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

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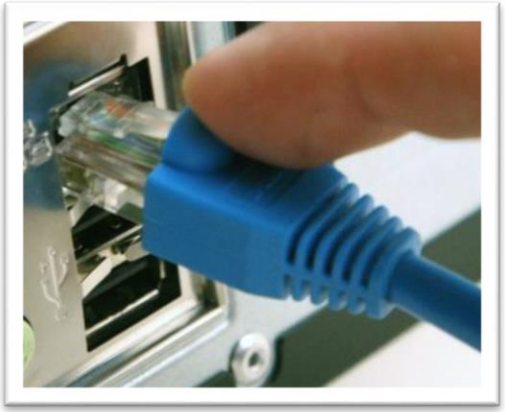
ESDEMC
EXPERT ESD/EMC SOLUTIONS

Cable Discharge Event (CDE) Background

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.

A Generic CDE System Concept

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

Type	Sub Connector Type	Min Pins #	Max Pins #	Practical Passive Cable Length (m)
Audio Connector	TRS connector	2	4	50
	XLR connector	3	7	250
	RCA connector	2	6	20
	BNC connector	2	2	305 (1000 ft)
Video Connectors	VGA (Video Graphics Array)		15	5 10 40
	DVI (Digital Visual Interface)		29	15
	S-Video (Mini-DIN_connector)	3	9	46 (150 ft)
Video and Audio	SCART			
	HDMI (High-Definition Multimedia Interface)		19	20
	DisplayPort			5
	HDBaseT	8	9	100
	IEEE 1394	4	9	4.5
	MHL (Mobile High-Definition Link)	6		1.5
	Thunderbolt		20	3
SATA	SATA		7 + 15	1
	eSATA		7	3
	eSATA USB Hybrid		4 + 7	
	eSATAp		4 + 7 + 2	

ESDEMC Collected Cable Pins and Practical Passive Cable Length - Page 2

Type	Sub Connector Type	Min Pins #	Max Pins #	Practical Passive Cable Length (m)
USB	USB 1.1		**4**	**5**
	USB 2.0		**4**	**5**
	USB 3.0	NA	**9**	**3 (practical for AWG26)**
	USB 3.1	NA	**24**	**3 (practical for AWG26)**
Serial Com	RS-232	3	**NA**	**50**
	RS-422	3	**NA**	**1500**
	RS-423	3	**NA**	**1200**
	RS-485	3	**NA**	**1200**
Ethernet	RJ45		**9**	**100**
Others	D-subminiature	9	**50**	**NA**
	IEEE-488		**24**	**20**
	OBD-2		**16**	**15**
Other Interface	SIM Cards		**8**	**NA**
	SDIO	8	**9**	**NA**
	Push Button	2		**NA**

ESDEMC Collected Critical Cable Parameters

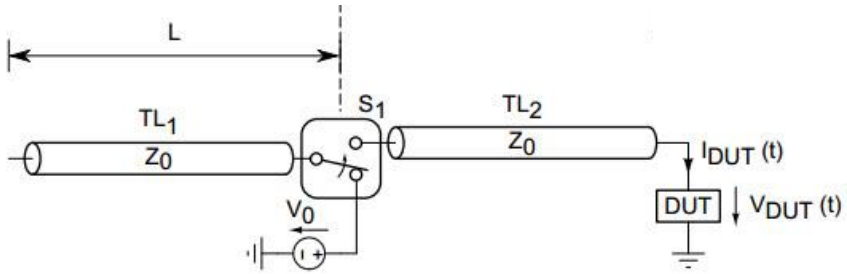
1. In general, maximum pin number for common cables is **< 32**

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**

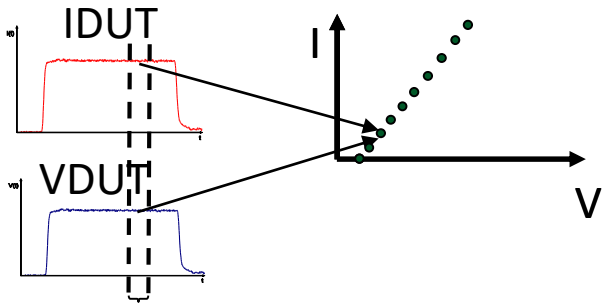
3. The rise-time, depends on cable arrangement, <10 ns is a good start.

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:



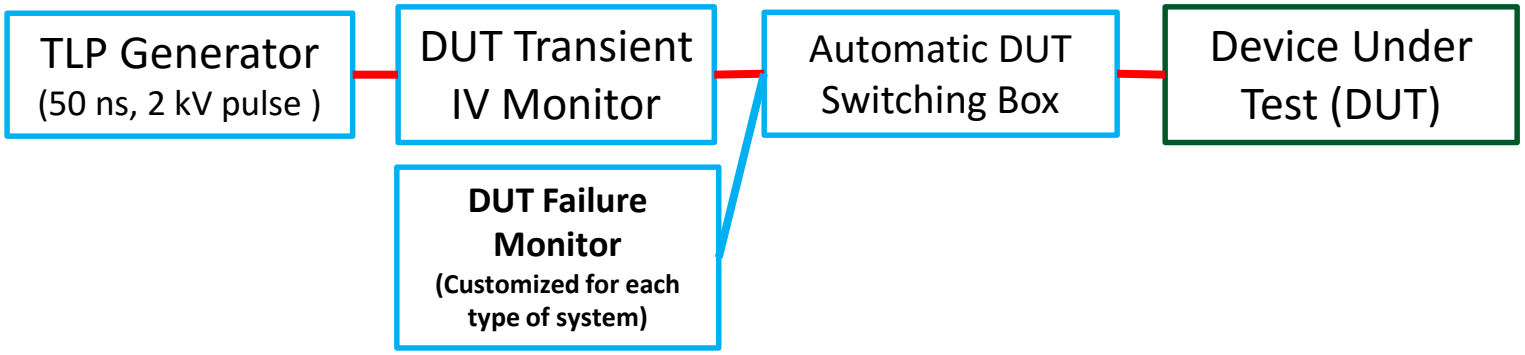
http://www.infineon.com/dgdl/AN210_v1_3.pdf?fileId=db3a30432cd42ee3012cee8d005b0c19



Semtech Introduction to Transmission Line Pulse (TLP) Testing.ppt

A Generic CDE System Concept

This generic CDE system will be consist of several functional units for specific applications



1. ES620 Transmission Line Pulse (TLP) System (Cost 25 to 60 K USD)

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, cost 20 K USD)

Monitor the current injected into and voltage applied across the 2 pin DUT

3. DUT Failure Monitor (customized module, cost ??, 10+ K USD for SMU)

This unit should be customized for each application with specific failure definition.

