>
<td>445.0</td>
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<tr>
<td>Amazon Basics</td>
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<td>11.0</td>
<td>470.0</td>
<td>9.4</td>
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<td>eLife</td>
<td>545.0</td>
<td>10.9</td>
<td>470.0</td>
<td>9.3</td>
</tr>
<tr>
<td>All FE1.1s</td>
<td>541.6</td>
<td>10.8</td>
<td>462.8</td>
<td>9.2</td>
</tr>
</tbody>
</table>
Four Zenhub comparison to Three Other USB 2.0 Hubs with FE1.1s Controllers Cont’d

Error bars indicate standard deviation
- Unpowered – 21.5
- Powered – 12.4

X-Axis Labeling Examples:
- Zenhub Avg – Data from all ports & data lines averaged
- Brand P1DM – Amazon Basics, Port1, Data (-)
- Brand P7DP – eLife Port7, Data (+)

Error bars indicate standard deviation
- Unpowered – 0.4
- Powered – 0.3
Two Other USB 2.0 Hubs with FE2.1 Controllers, and Two USB 3.0 Controllers

Error bars indicate standard deviation
- Unpowered – 129.1
- Powered – 23.2

X-Axis Labeling:
- All FE1.1s Avg – Data from all ports & data lines of all FE1.1s controllers averaged
- Pisen USB 2.0 FE2.1 – Data from all ports & data lines averaged for this brand
- Moelissa USB 2.0 FE2.1 – Data from all ports & data lines averaged for this brand
- Sabrent USB 3.0 – Data from all ports & data lines averaged for this brand
- Plugable USB 3.0 – Data from all ports & data lines averaged for this brand

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Sample Device</th>
<th>Unpowered</th>
<th>Powered</th>
<th>Unpowered</th>
<th>Powered</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All FE1.1s</td>
<td>541.6</td>
<td>10.8</td>
<td>462.8</td>
<td>9.2</td>
</tr>
<tr>
<td>2</td>
<td>Pisen FE2.1</td>
<td>840.0</td>
<td>16.8</td>
<td>493.3</td>
<td>9.9</td>
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<td>3</td>
<td>Moelissa FE2.1</td>
<td>595.0</td>
<td>11.8</td>
<td>497.5</td>
<td>9.9</td>
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<td>4</td>
<td>Sabrent RTS5411</td>
<td>450.0</td>
<td>8.8</td>
<td>450.0</td>
<td>8.8</td>
</tr>
<tr>
<td>5</td>
<td>Plugable VL812</td>
<td>610.0</td>
<td>11.9</td>
<td>512.5</td>
<td>12.4</td>
</tr>
</tbody>
</table>

Error bars indicate standard deviation
- Unpowered – 2.6
- Powered – 1.3
USB 2.0 FE1.1s Testing: Data (-) Pin Unpowered & Powered

Unpowered, degradation begins @ 10 A

Unpowered, permanent damage @ 11.3

Powered, permanent damage @ 9.5 A

Powered, degradation begins @ 6.3 A

https://en.wikipedia.org/wiki/USB#2.0

http://www.dx.com/p/asus-zenhub

The type-A plug (left) and type-B plug (right)

Pin 1: Vbus (+5 V)
Pin 2: Data-
Pin 3: Data+
Pin 4: Ground

http://www.dx.com/p/asus-zenhub
USB 2.0 FE1.1s Testing: Data (-) Pin Unpowered & Powered

- Unpowered, degradation begins at 9 A
- Unpowered, permanent damage at 10.8 A
- Powered, degradation begins at 6 A
- Powered, permanent damage at 9.1 A

https://en.wikipedia.org/wiki/USB#2.0
http://www.dx.com/p/asus-zenhub

The type-A plug (left) and type-B plug (right)

Pin 1: Vbus (+5 V)
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http://www.dx.com/p/asus-zenhub

ESDEMC
Expert ESD/EMC Solutions
USB 2.0 FE1.1s Testing: Data (-) Pin Unpowered & Powered

Unpowered, degradation begins @ 9.4 A

Unpowered, permanent damage @ 11.1

Powered, permanent damage @ 9.6 A

Powered, degradation begins @ 6.7 A

https://en.wikipedia.org/wiki/USB#2.0

http://www.amazon.com/AmazonBasics-4-Port-USB-2-0-Ultra-Mini/dp/B003M0NURK
USB 2.0 FE1.1s Testing: Data (-) Pin Unpowered & Powered

- Unpowered, degradation begins @ 9 A
- Unpowered, permanent damage @ 10.4 A
- Powered, permanent damage @ 8.8 A
- Powered, degradation begins @ 2.8 A

https://en.wikipedia.org/wiki/USB#2.0
https://www.sabrent.com/category/usb-hubs
USB 2.0 FE1.1s Testing: Data (-) Pin Unpowered & Powered