4. Automatic DUT Switching Box (optional module of ES620 TLP System, cost 20 K USD)

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 costs 25 to 100+ K USD 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 cover 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 can not be easily injection 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

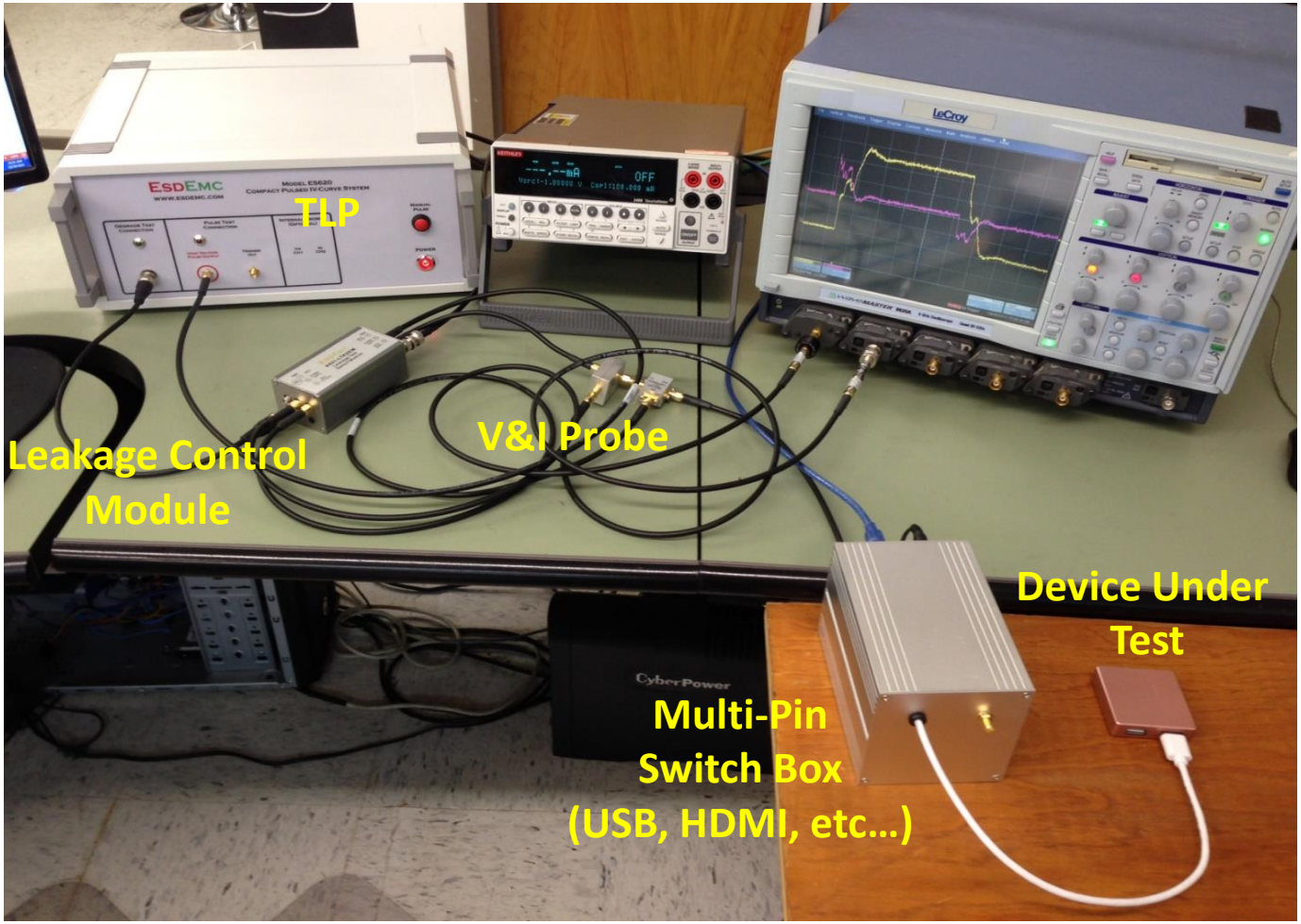
When the cable length is so long, the generic CDE system setup may not be able to handle the pulse energy or measure the long duration pulse. Specialized CDE test setup should be developed for those cases, such as ES631 Ethernet Cable Discharge System.

3. Multiple-pins pre-connected configuration

The current design allow 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 can not 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

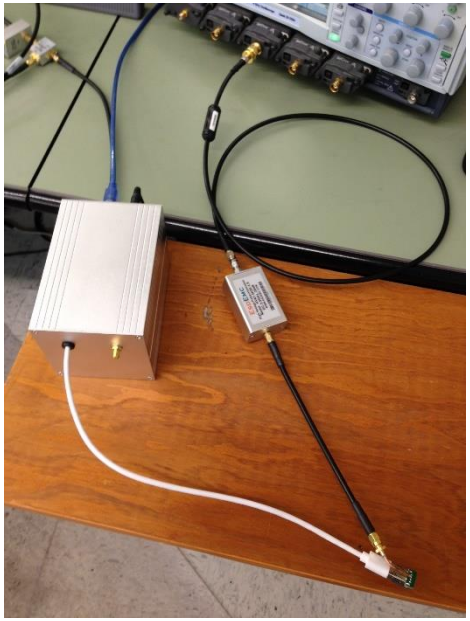
- TLP Pulse, rise-time <=5 ns, Pulse width 100ns
- 70 to 90 % Measurement Window
- Voltage Sweep: 3 to 2550V or to failure as indicated by leakage current change

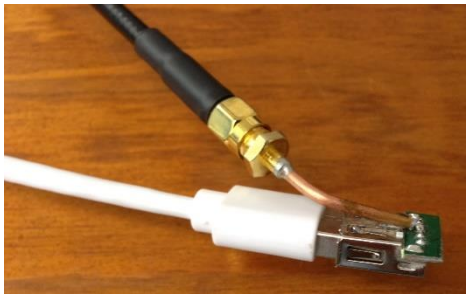


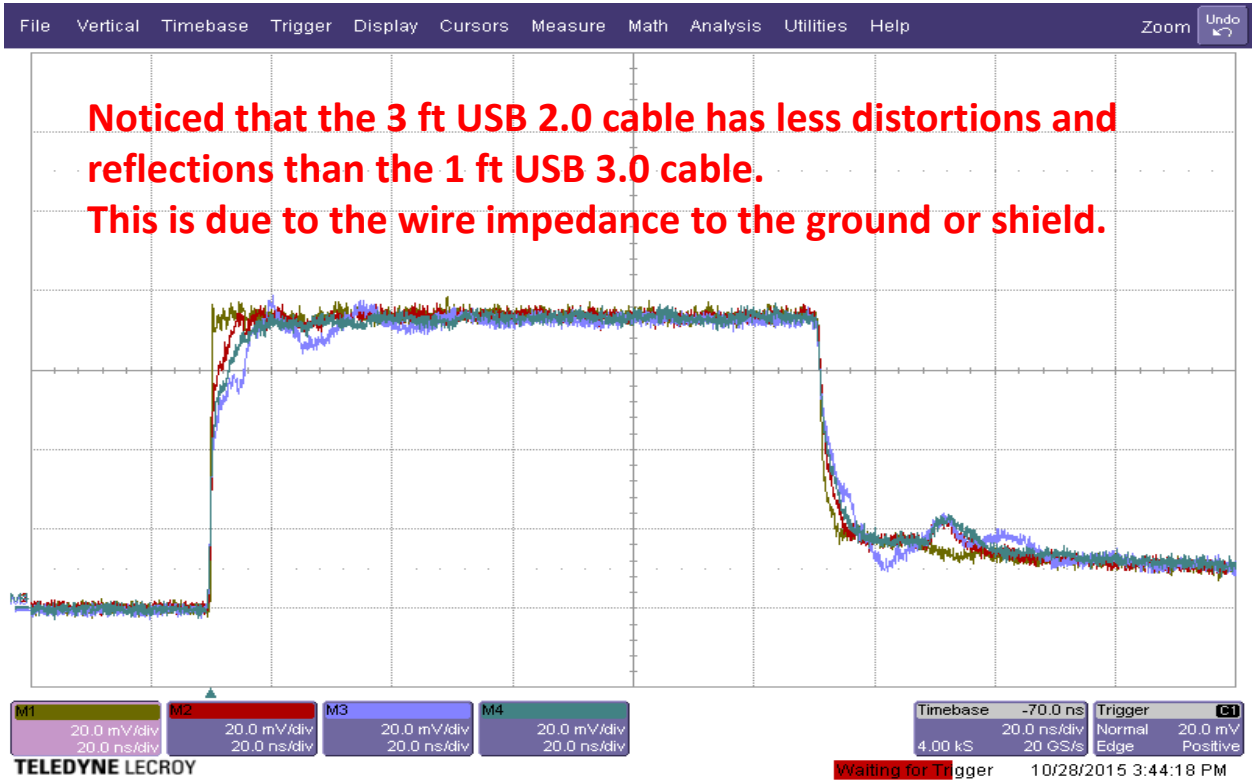
Pulse Shape Check with different cable length from DUT

The characteristics (length and impedance) of the cable between Multi-Pin Switch Box and DUT could changes 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







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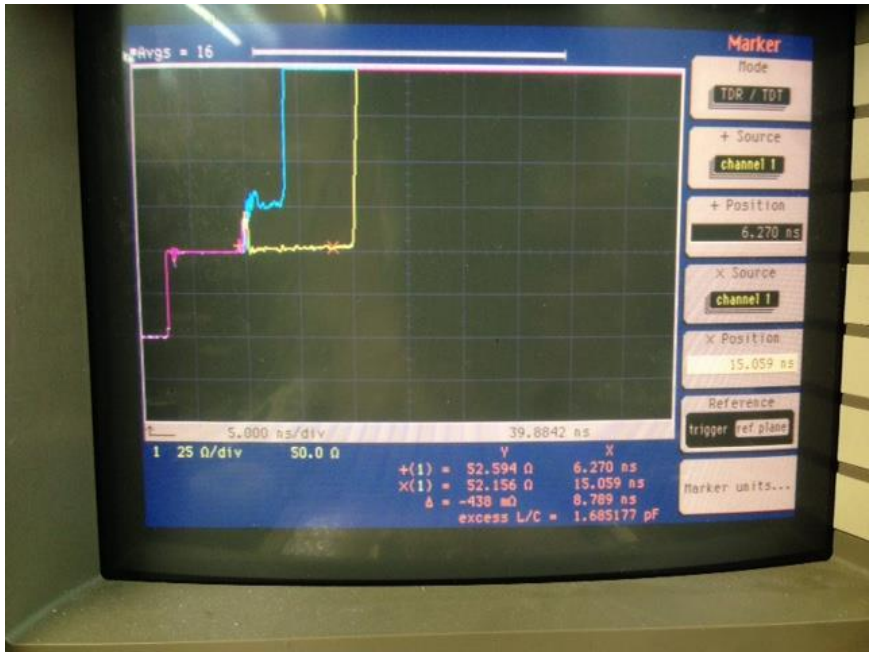
TDR Comparison of the previously used 1ft and 3 ft cables