Unpowered, degradation begins @ 9.5 A

Unpowered, permanent damage @ 10.9

Powered, permanent damage @ 9.4 A

Powered, degradation begins @ 6.1 A

https://en.wikipedia.org/wiki/USB#2.0
USB 2.0 FE2.1 Testing: Data (-) Pin Unpowered & Powered

+ Leakage does not go to compliance, - Leakage goes to compliance at 21.8 A, to keep scales consistent, did not plot to 22 A

Unpowered, degradation begins @ 12 A
Unpowered, permanent damage @ 21.8

Powered, permanent damage @ 10.2 A
Powered, degradation begins @ 7.1 A

http://www.aliexpress.com/store/product/Pisen-7-port-USB-HUB-TS-E017/712557_579624169.html

https://en.wikipedia.org/wiki/USB#2.0
USB 2.0 FE2.1 Testing: Data (-) Pin Unpowered & Powered

- Unpowered, degradation begins @ 10.3 A
- Unpowered, permanent damage @ 11.7
- Powered, permanent damage @ 10.6 A
- Powered, degradation begins @ 6 A
USB 3.0 Testing: Data (-) Pin Unpowered & Powered

Unpowered, degradation begins @ 8 A

Unpowered, permanent damage @ 8.8

Powered, permanently damaged @ 9.7 A

Powered, degradation begins @ 7.7 A

Sabrent USB3.0 Hub
- RTS5411 Controller

http://www.addonics.com/technologies/usb3_tutorial.php

https://www.sabrent.com/category/usb-hubs

EsdEMC
EXPERT ESD/EMC SOLUTIONS
USB 3.0 Testing: Data (-) Pin Unpowered & Powered

Unpowered, degradation begins @ 10.7 A

Unpowered, permanent damage @ 11.9

Powered, permanent damage @ 9.1 A

Powered, degradation begins @ 8.5 A

Plugable USB3.0 Hub
  • VL812 Controller

http://www.amazon.co.uk/Plugable-SuperSpeed-Adapter-Backwards-Compatibility/dp/B009EX24T4
USB 2.0 FE1.1s Testing: Data (+) Pin Unpowered & Powered

Unpowered, degradation begins @ 9.8 A
Unpowered, permanent damage @ 11.6

Powered, permanent damage @ 9.5 A
Powered, degradation begins @ 7 A

https://en.wikipedia.org/wiki/USB#2.0
http://www.dx.com/p/asus-zenhub

The type-A plug (left) and type-B plug (right)

Pin 1: Vbus (+5 V)
Pin 2: Data-
Pin 3: Data+
Pin 4: Ground

http://www.dx.com/p/asus-zenhub
USB 2.0 FE1.1s Testing: Data (-) Pin Unpowered & Powered

Measured Data (-) again, instead of Data (+)

- Unpowered, degradation begins @ 9 A
- Unpowered, permanent damage @ 10.9 A
- Powered, permanent damage @ 9.3 A
- Powered, degradation begins @ 6.1 A

https://en.wikipedia.org/wiki/USB#2.0
http://www.dx.com/p/asus-zenhub
USB 2.0 FE1.1s Testing: Data (+) Pin Unpowered & Powered

- Unpowered, degradation begins @ 9.6 A
- Unpowered, permanent damage @ 10.9 A
- Powered, permanent damage @ 9.6 A
- Powered, degradation begins @ 6.7 A

https://en.wikipedia.org/wiki/USB#2.0

http://www.amazon.com/AmazonBasics-4-Port-USB-2-0-Ultra-Mini/dp/B003M0NURK
USB 2.0 FE1.1s Testing: Data (+) Pin Unpowered & Powered

Unpowered, degradation begins @ 8.2 A

Unpowered, permanent damage @ 10

Powered, permanent damage @ 8.7 A

Powered, degradation begins @ 4.4 A

Data (+): Sabrent USB 2.0: FE1.1s Controller

Leakage Current, [A]

Current, [A]

Voltage, [V]

https://en.wikipedia.org/wiki/USB#2.0

https://www.sabrent.com/category/usb-hubs
USB 2.0 FE1.1s Testing: Data (+) Pin Unpowered & Powered

Unpowered, degradation begins @ 9.1 A

Unpowered, permanent damage @ 10.8 A

Powered, permanent damage @ 9.2 A

Powered, degradation begins @ 5.5 A

https://en.wikipedia.org/wiki/USB#2.0
USB 2.0 FE2.1 Testing: Data (+) Pin Unpowered & Powered

- Unpowered, degradation begins @ 10.8 A
- Unpowered, permanent damage @ 11.8
- Powered, permanent damage @ 10.2 A
- Unpowered, permanent damage @ 11.8

https://en.wikipedia.org/wiki/USB

http://www.aliexpress.com/store/product/Pisen-7-port-USB-HUB-TS-E017/712557_579624169.html
USB 2.0 FE2.1 Testing: Data (+) Pin Unpowered & Powered