- 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

1ft USB3.0 Cable
75 ohm impedance from trace to shield

3ft USB2.0 Cable
50 ohm impedance from trace to shield



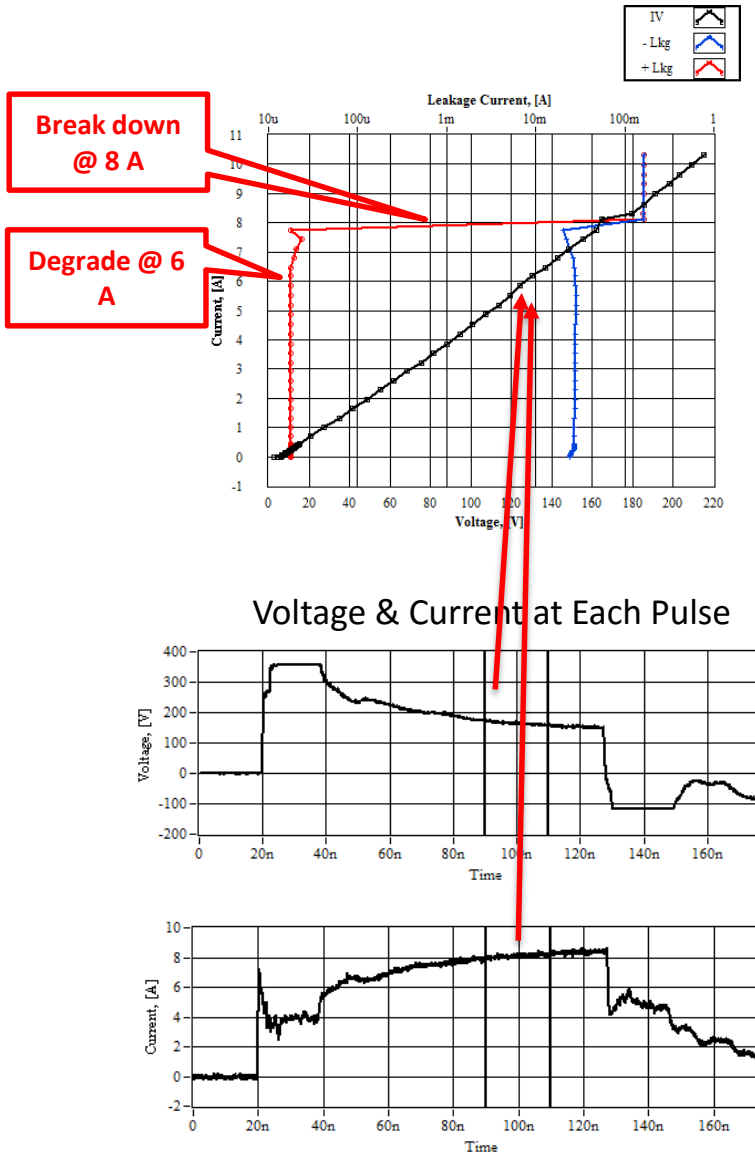
CDE Test and Failure Check Method

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.

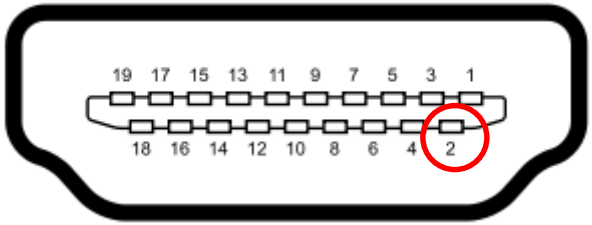
A minor change indicates the degrade of the device.

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.

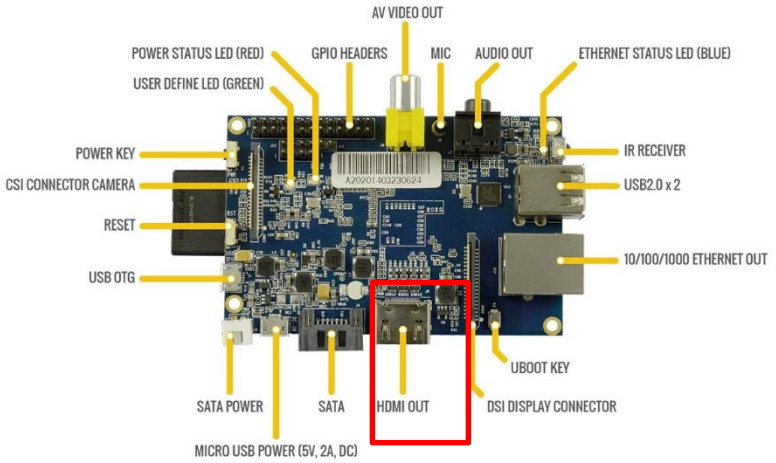


HDMI Port Testing



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

http://www.cnet.com/products/sony-bravia-kdl-ex523/2/



http://artofcircuits.com/product/banana-pi

DUT 1

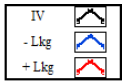
- Sony EX52 Bravia LCD TV
- Line: SDA (Pin 2)

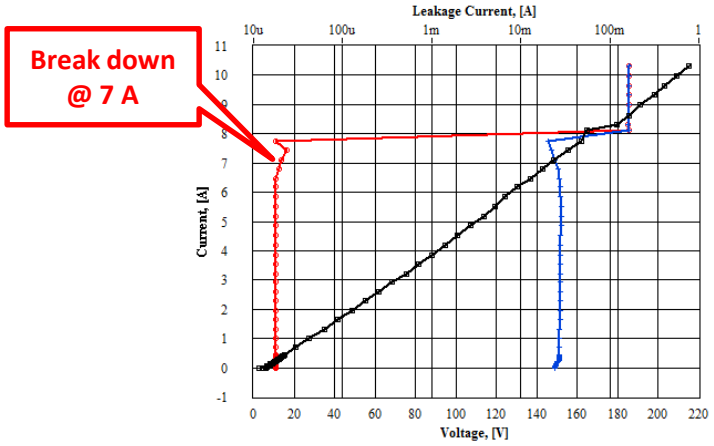
DUT 2

- Banana Pi
- Line: SDA (Pin 2)

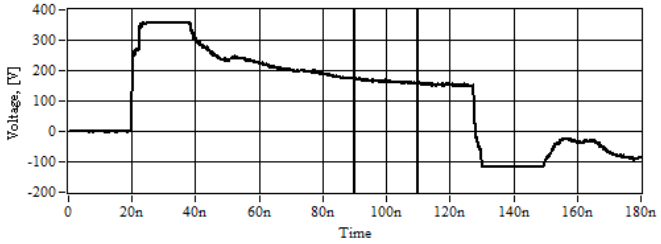
HDMI Port Testing

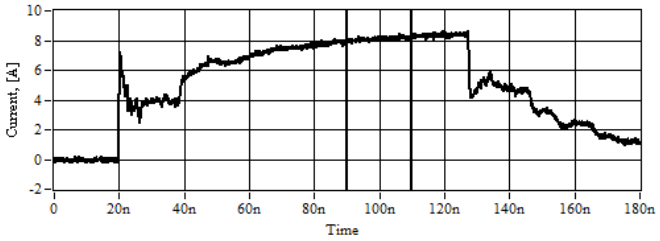
- Sony Bravia LCD TV
- Line: SDA (Pin 2)



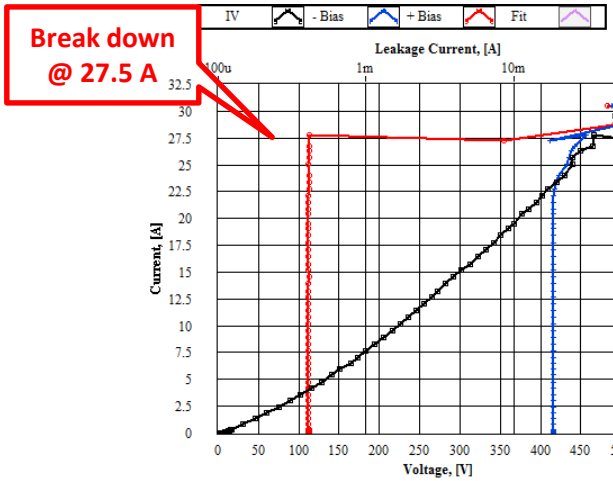


Voltage & Current at Failure

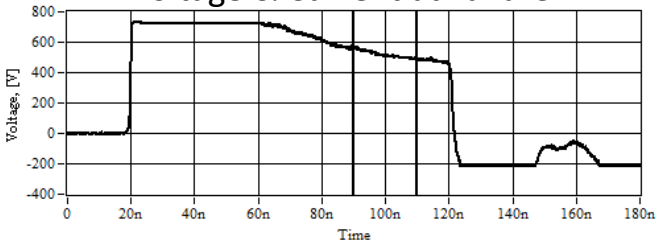


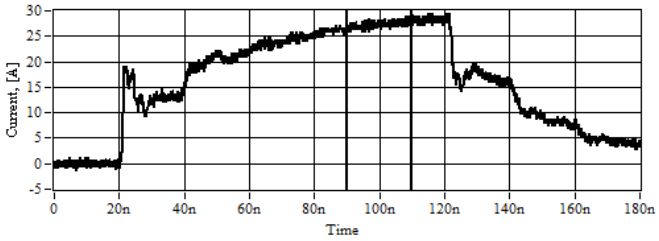


- Banana Pi
- Line: SDA (Pin 2)



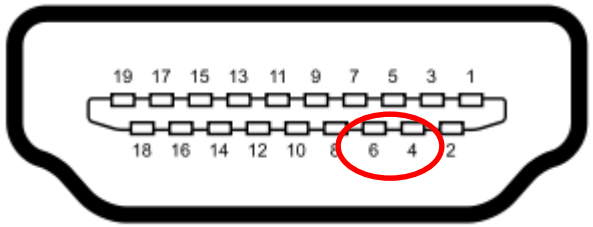
Voltage & Current at Failure





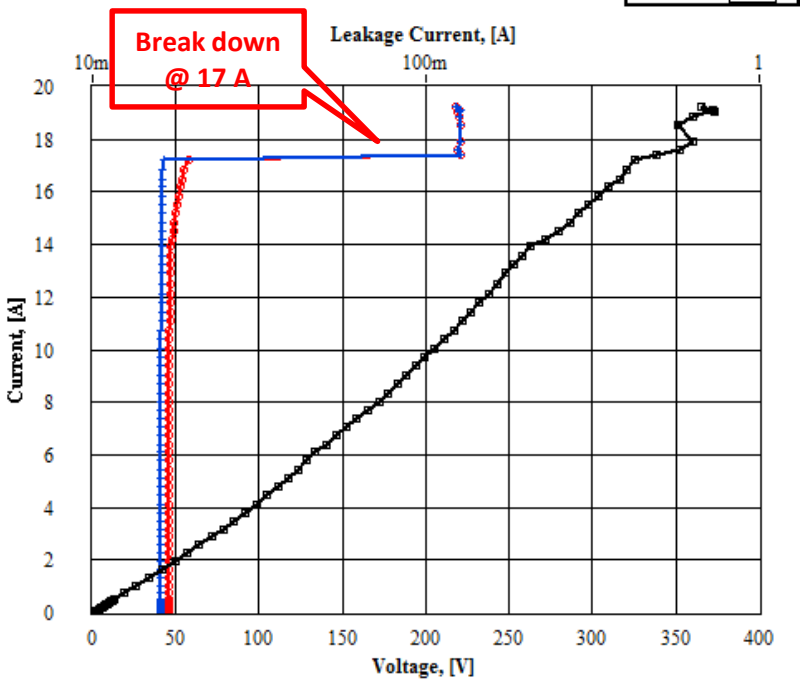
HDMI Port Testing

- Sony Bravia LCD TV
- Lines: Data 1 + & - (Pins 4 & 6)



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

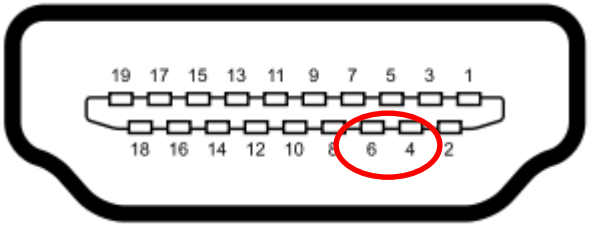
Data 1 +



Data 1 -

HDMI Port Testing

- Banana Pi
- Lines: Data 1 + & - (Pins 4 & 6)