Unpowered, degradation begins @ 10.5 A

Unpowered, permanent damage @ 11.9

Powered, permanent damage @ 9.7 A

Powered, degradation begins @ 2.4 A

https://en.wikipedia.org/wiki/USB#2.0

USB 3.0 Testing: Data (+) Pin Unpowered & Powered

Unpowered, degradation begins @ 7.7 A
Unpowered, permanent damage @ 8.8 A

Powered, permanent damage @ 7.8 A
Powered, degradation begins @ 4.9 A

Sabrent USB3.0 Hub
• RTS5411 Controller

http://www.addonics.com/technologies/usb3_tutorial.php

https://www.sabrent.com/category/usb-hubs
USB 3.0 Testing: Data (+) Pin Unpowered & Powered

Unpowered, degradation begins @ 10.9 A

Unpowered, permanent damage @ 11.8

Powered, degradation begins @ 8.7 A

Powered, permanent damage @ 10 A

Data (+): Plugable USB 3.0: VL812 Controller

Leakage Current, [A]

Current, [A]

Voltage, [V]

Plugable USB3.0 Hub
• VL812 Controller

http://www.amazon.co.uk/Plugable-SuperSpeed-Adapter-Backwards-Compatibility/dp/B009EX24T4

http://www.addonics.com/technologies/usb3_tutorial.php
USB 2.0 FE1.1s Testing: Vcc Pin Unpowered & Powered

Software was removing offset from measurement

- Unpowered: Leakage current depends on support circuitry, which is manufacturer dependent
- Powered: Both leakage currents at compliance
USB 2.0 FE1.1s Testing: Vcc Pin Unpowered & Powered

Software was removing offset from measurement

- Unpowered: + Leakage current depends on support circuitry, which is manufacturer dependent
- Powered: Both leakage currents at compliance

https://en.wikipedia.org/wiki/USB#2.0
http://www.dx.com/p/asus-zenhub
USB 2.0 FE1.1s Testing: Vcc Pin Unpowered & Powered

- Unpowered: + Leakage current depends on support circuitry, which is manufacturer dependent
- Powered: Both leakage currents at compliance

Offset was kept in the measurement

Vcc: Amazon Basics USB 2.0: FE1.1s Controller

Leakage Current, [A]

Unpowered Vcc
+Leakage
-Leakage
Powered Vcc
+Leakage
-Leakage

https://en.wikipedia.org/wiki/USB#2.0
http://www.amazon.com/AmazonBasics-4-Port-USB-2-0-Ultra-Mini/dp/B003M0NURK
USB buss was interrupted during measurement, and communication lost

- Unpowered: + Leakage current depends on support circuitry, which is manufacturer dependent
- Powered: Both leakage currents at compliance
**USB 2.0 FE1.1s Testing: Vcc Pin Unpowered & Powered**

- **Unpowered:** + Leakage current depends on support circuitry, which is manufacturer dependent
- **Powered:** Both leakage currents at compliance

[Graph showing leakage current vs voltage for Vcc pin in Unpowered and Powered modes]

Reference: https://en.wikipedia.org/wiki/USB#2.0
USB 2.0 FE2.1 Testing: Vcc Pin Unpowered & Powered

- Unpowered: + Leakage current depends on support circuitry, which is manufacturer dependent
- Powered: Both leakage currents at compliance
USB 2.0 FE2.1 Testing: Vcc Pin Unpowered & Powered

- Unpowered: + Leakage current depends on support circuitry, which is manufacturer dependent
- Powered: Both leakage currents at compliance
USB 3.0 Testing: Vcc Pin Unpowered & Powered

- Unpowered: + Leakage current depends on support circuitry, which is manufacturer dependent
- Powered: Both leakage currents at compliance

Sabrent USB3.0 Hub
- RTS5411 Controller

http://www.addonics.com/technologies/usb3_tutorial.php
https://www.sabrent.com/category/usb-hubs
USB 3.0 Testing: Vcc Pin Unpowered & Powered

- Unpowered: + Leakage current depends on support circuitry, which is manufacturer dependent
- Powered: Both leakage currents at compliance
ESDEMC starts the CDE related test equipment development from the early 2013, publications and test solutions has been achieved:

ES631-LAN 4kV Ethernet Cable Discharge Evaluation System
( Final development completed Dec 2014, Cisco has system installed May 2015)
Multi-pin contact sequence control is achievable, current probes are embedded, device failures can be automated with LabVIEW.
Related publication:
An Ethernet Cable Discharge Event (CDE) Test and Measurement System (pdf Link)

ES621-200 (10kV, 200 A) TLP system for solar cell bypass diodes ESD failure
(Developed in Dec 2013, test service has been used many times for PV diode qualification)
ESD Failure Analysis of PV Module Diodes and TLP Test Method (pdf Link)

ES620-50 (2.5KV, 50A) TLP system with X32 Multiplexer for Generic CDE (USB, HDMI ...)
(Latest development in Oct 2015, approaching potential customers for feedback and prepare commercial release)