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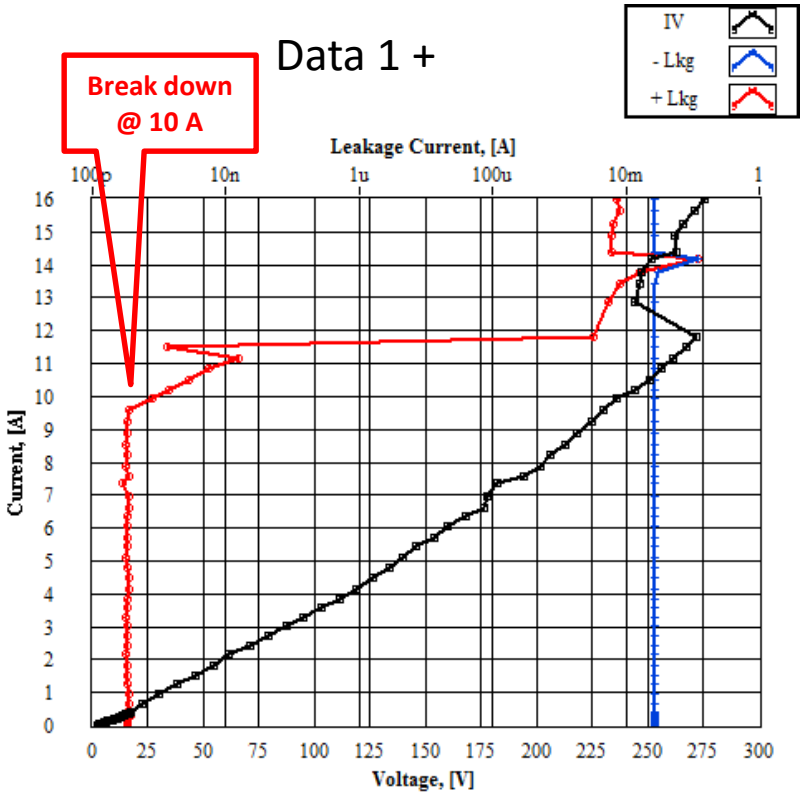
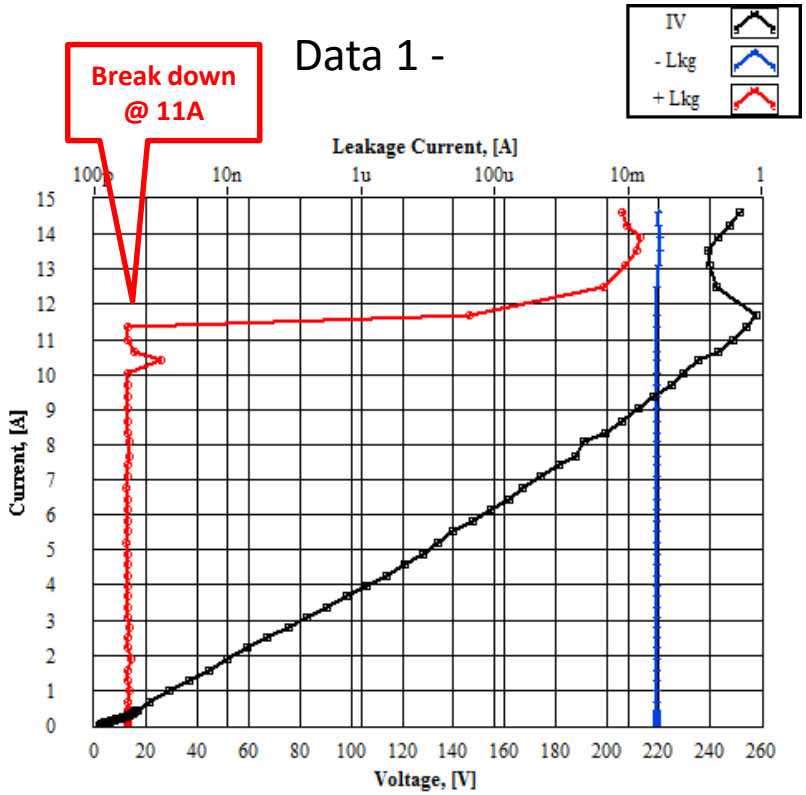
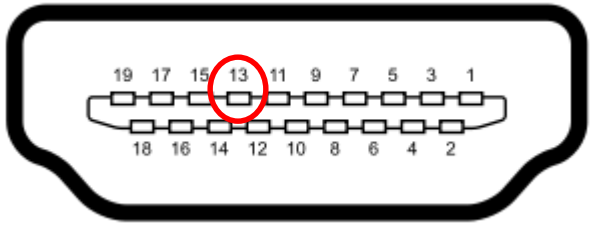
Data 1 +



Data 1 -

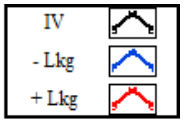


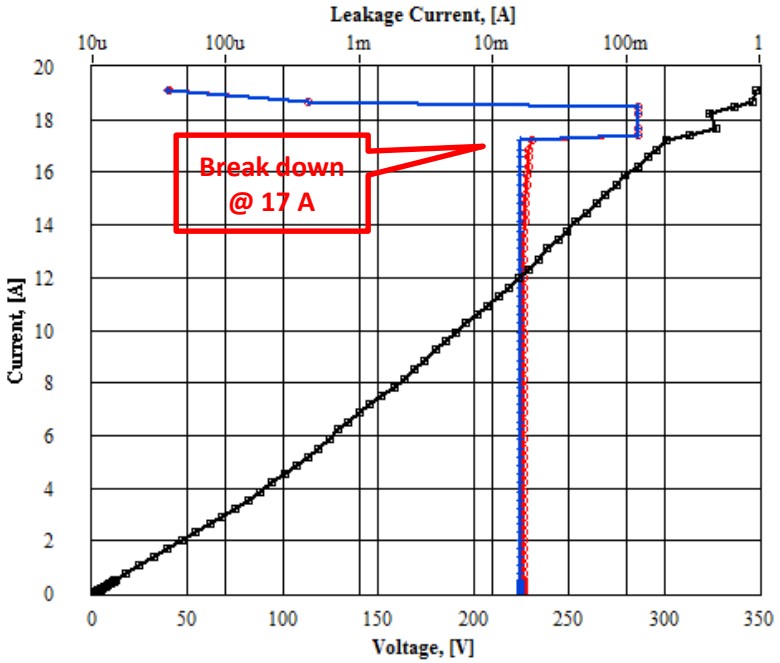
HDMI Port Testing



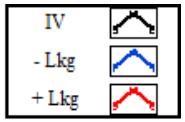
https://en.wikipedia.org/wiki/HDMI

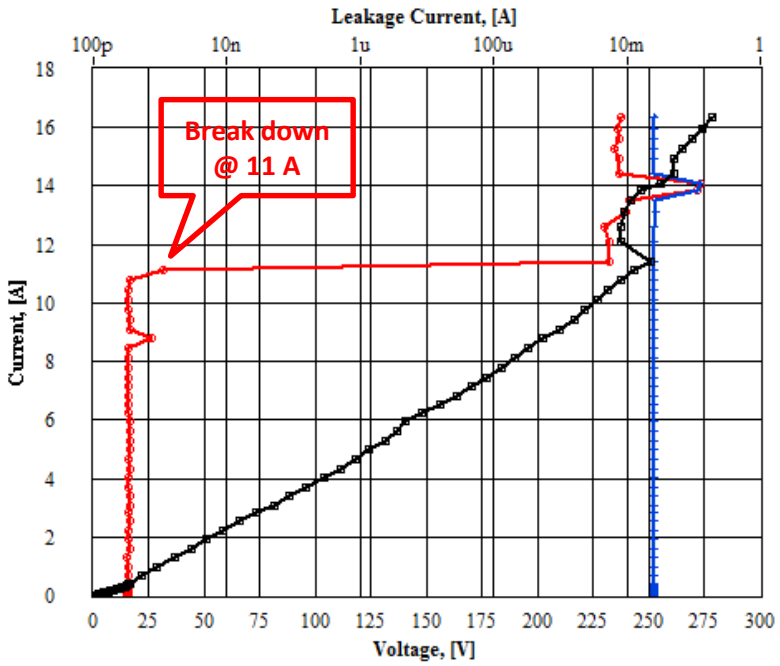
- Sony Bravia LCD TV
- Line: CEC (Pin 13)





- Banana Pi
- Line: CEC (Pin 13)





USB Hub Testing

- VCC Pin

Asus Zenhub USB2.0 Hub

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

After test, we find out that this unit might be okay for ESD shielding, but is NOT designed for CDE type of ESD damage

SIIG Industrial USB3.0 Hub With 15kV ESD Protection

http://www.amazon.com/SIIG-7-Port-Industrial-Protection-ID-US0511-S1/dp

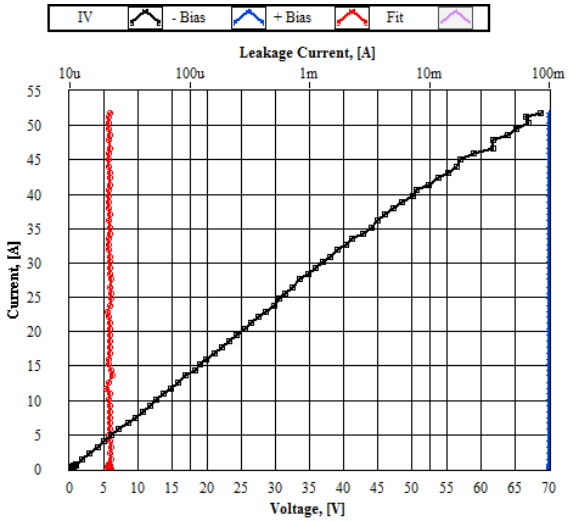
Plugable USB3.0 Hub

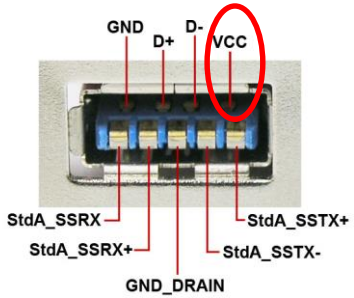
http://www.amazon.co.uk/Plugable-SuperSpeed-Adapter-Backwards-Compatibility/dp/B009EX24T4

USB Hub Testing

- VCC Pin

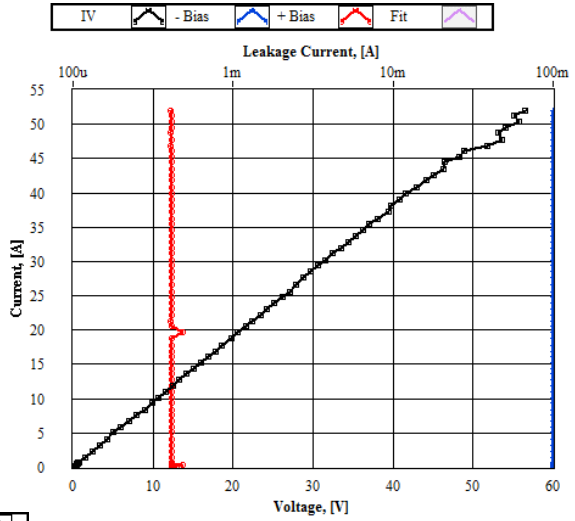
Asus Zenhub USB2.0 Hub



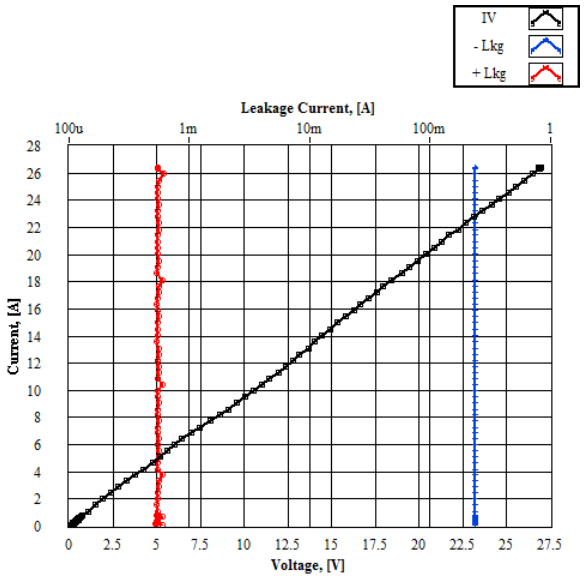


http://www.addonics.com/technologies/usb3_tutorial.php

SIIG Industrial USB3.0 Hub With 15kV ESD Protection



Plugable USB3.0 Hub

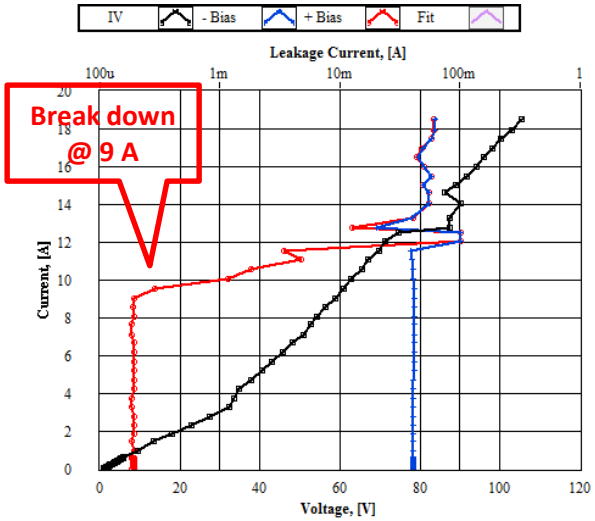


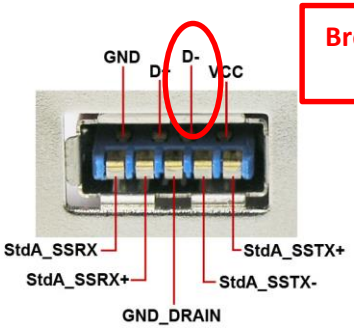
USB Hub Testing

- Data Minus Pin

Not designed for CDE type of damage

Asus Zenhub USB2.0 Hub





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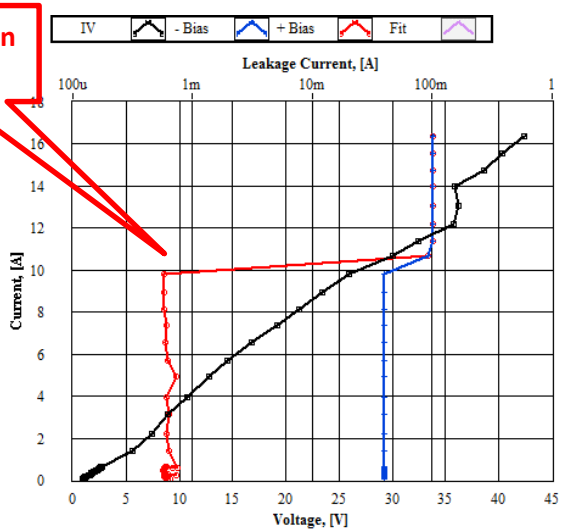
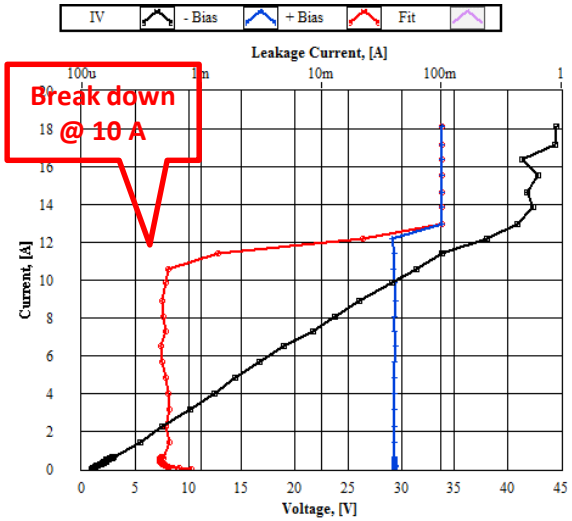
SIIG Industrial USB3.0 Hub With 15kV ESD Protection

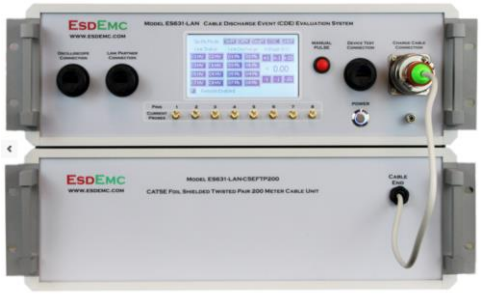


Plugable USB3.0 Hub



Summary of ESDEMC CDE Developments in the last 2 years

ESDEMC starts the CDE related test equipment development from the early 2013, publications and test solutions has been achieved:

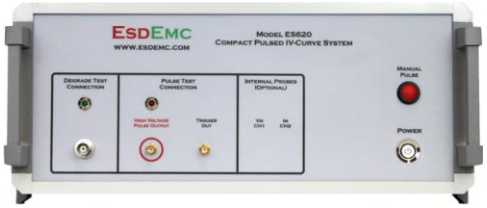


ES631-LAN 4kV Ethernet Cable Discharge Evaluation System

(Final development completed Dec 2014, Cisco has 1 system installed May 2015)
http://www.esdemc.com/public/datasheets/ES631-LAN_Datasheet.pdf
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)

10kV, 200 A TLP system for solar cell bypass diodes ESD failure

(Latest development 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 TLP with X32 Multiplexer for generic CDE (USB/HDMI …)

(Latest development in Oct 2015, approaching potential customers for feedback and prepare commercial release)